Nueces Delta Salinity Effects from Pumping Freshwater into the Rincon Bayou: 2009 to 2017

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Nueces Delta Salinity Effects from Pumping Freshwater into the Rincon Bayou: 2009 to 2017

INTRODUCTION

This project's focus is monitoring the hydrological effects sourced from the Rincon Bayou Pipeline (RBP) in the Nueces Delta near Corpus Christi, Texas (Figure 1). This report will highlight trends in salinity changes throughout pumping events from 2009 to 2017 and have a more detailed look at the effects seen during the 2016-2017 sampling year (September 1, 2016 to August 31, 2017). The results of this study are used for the continual adaptation of a water management plan that will help water managers make decisions on quantity, timing, and duration of pipeline inflows that are most productive and important to the ecology of the Nueces Delta.

The Nueces Delta has been a scientific research focus due to its hypersaline condition (Matthews and Mueller 1987; Whitledge and Stockwell 1995; Montagna et al. 2002; Palmer et al. 2002; Montagna et al. 2009; Hill et al. 2011; Nueces BBEST 2011; Nueces BBASC 2012; Hodges et al. 2012). Because of watershed impoundments, riverbank modifications, and increased urbanization along the Nueces River, the Nueces Delta is no longer connected to the Nueces River, except through the Nueces River overflow channel that was permanently opened in 2001. Because of these factors, the majority of freshwater flow is diverted from the river directly to the bay, bypassing the delta. The only natural means of freshwater flow through the Nueces Delta is during severe flooding events or local heavy rainfall causing the flow to over bank into the delta (BOR 2000; Pulich et al. 2002; Hill et al. 2011). Decreased inflows into the delta and prolonged Texas droughts have caused frequent hypersaline conditions in the Nueces Delta. Freshwater inundation within the Nueces Delta over the past 30 years has been insufficient in volume and distribution to maintain a healthy marsh, the lack of sediment loading in the system is leading to the delta front eroding into Nueces Bay, the marsh plants are under stress, and the connectivity of aquatic habitat is threatened (Hodges et al. 2012).

In 1990, studies of this hypersaline environment found to pose harm to ecological and biological processes and overall health degradation of the Nueces Estuary. This impact evoked the state of Texas to develop an inflow criterion for freshwater inflows (Dunton and Alexander 2000; Montagna et al. 2002; Palmer et al. 2002). The resultant 2001 Agreed Order, from the Texas Commission on Environmental Quality (TCEQ), requires the City of Corpus Christi (City) to provide no less than 151,000 acre-feet (186,255,757 m^3) per year to the Nueces Estuary (TCEQ 1995). Each month the City is required to "pass through" inflow to the Nueces Estuary equal to the measured instream flow into the Choke Canyon Reservoir/Lake Corpus Christi Reservoir System up to a target amount (TCEQ 1995). The target amount varies by month and is calculated based on the combined storage volume of the Reservoir System. The City may receive credits for excess flow from the previous month or from relief credits based on salinity measured at the SALT03 monitoring station in Nueces Bay (Montagna et al. 2009).

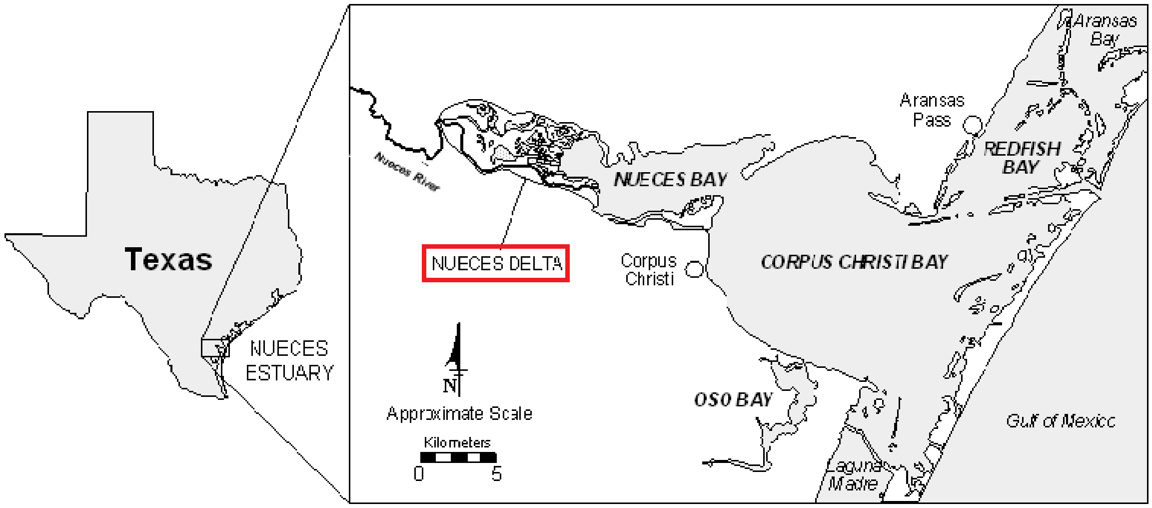


Figure 1. Location of the Nueces Delta within Texas and the Nueces Watershed.

To efficiently deliver freshwater to the Nueces Delta, the City built the Rincon Bayou pump station and pipeline (RBP) to divert up to the first 3,000 acre-feet (3,700,446 m^3) of required "pass throughs" to the upper Rincon Bayou in the Nueces Delta. The RBP became operational in November 2007. The RBP pump station includes three 350 horsepower mixed flow submersible pumps capable of moving up to 60,000 gallons per minute with all three pumps operating (Table 1; Figure 2). The number of days to deliver a given volume of freshwater through the RBP depends on the number of pumps used.

Table 1. Capacity of the Rincon Bayou Pipeline.

	Number of Rincon Bayou Pumps in Operation		
	1	**2**	**3**
Flow, gallons/minute	28,000	46,000	60,000
Flow, cubic feet/second	62	102	134
Flow, acre-feet/day	124	203	265
Total kW	230	455	675

This project's principal objective is to monitor the RBP as it releases freshwater into the Nueces Delta system with monitoring stations to measure the salinity downstream and in adjacent areas to the main channel. The results of this study will be used in the development of a Rincon Bayou Pipeline Management Plan that will help water managers make decisions on quantity, timing, and duration of pipeline inflow events that are most productive and significant to the ecology of

A)

B)

Figure 2. View of RBP pumping facilities depicting A) the intake pumps located on the Nueces River above the Calallen Dam and B) the pipeline outfall in the Rincon Bayou. Photos taken by Jace Tunnell.

the Nueces Delta. This report will focus on describing the distribution of RBP freshwater inflows in the Nueces Delta and provide a descriptive analysis for the six RBP pumping events that occurred between September 1st 2016 and August 15th 2017. This project represents the seventh year of monitoring the RBP in the Nueces Estuary.

METHODS

The Coastal Bend Bays & Estuaries Program (CBBEP) contracts this salinity-monitoring project to the Conrad Blucher Institute for Surveying and Science (CBI) at Texas A&M University - Corpus Christi (TAMU-CC). CBI installed and maintains a network of four salinity monitoring stations located downstream in the Nueces Delta and Bay recording data in correspondence with the RBP freshwater releases (Figure 3). Each Nueces Delta (NUDE) station is jetted

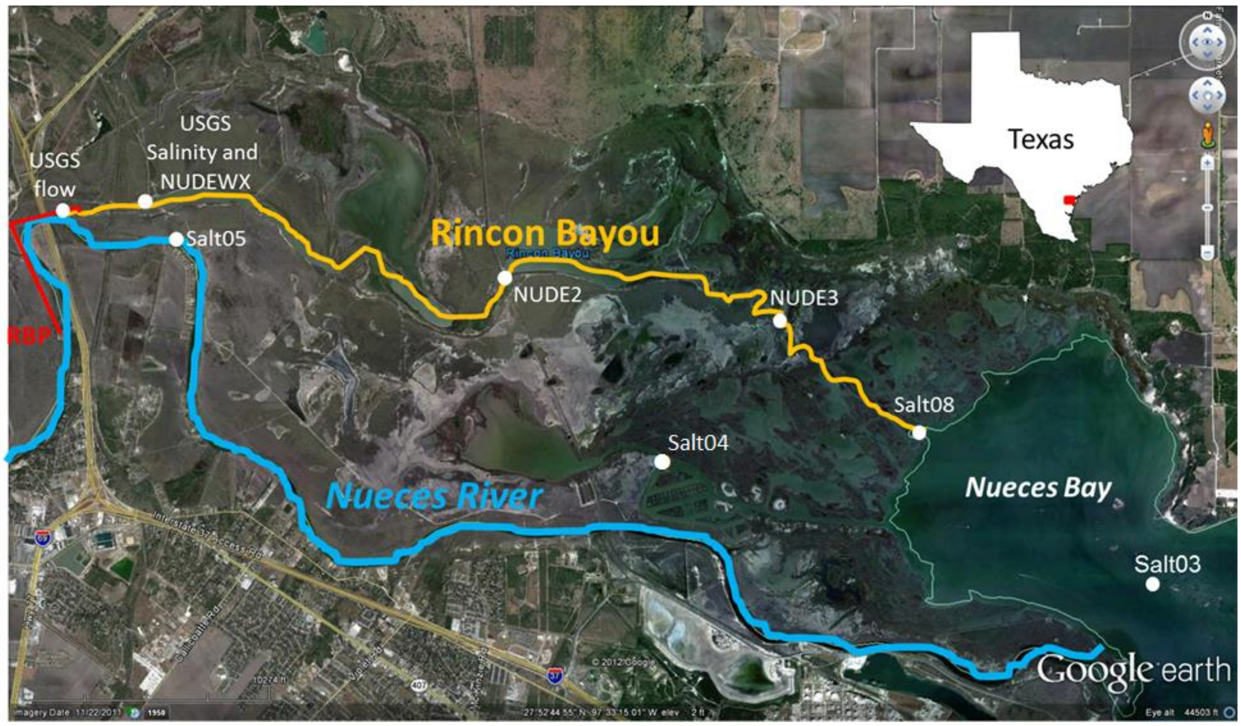


Figure 3. Map showing the RBP (Rincon Bayou Pipeline [red line]) and the four salinity monitoring stations for this project (NUDE2, NUDE3, SALT04, and SALT08).

approximately five feet into the sediment near the water's edge with a water quality datasonde extending into the deepest parts of the channel, which vary in distance at each location. NUDE2 is located in the middle reach of Rincon Bayou (27.888611°N, 97.569444°W) and NUDE3 is located in the lower tidally influenced reach of Rincon Bayou (27.883774°N, 97.533188°W). SALT08 is located in the lower Rincon Bayou at the confluence of Nueces Bay (27.870428°N, 97.517090°W). Salinity data from SALT08 provides verification RBP freshwater has reached the interface to Nueces Bay. SALT03 (27.851561°N, 97.482028°W) is located in the middle of Nueces Bay and SALT05 (27.891601°N, 97.610684°W) is located in the Nueces River; both stations are used as references in the report to compare bay and river salinity, respectively, to Rincon Bayou. The SALT04 monitoring station was reinstalled in the mitigation channel southeast of South Lake (27.867197°N, -97.549240°W). SALT04 collects baseline salinity data for comparison to a potential flow regime change that may results from future construction of a diversion channel from the Rincon Bayou to the mitigation channel.

A tide gauge (NUEBAY 185) is located in Nueces Bay (27.832149°N, -97.485056°W) and measures primary water level (m), water temperature (°C), wind speed (m/s), wind gusts (m/s), wind direction (°), and barometric pressure (mbar). A weather station, NUDEWX is located on Rincon Bayou downstream from the RBP outfall (27.897582°N, -97.616524°W). The NUDEWX measures wind speed (m/s), wind direction (°), barometric pressure (mbar), rainfall (mm), relative humidity (%), and solar radiation (cal/cm^2/min). The CBI performed monthly maintenance to NUDEWX including a rain gauge calibration check. NUEBAY 185 is serviced annually as per NOAA COOPS standards for water level monitoring stations (http://tidesandcurrents.noaa.gov/).

The CBI salinity monitoring stations consists of Hydrolab® MS5 and H20 water quality datasondes interfaced with cellular IP modem (Figure 4). Stations are polled by an automated computer program designed and implemented by the Information Technology staff at CBI. Data is stored in the CBI project webpage that includes a map showing station locations, Quality Assurance Project Plan, Scope of Work, Data Management Documentation, Datasonde Standard Operating Procedures, Quality Assurance Quality Control documents, datasonde calibration records, and graphs of the previous seven days of data collected from each station. Each Hydrolab measures water quality parameters. Hydrolab MS5 datasondes at SALT01, SALT03, & SALT05 measure: water temperature (°C), specific conductance (µS/cm), salinity (PSU), pH, dissolved oxygen (% saturation & mg/L), and depth (m). Hydrolab H20 datasondes at SALT08, NUDE2, and NUDE3 measure: water temperature (°C), specific conductance (µS/cm), salinity (ppt). Instruments are exchanged monthly with calibrated datasondes (Figure 5). Calibration and post-calibration of datasondes are performed at the CBI wet lab with all quality control forms retained in the laboratory record book and stored online in the publically accessible CBI Environmental Database http://lighthouse.tamucc.edu/RinconSalinity.

Figure 4. Dominic Burch uses a radio and computer to call NUDE3 and SALT08 before and after exchanging the datasondes to ensure the devices are measuring salinity accurately.

Figure 5. SALT08 (top image) and NUDE3 (bottom image) datasondes are being exchanged with a newly calibrated datasonde which will remain deployed for approximately 4 weeks after which the datasonde will be replaced in the same fashion.

RESULTS AND DISCUSSION

Thirty-nine pumping events have occurred since the RBP became operational in late 2007 (Table 2). No pumping events occurred during the first year (September 2008-August 2009) due to a persistent drought limiting freshwater supply. Three pumping events occurred during year two (2009-2010) totaling 6,017 acre-feet (7,421,860 m^3), three pumping events in year three (2010-2011) totaling 2,997 acre-feet (3,696,745 m^3), four pumping events in year four (2011-2012) totaling 5,695 acre-feet (7,024,679 m^3), four pumping events occurred in year five (2012-2013) totaling 3,991 acre-feet (4,922,826 m^3), five pumping occurred in year six (2013-2014) totaling 11,694 acre-feet (14,424,337 m^3), and six pumping events occurred during year seven (2014-2015) totaling 14,097 acre-feet (17,388,394 m^3) of freshwater delivered to the Rincon Bayou. Seven pumping events have occurred during year eight (2015-2016) during which 18,616 acre-feet (22,962,464 m^3) were pumped. Eight pumping events have occurred so far in year nine (2016-2017) during which 25,844 acre-feet (31,878,105 m^3) were pumped (Figures 6-7).

Table 2. RBP pumping events including pumping dates, duration, and acre-feet pumped. * = ongoing pumping event at time of writing

Year	Pumping Event	Dates of Event	Duration (days)	Avg. water level (m above MSL)	Acre-Feet Pumped	Wet/Dry Period
1	-	No pumping occurred	-	-	-	-
2	1	Sep. 28 to Oct. 21, 2009	24	0.14	2,987	Wet
	2	Jan. 6 to Jan. 14, 2010	9	-0.21	742	
	3	May 10 to May 31, 2010	21	0.14	2,288	
3	4	Mar. 21 to Mar. 30, 2011	10	0.03	1,001	Dry
	5	May 3 to May 12, 2011	10	0.08	1,002	
	6	Jun. 13 to Jun. 22, 2011	10	0.03	994	
4	7	Nov. 2 to Nov. 22, 2011	21	0.03	2,031	Dry
	8	Mar. 7 to Mar. 19, 2012	13	0.08	1,310	
	9	Jun. 21 to Jul. 13, 2012	23	0.19	2,354	
5	10	Oct. 5 to Oct. 18, 2012	13	0.07	2,017	Dry
	11	Jun. 1 to Jun. 10, 2013	10	0.16	717	
	12	Jun. 24 to Jul. 2, 2013	9	-0.01	731	
	13	Jul. 17 to Jul. 21, 2013	5	0.19	526	
6	14	Oct. 21 to Nov. 9, 2013	16	0.24	2,348	Dry
	15	Nov. 22 to Dec. 8, 2013	12	0.04	613	
	16	Feb. 3 to Feb. 15, 2014	13	-0.10	2,466	
	17	May 9 to Jun. 3, 2014	24	0.12	2,736	
	18	Jun. 23 to Jul. 15, 2014	23	0.05	3,531	
7	19	Oct. 1 to Oct. 6, 2014	6	0.23	319	Wet
	20	Jan. 18 to Jan 27, 2015	10	-0.14	695	
	21	Mar. 10 to Mar. 12, 2015	3	-0.06	210	
	22	Mar. 19 to Mar. 25, 2015	7	-0.04	1,535	
	23	Apr. 13 to Apr. 28, 2015	16	0.16	2,455	
	24	May 12 to Jun. 15, 2015	35	0.24	8,883	
8	25	Aug. 29 to Sep. 1, 2015	4	0.14	449	Wet
	26	Sep. 21 to Oct. 1, 2015	11	0.26	642	
	27	Oct. 17 to Nov. 10, 2015	25	0.33	3,821	
	28	Jan. 3 to Jan. 28, 2016	26	0.06	2,160	
	29	Feb. 18 to Feb. 23, 2016	6	0.05	672	
	30	Mar. 16 to Mar. 23, 2016	8	0.05	794	
	31	May 23 to Jul. 14, 2016	53	0.16	10,078	
9	32	Aug. 8 to Sep. 22, 2016	46	0.20	7,816	Wet
	33	Nov. 13 to Nov. 29, 2016	16	0.21	1,429	
	34	Dec. 12 to Dec. 27, 2016	15	0.13	2,492	
	35	Jan. 10 to Jan. 23, 2017	14	0.09	1,959	
	36	Feb. 15 to Mar. 2, 2017	16	0.04	1,382	
	37	Mar. 13 to Mar. 23, 2017	11	0.06	1,997	
	38	Apr. 16 to Apr. 28, 2017	13	0.22	2,145	
	39	May 16 to Jul. 1, 2017	43	0.22	6,624	

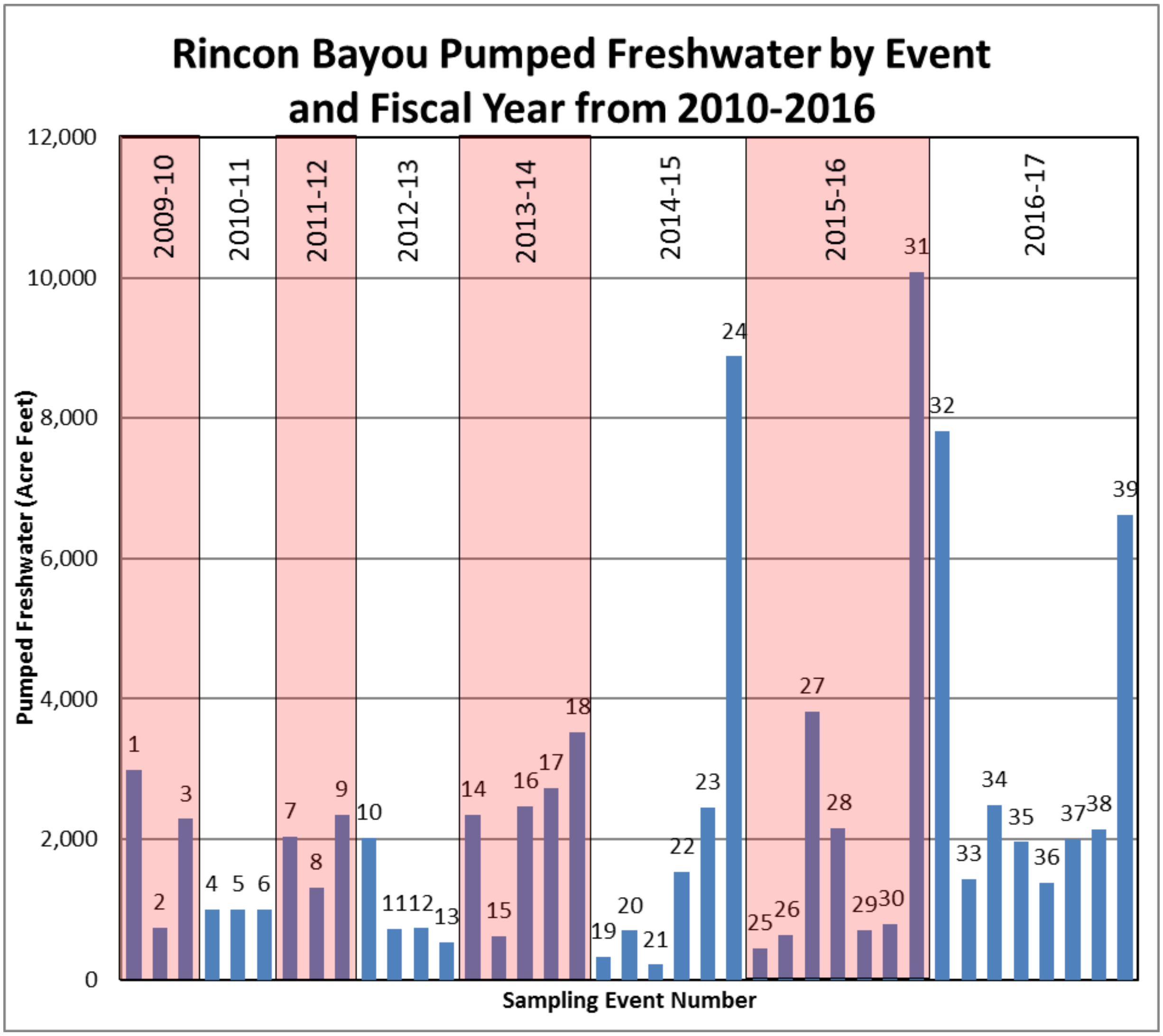


Figure 6. Rincon Bayou pumping events by year from 2010-2017.

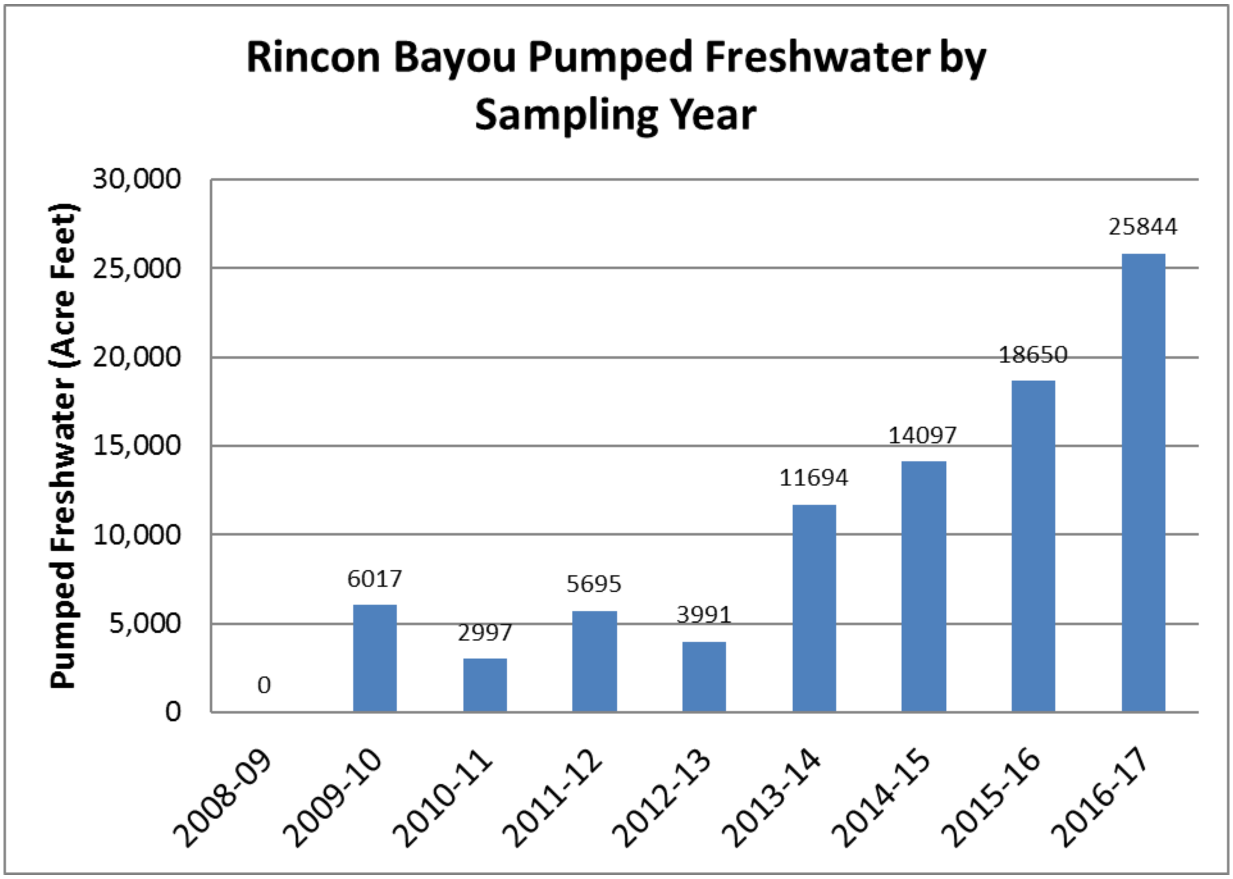


Figure 7. Total amount of freshwater pumped for each sampling year.

Local rainfall varied spatially between the National Weather Service (National Weather Service 2017) at Corpus Christi International Airport (CRP) at 27°46'22.43"N, 97°30'8.47"W and at NUDEWX at 27°53'50.47"N, 97°36'58.73"W with more rainfall frequently occurring at CRP (Table 3). NUDEWX is approximately 11 miles northwest of CRP and is located directly in the Nueces Delta. Despite the regional difference in rainfall, both locations still recorded similar rainfall trends and were representative of the general meteorological conditions in the Nueces Delta watershed.

Table 3. Total rainfall per sampling year for NUDEWX and CRP.

	2008-09	**2009-10**	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**
NUDEWX	3.0 in.	15.6 in.	7.9 in.	NA	7.13 in.	19.29 in.	29.68 in.	18.24 in.	35.49 in.
CRP	8.81 in.	42.9 in.	25.3 in.	18.68 in.	14.16 in.	18.69 in.	48.51 in.	30.18 in.	28.03 in.

Rainfall data varied greatly between years with the first year in 2008-2009 starting in a persistent drought and the following 2009-2010 year being the wettest period on Texas record with 42.9 in (108.87cm) at CRP and 15.6 in (39.62 cm) at NUDEWX. The 2010-2011 and 2011-2012 years had progressively less rainfall on record with 25.3 in (64.26 cm) at CPR and 7.9 in (20.01 cm) at NUDEWX in the 2010-2011 year and 18.68 in (47.45 cm) at CRP during the 2011-2012 year.

The precipitation sensor at NUDEWX was offline for repairs for approximately 3 months during 2011-2012 year and missed several rain events causing the annual rainfall total to be inaccurate. The 2012-2013 year had the least precipitation to date among sampling years with only 14.16 in (35.97 cm) of rainfall recorded at CRP and 7.13 in (18.11 cm) at NUDEWX. The precipitation during the 2013-2014 year was the third wettest year compared to previous sampling years with 18.69 in (47.47 cm) of rainfall at CRP and 19.29 in (49.00 cm) at NUDEWX. The 2014-2015 sampling year was the wettest to date with 48.51 in (123.22 cm) of rainfall at CRP and 29.68 in (75.39 cm) recorded at NUDEWX. The 2015-2016 sampling year was the third wettest year with 30.18 in (76.66 cm) of rainfall at CRP and 18.24 in (46.33 cm) at NUDEWX. Drought conditions were absent throughout most of Texas during the 2016-2017 sampling season (Figure 8). The most recent 2016-2017 sampling year was one of the wettest years to date with NUDEX recording a sampling year record of 35.49 in (90.14 cm) and CRP reporting 28.03 in (71.20 cm).

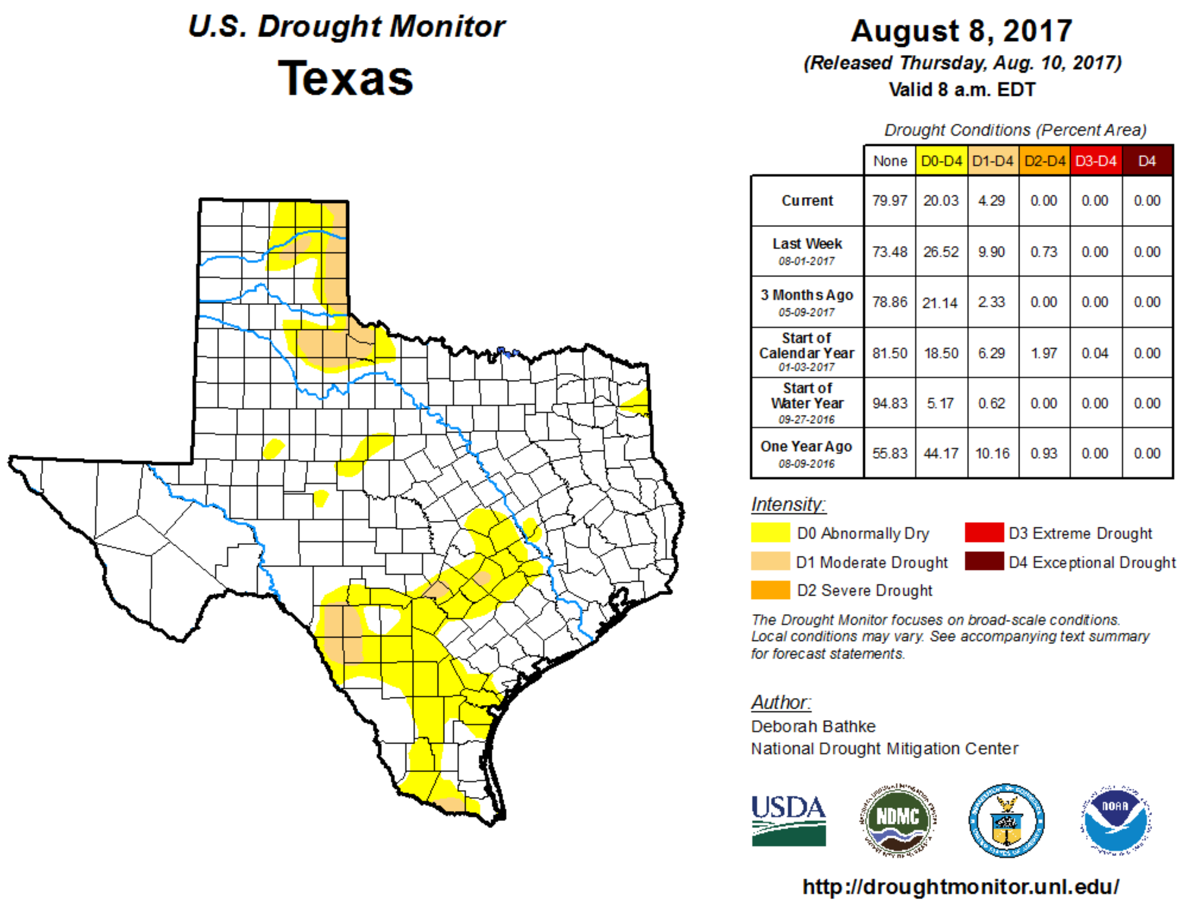


Figure 8. Drought condition throughout the state of Texas on August 8, 2017, which was generally representative of drought, conditions throughout the 2016-2017 sampling year.

Capacities at Lake Corpus Christi varied between 15.1% and 29.9% with a daily average of 17.5% throughout the 2012-2013 sampling year, the lowest levels seen in over 16 years (Nueces River Authority 2016). The Choke Canyon reservoir levels varied between 38.6% and 52.5%

with an average of 45.8% during the 2012-2013 year (Nueces River Authority 2016). The following 2013-2014 sampling year were generally greater with Lake Corpus Christi ranging between 23.6% and 100.0% with a daily average of 74.5% and the Choke Canyon Reservoir ranging between 29.3% and 36.8% with a daily average of 33.5% (Nueces River Authority 2016). The 2014-2015 sampling year exhibited the highest reservoir capacities to date with Lake Corpus Christi ranging between 45.7% to 100.0% capacity with a daily average of 63.5% and Choke Canyon Reservoir ranging between 24.0% to 41.3% capacity with a daily average of 28.5%. The high amount of rainfall during the 2015-2016 sampling year resulted in generally high reservoir capacities with Lake Corpus Christi ranging between 63.0% to 89.4% capacity with a daily average of 79.3% and Choke Canyon Reservoir ranging between 32.8% to 38.4% capacity with a daily average of 28.5%. Reservoir capacities during the 2016-2017 sampling year were similar to the 2015-2016 sampling year in that both resulted in relatively high rainfall amounts and reservoir capacities. Lake Corpus Christi reservoir levels ranged between 71.8% and 96.3% and Choke Canyon reservoir levels varied between 33.4% and 43.8% during the 2016-2017 sampling year.

Salinities recorded at NUDE2 generally drop shortly after a pumping event was initiated and gradually increased after the end of a pumping event (Figure 9). Pumping event 32 represented the second longest pumping event (46 days) and third largest amount of water pumped (7,816 acre-feet) to date which resulted in salinities dropping from approximately 33 PSU to under 5 PSU within 5 days. During pumping event 33, the salinity at NUDE2 slowly fell from approximately 19 PSU to under 5 PSU approximately 6 days after initiating the pumps. Pumping event 34 was relatively short with NUDE2 salinities persistently remaining under 5 PSU throughout pumping. Salinities dropped from 10 PSU to under 5 PSU approximately 4 days after pumping during event 35. Salinities rapidly dropped from approximately 14 PSU to under 5 PSU within just 2 days of pumping during event 36 and remained under 5 PSU during pumping event 37 which started just 11 days after the end of event 36. Salinities fell from approximately 22 PSU to under 5 PSU within 3 days of pumping during event 38. Pumping event 39 was relatively long with salinities dropping from 20 PSU to under 5 PSU within approximately 5 days.

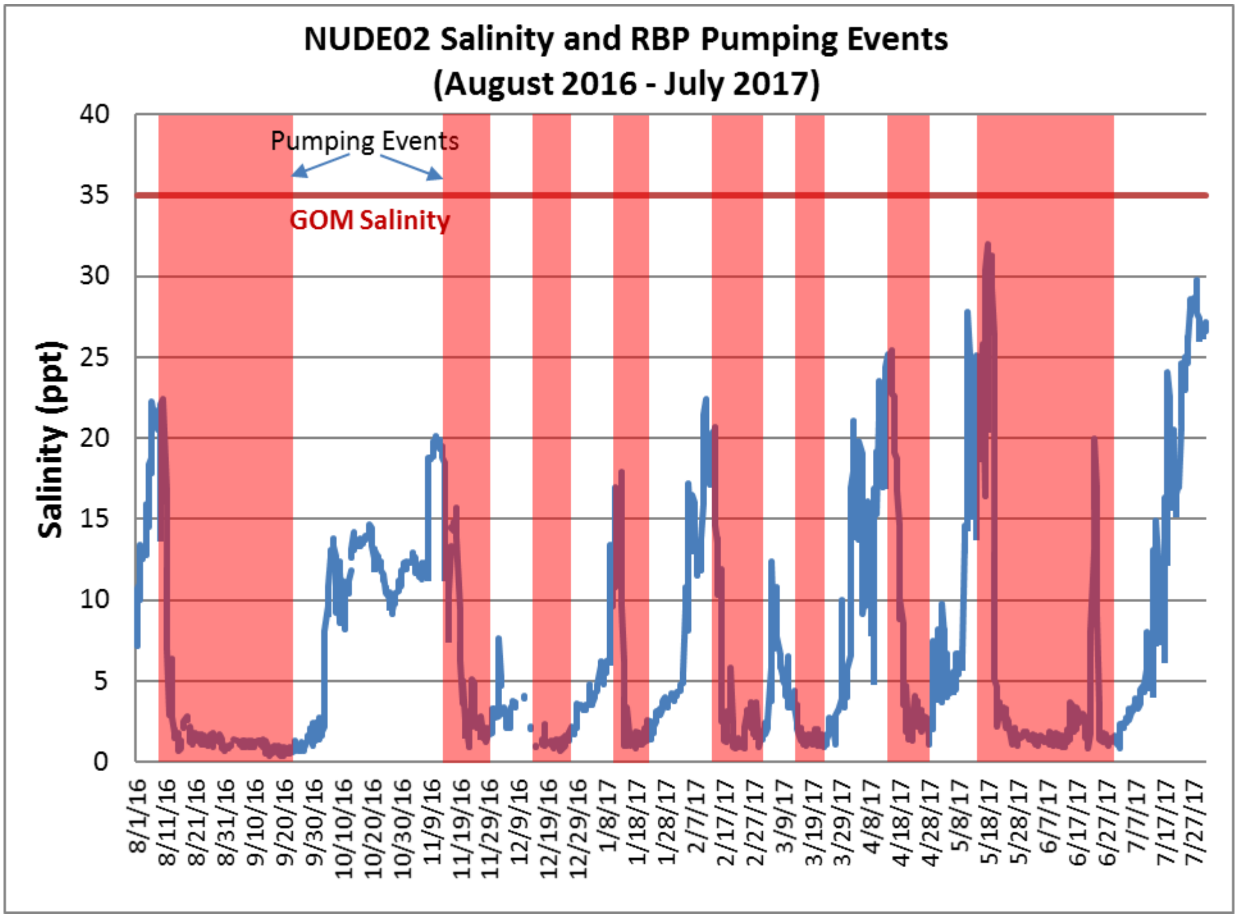
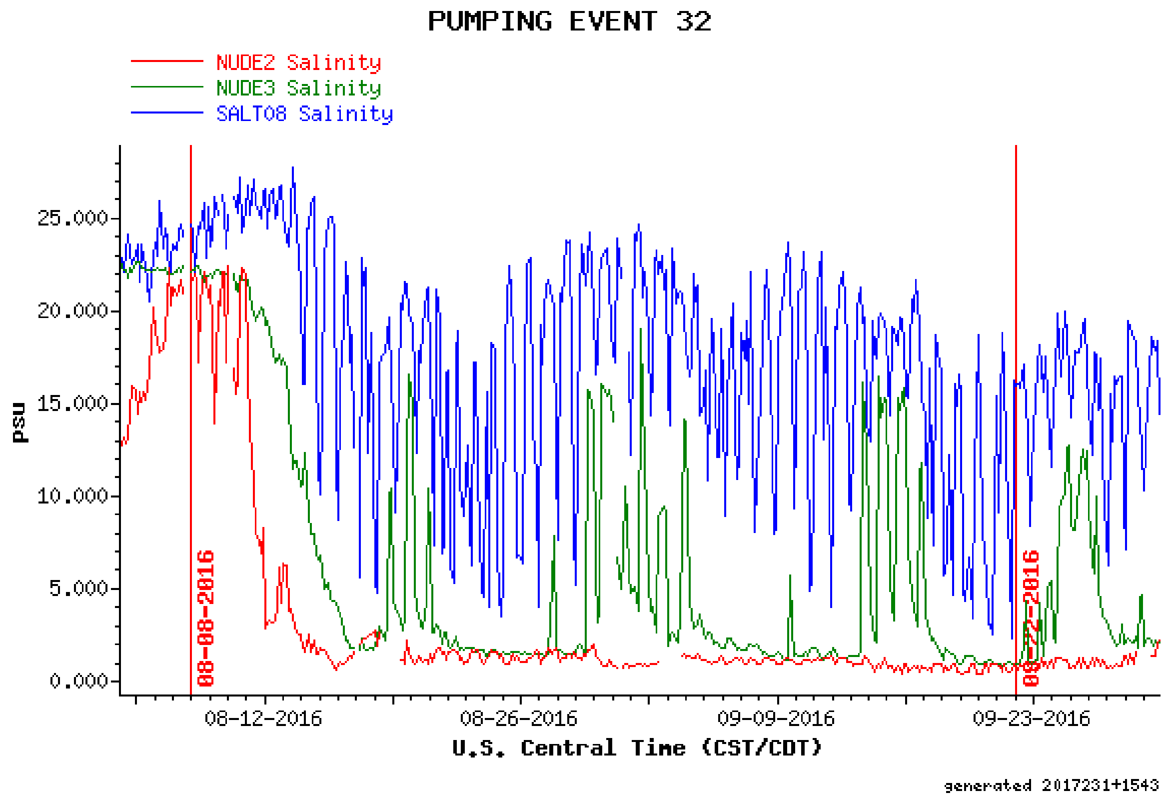


Figure 9. NUDE2 salinity during the 2015-2016 sampling year. Shaded areas denote the seven pumping event, thickness of each shaded area represents duration (days) of pumping events. The horizontal red line represents 35 PSU which is typical Gulf of Mexico (GOM) salinity.


PUMPING EVENT 32
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NUDE3 Salinity
SALT08 Salinity
psu
25.000
20.000
15.000
10.000
5.000
0.000
08-08-2016
08-12-2016
08-26-2016
09-09-2016
09-23-2016
U.S. Central Time (CST/CDT)
generated 2017231+1543

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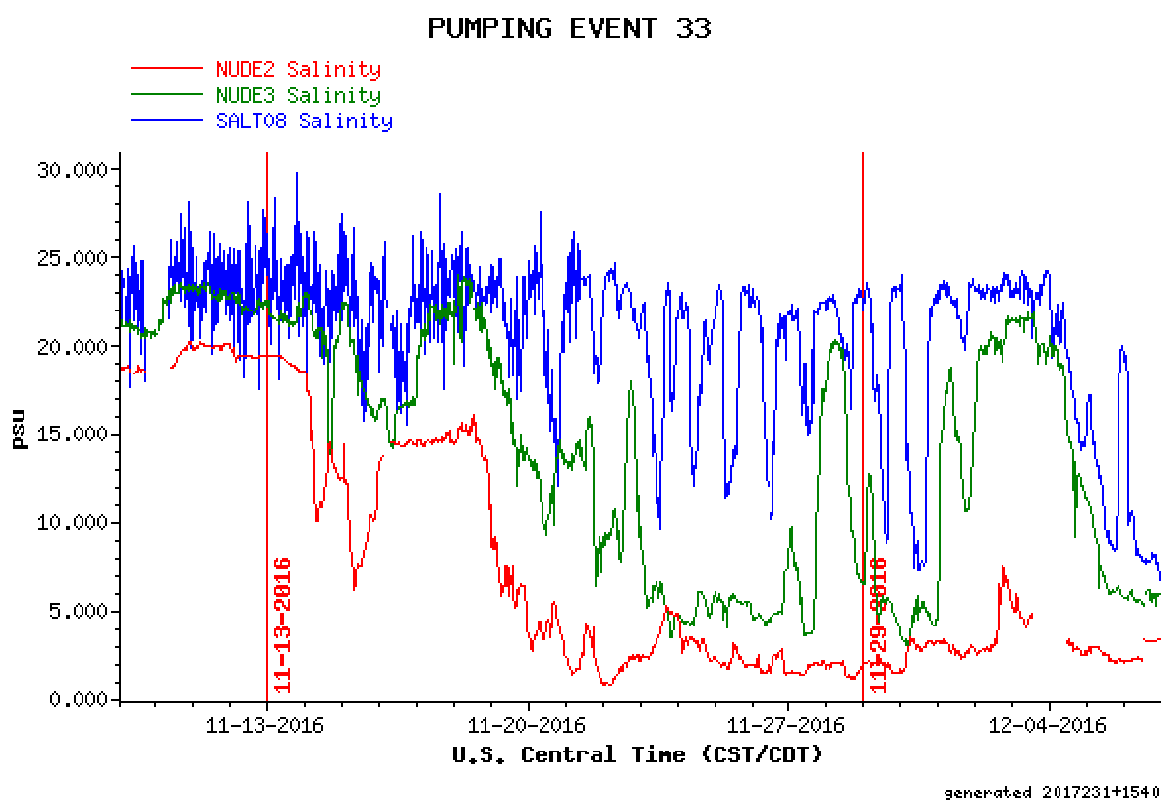
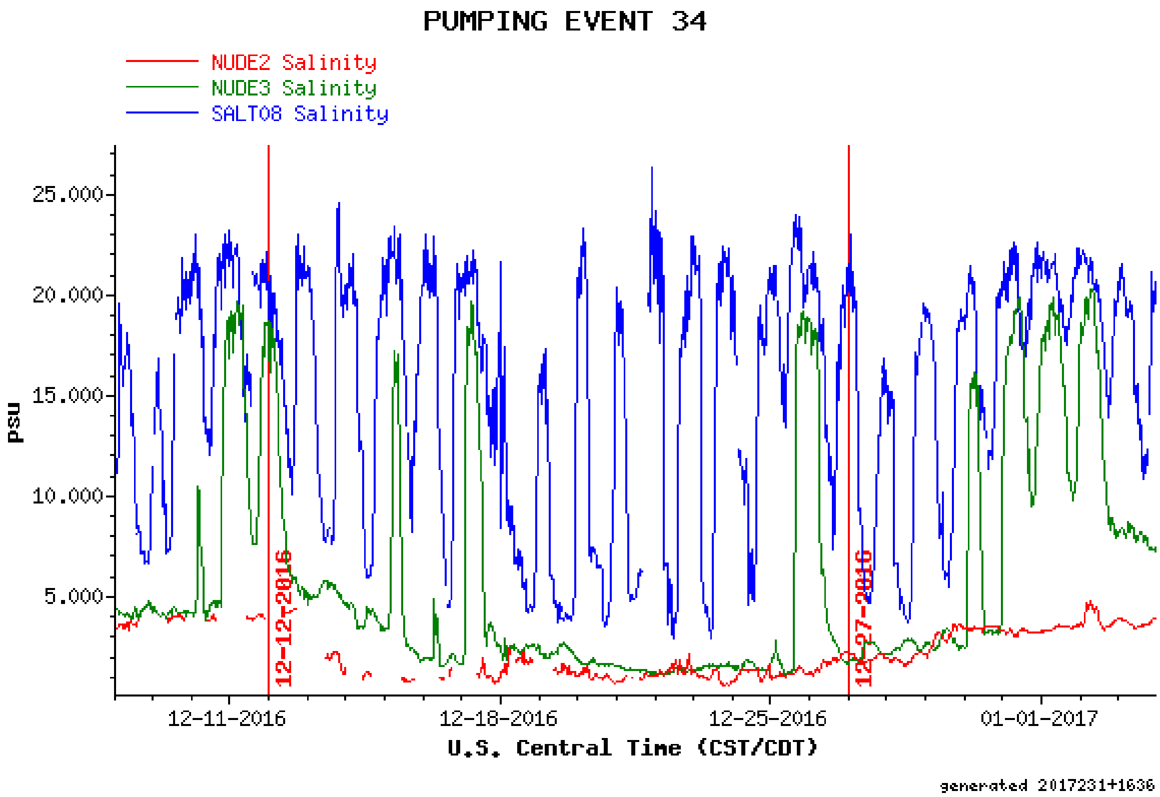

PUMPING EVENT 33
NUDE2 Salinity
NUDE3 Salinity
SALT08 Salinity
psu
30.000
25.000
20.000
15.000
10.000
5.000
0.000
11-13-2016
11-20-2016
11-27-2016
12-04-2016
U.S. Central Time (CST/CDT)
generated 2017231+1540

B)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NUDE3 Salinity
SALT08 Salinity
psu
25.000
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15.000
10.000
5.000
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12-25-2016
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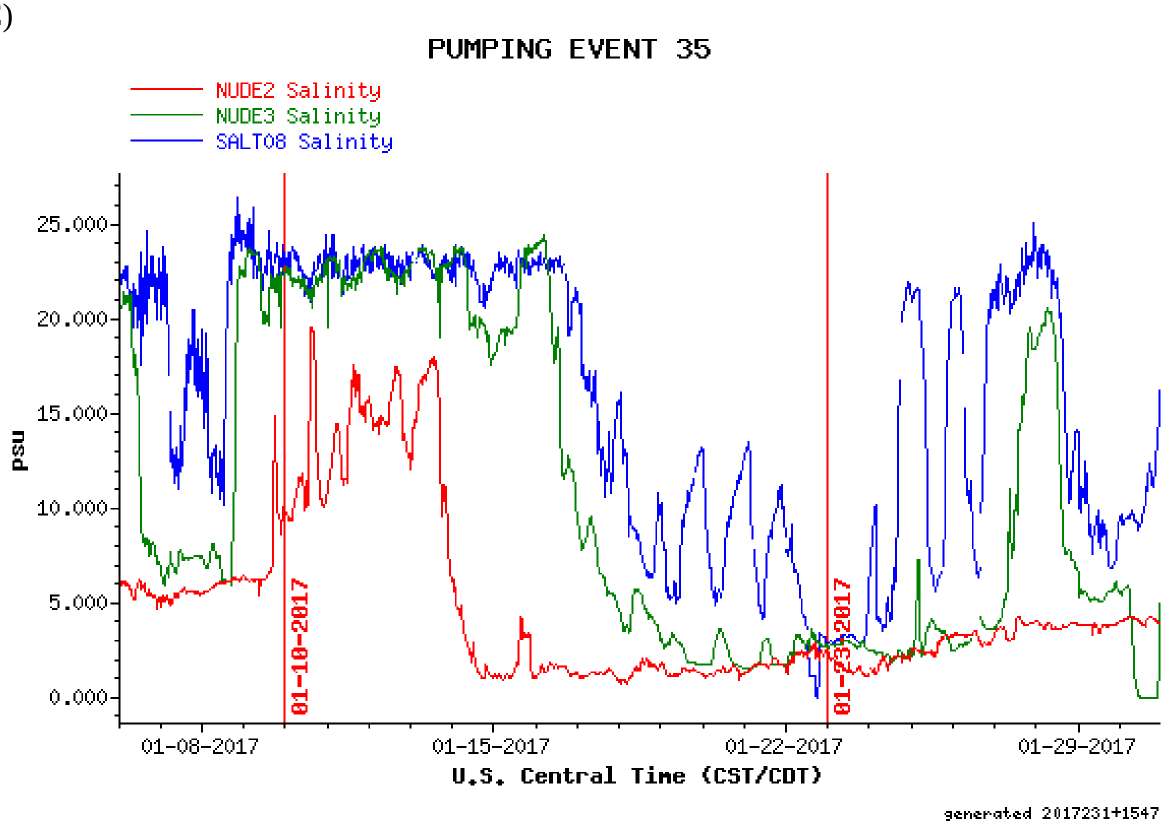
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NUDE3 Salinity
SALT08 Salinity
psu
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15.000
10.000
5.000
0.000
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01-23-2017
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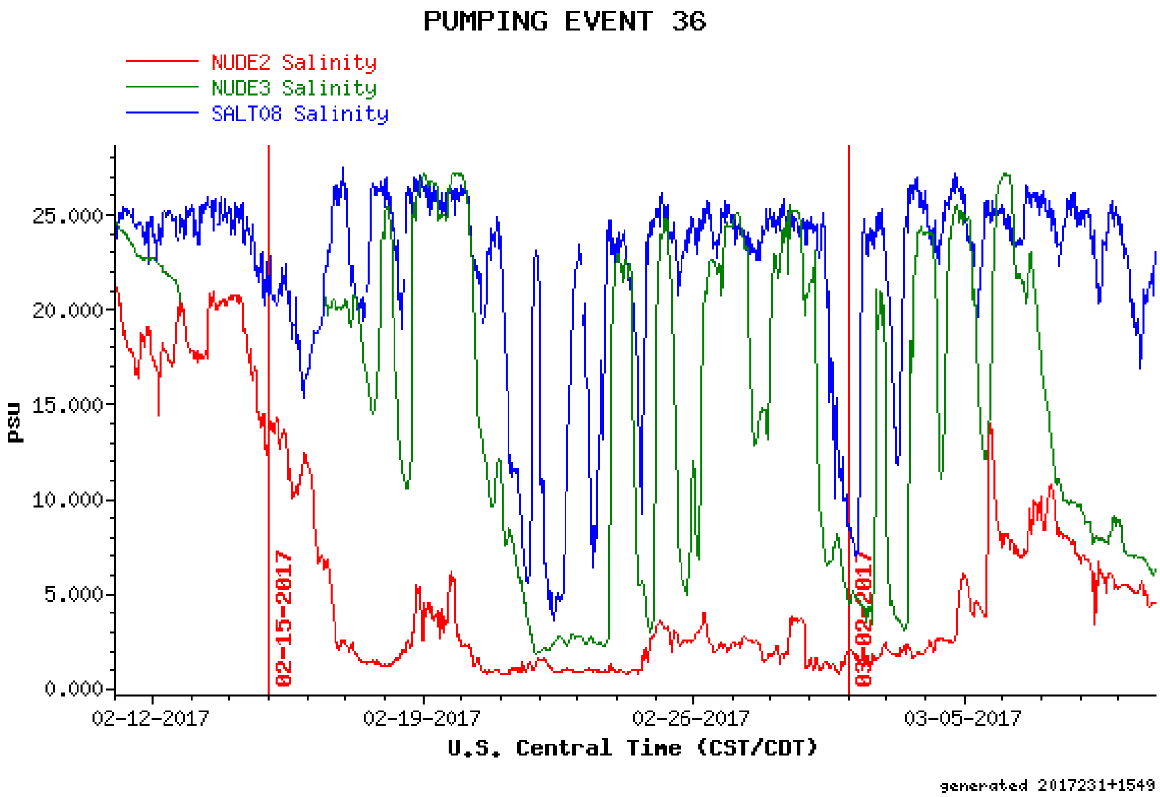
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NUDE3 Salinity
SALT08 Salinity
psu
25.000
20.000
15.000
10.000
5.000
0.000
02-15-2017
03-02-2017
02-12-2017
02-19-2017
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03-05-2017
U.S. Central Time (CST/CDT)
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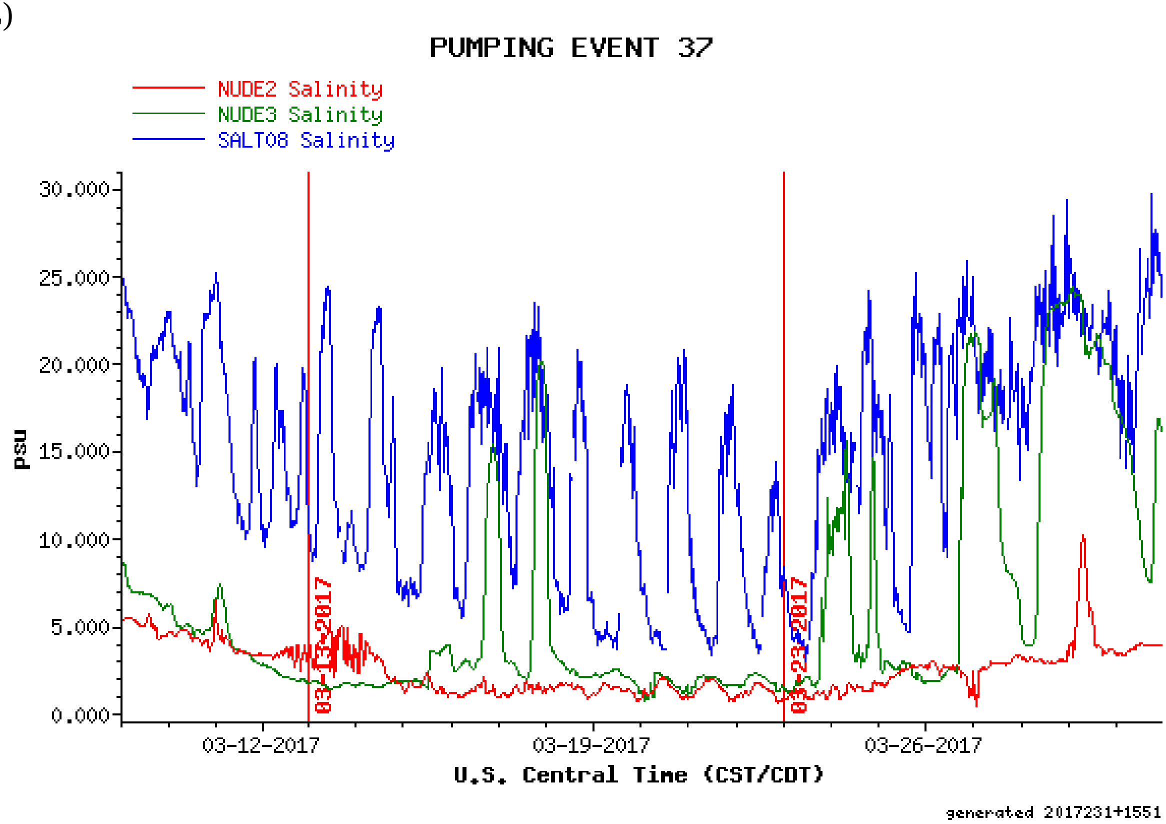
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NUDE2 Salinity
NUDE3 Salinity
SALT08 Salinity
psu
30.000
25.000
20.000
15.000
10.000
5.000
0.000
03-13-2017
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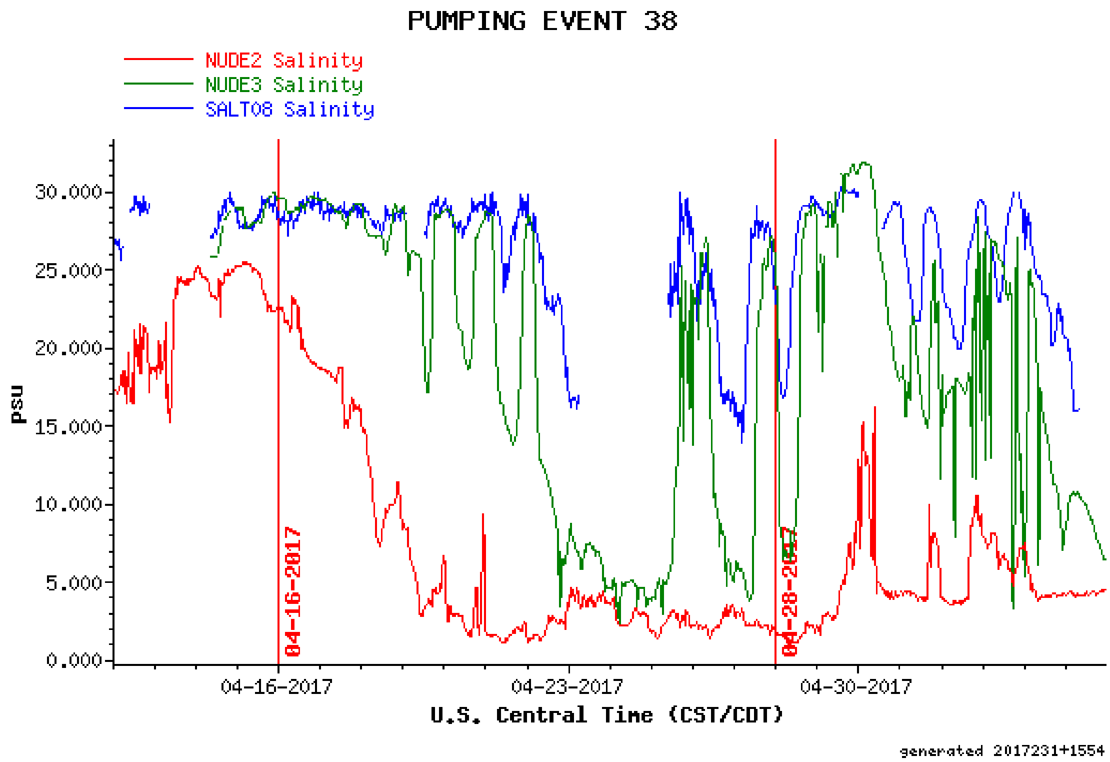
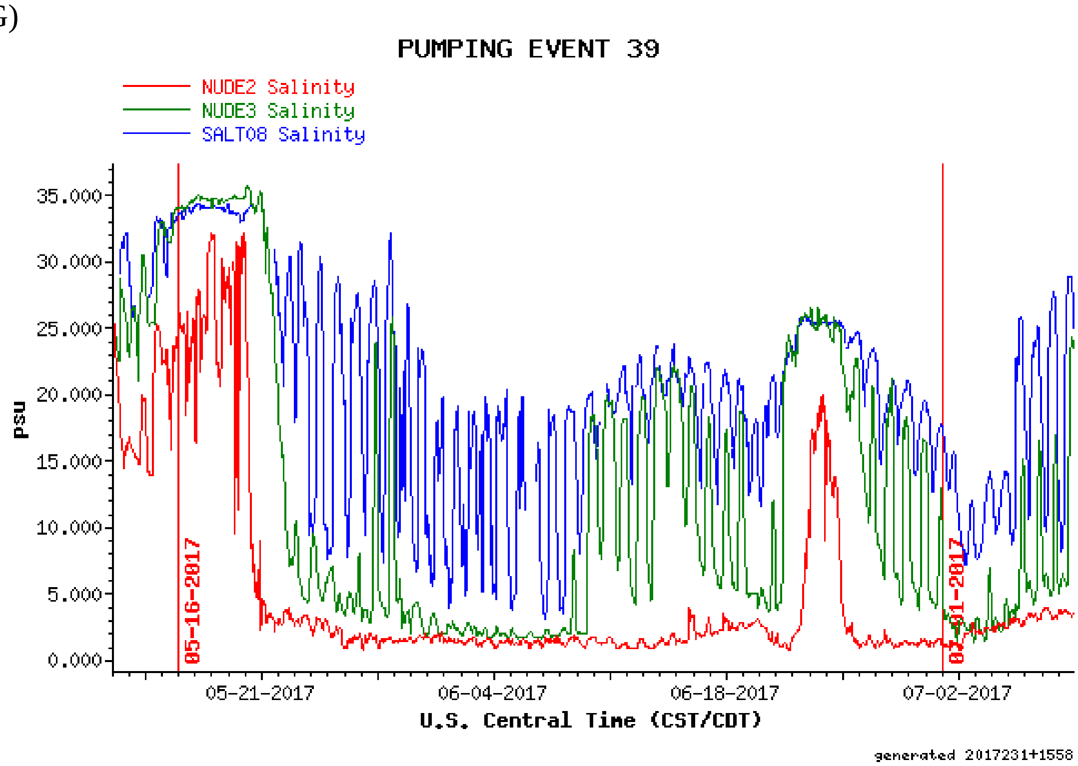
F)



G)



H)

Figure 10. Individual pumping events during the 2016-2017 year. Vertical lines represent the start (left line) and end (right line) of pumping events. Each graph represents 4 days before pumping start and 7 days after pumping end for A) event 32, B) event 33, C) event 34, D) event 35, E) event 36, F) event 37, G) event 38, and H) event 39.

In addition to freshwater inflows, the salinities in the Nueces Delta are also influenced by tidal variations which will cause movements of fresh and saltwater separated by a halocline (Adams and Tunnell 2010). As the tide rises, saltwater nearer to the bay is forced further back into the delta, and as the tide lowers, freshwater located further away from the bay is pulled closer to the bay. This is evident at SALT08, which will undergo rapid increases and decreases in salinity after a pumping event in correlation with rising and lowering tides (Figure 11).

At least some tidal influence on salinity levels at SALT08 appeared to be present during periods of all pumping events during the 2016-2017 sampling year. Diurnal tidal variation appeared to have little to no effect on salinities at NUDE2 and NUDE3 during pumping events. Wind direction, wind velocity, evaporation and rainfall during pumping events have all had an effect on hydrodynamics in the Nueces Delta (Adams and Tunnell 2010).

Pumping events did not seem to have a significant effect on salinity levels at the new SALT04 monitoring station (Figure 12). This is as expected as the mitigation channel currently has no direct connection to the Rincon Bayou. Salinity values at SALT04 ranged from 9.3 to 42.9 PSU with an average of 29.1 PSU during the sampling year. SALT04 will continue to monitor salinity values for the potential construction of a diversion channel that will connect the Rincon Bayou to the mitigation channel.

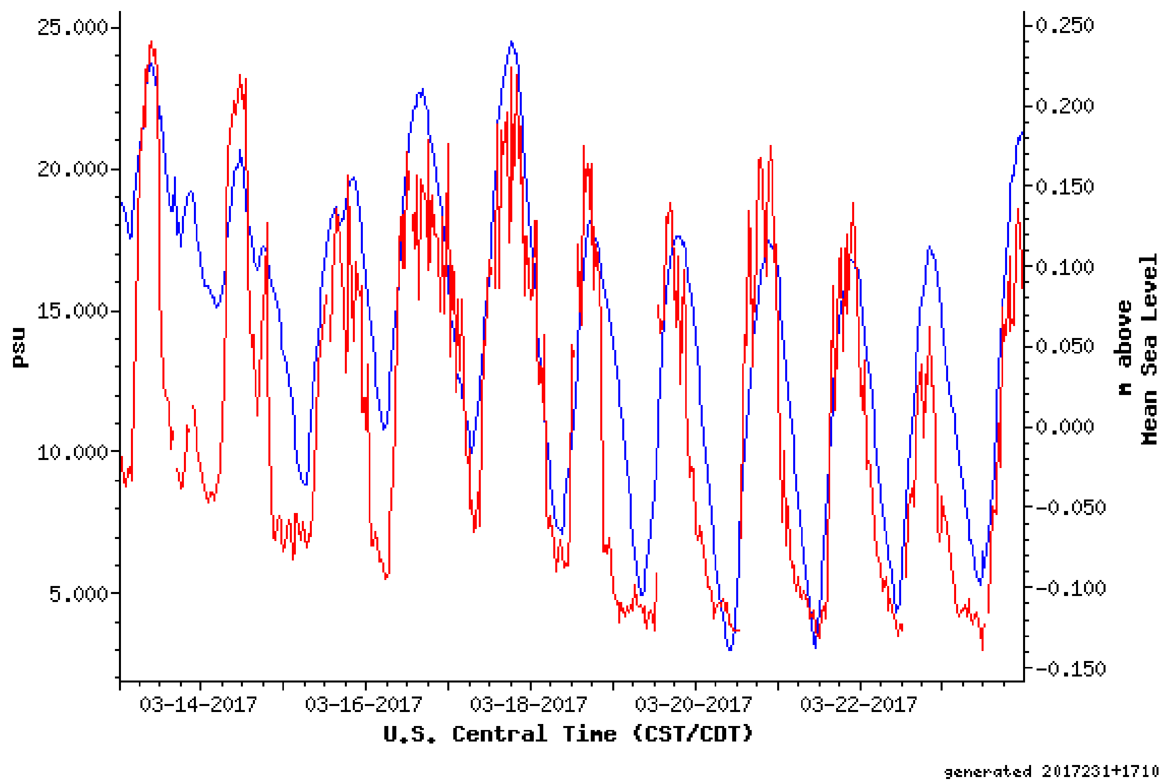


Figure 11. SALT08 salinity (red line) and NUEBAY water level (blue line) during pumping event 37.

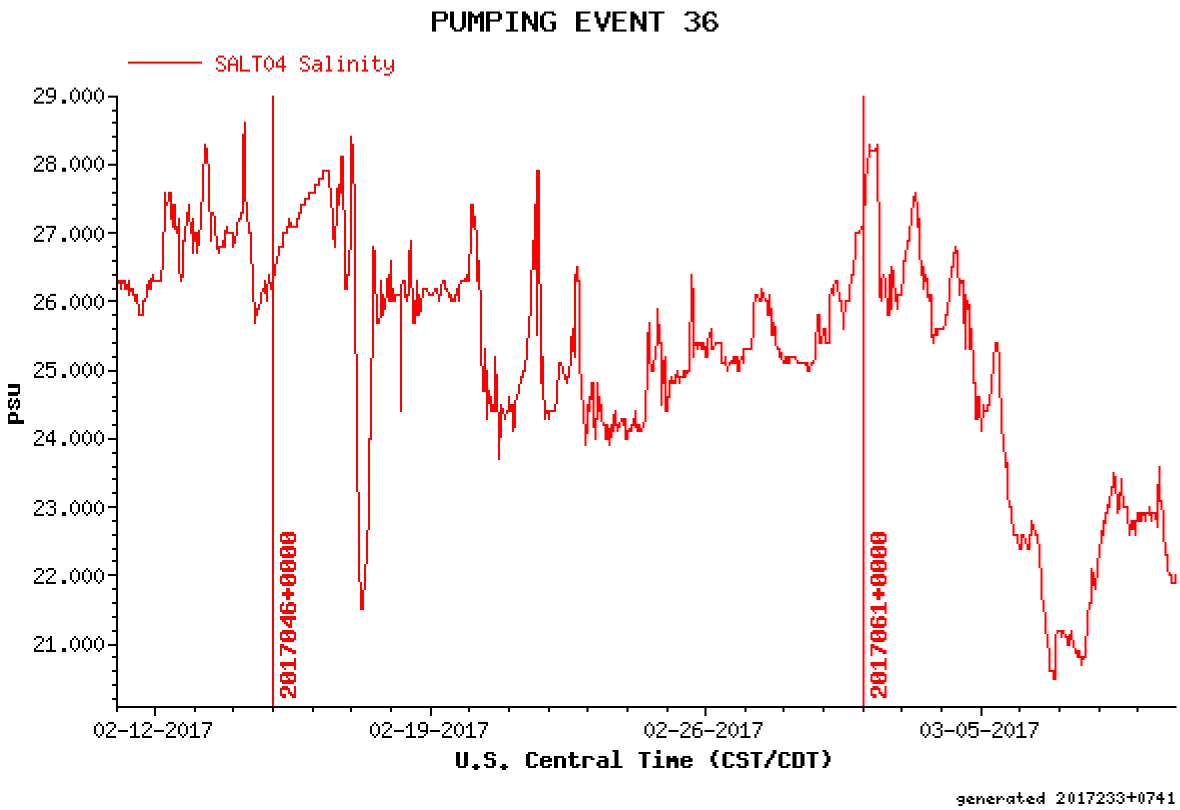


Figure 12. SALT04 salinity during pumping event 36. Vertical lines represent the start (left line) and end (right line) of pumping events.

CONCLUSIONS

The 2016-2017 sampling year had more total pumped water via the RBP to date with a total of 25,844 acre-feet, 7,228 acre-feet more than the previous sampling year. All of the pumping events during the 2016-2017 sampling year were relatively large in terms of amount of water pumped with the minimum amount pumped at 1,382 acre-feet during event 36. The majority of the 2016-2017 sampling year pumping volume and number of total pumping days is attributed to pumping events 32 and 39 which represented 55.9% of the total pumped water (14,440 of 25,844 total acre-feet) and 51.1% of the total number of days pumped (89 of 174 total pumping days).

Most of the pumping events during the 2015-2017 sampling year were typical with salinities dropping to below 5 PSU shortly after initiating the pumps. Events 34 and 37 were the exception due to pumping being initiated relatively close to the end dates of the previous pumping event.

A review of all the pumping events since this project began in 2009 appears to indicate that the pipeline is an effective tool for managing salinities within the Rincon Bayou. The combined effects of precipitation, wind direction and velocity, tidal variations and evaporation has a significant effect on salinity levels in the Nueces Delta, and the data gathered from this project will be incorporated into the overall water management strategy for reestablishing the connectivity and salinity gradient back in the Nueces Delta.

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