Nueces Delta Salinity Effects from Pumping Freshwater into the Rincon Bayou: 2009 to 2014

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Prepared by
Larry Lloyd
Principal Investigator
Conrad Blucher Institute for Surveying and Science
Texas A&M University-Corpus Christi
6300 Ocean Drive, Corpus Christi, TX 78412

Submitted to:
Coastal Bend Bays & Estuaries Program
1305 N. Shoreline Blvd., Suite 205
Corpus Christi, TX 78401

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Larry Lloyd, Principal Investigator
Conrad Blucher Institute for Surveying and Science
Texas A&M University-Corpus Christi
6300 Ocean Drive, Corpus Christi, TX 78412
Larry.Lloyd@tamucc.edu
Phone: (361) 825-5759 office

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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 some of the trends in salinity changes throughout all the pumping events since 2009, and have a more detailed look at the effects seen during fiscal year 2014 (September 1, 2013 to August 31, 2014). The results of this study are being used in the development of a water management plan that will help water managers make important 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 concentration 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 way freshwater flows 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). These decreased inflows into the delta and the prolonged Texas droughts cause the hypersaline conditions we see currently. 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).

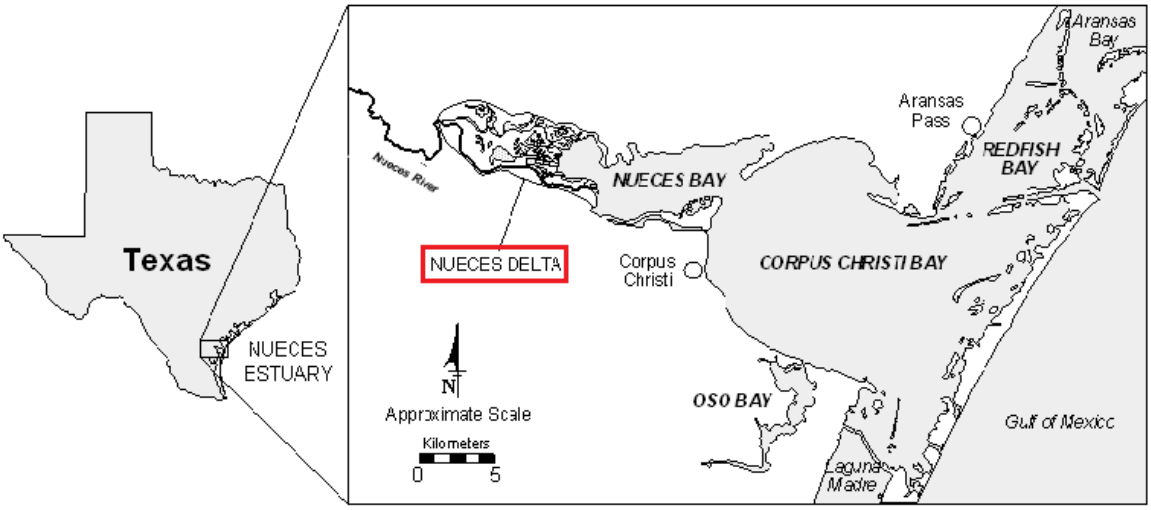


Figure 1.Location of the Nueces Delta within Texas and the Nueces Watershed.

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 Conrad Blucher Institute 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 important decisions on quantity, timing, and duration of pipeline inflow events that are most productive and

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.

important to the ecology of 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 five (5) RBP inflow events that occurredbetween September 1st, 2013 and August 31st, 2014. This project represents the sixth 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 three salinity-monitoring stations located downstream in the Nueces Delta and Bay recording data in correspondence with the RBP freshwater releases (Figure 3).

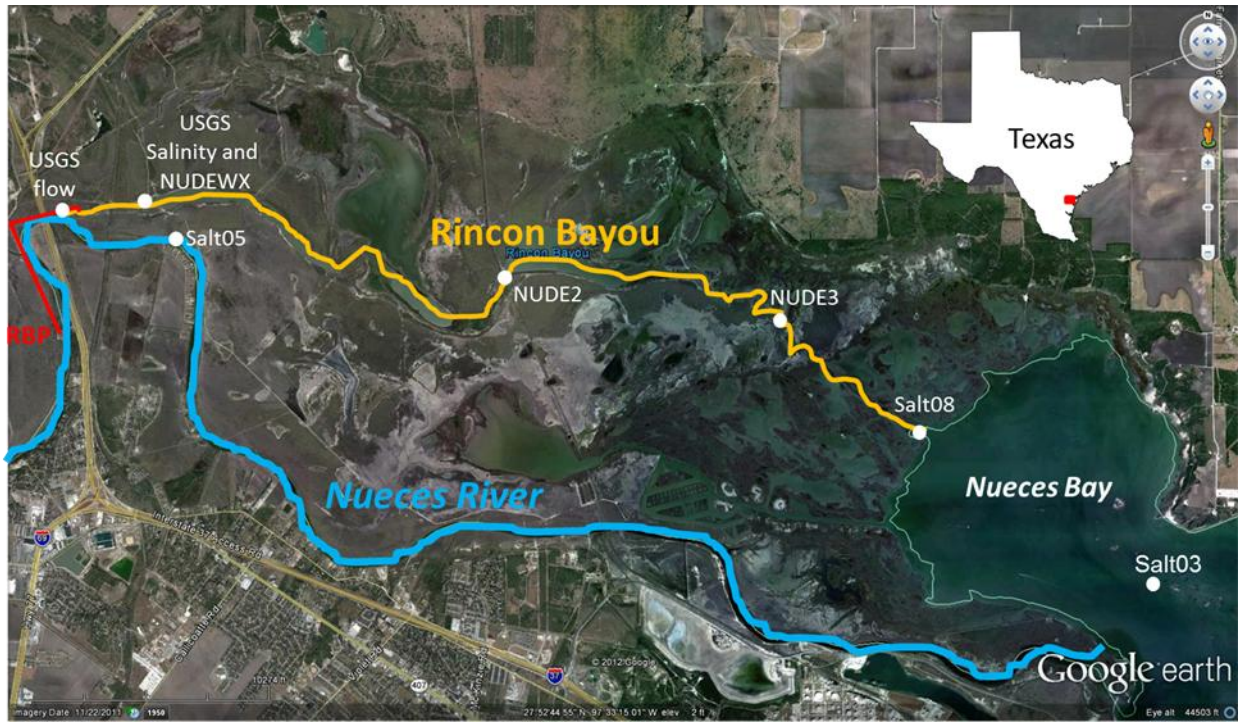


Figure 3. Map showing the RBP (Rincon Bayou Pipeline [red line]) and the three salinity monitoring stations for this project (NUDE2, NUDE3, and SALT08).

Each Nueces Delta (NUDE) station is jetted approximately five feet down into the sediment near the water's edge and the sondeis extended 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.

A tide gauge (NUDEBAY 185) is located in Nueces Bay and measures primary water level (m), water temperature (°C), wind speed (m/s), wind gusts (m/s), wind direction (°), and barometric pressure (mbar). The weather station, NUDEWX is located on Rincon Bayou downstream from the RBP outfall. 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. NUDEBAY 185 is serviced every 6 months.

The CBI salinity monitoring stations involve 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), conductivity (µS), salinity (ppt), pH, dissolved oxygen (% saturation & mg/L), and depth (m). Stations Hydrolab H20 datasondes at SALT08, NUDE2, and NUDE3 measure: water temperature (°C), conductivity (µS), salinity (ppt). Instruments are exchangedmonthly with replacement calibrateddatasondes (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.

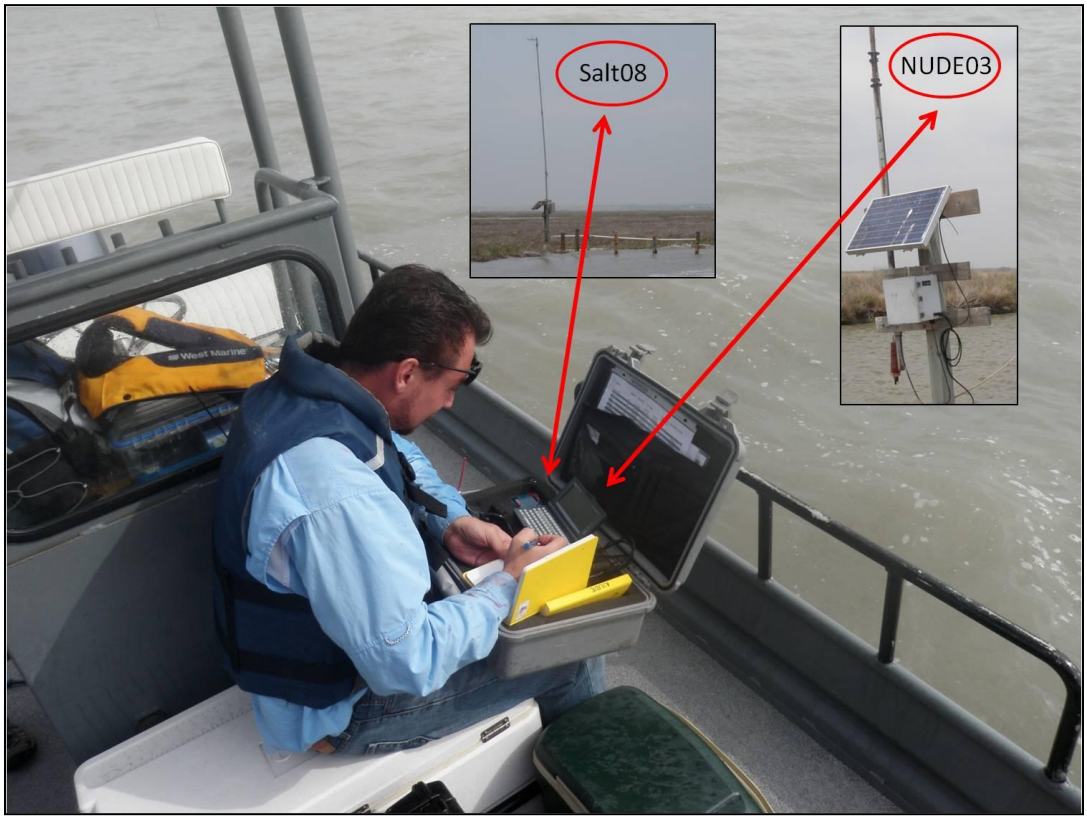


Figure 4. Dominic Burch uses a radio and computer to call NUDE3 and SALT08 before and after exchanging the sondes to ensure the devices are measuring salinity accurately.

Figure 5. Salt08 (top image) and NUDE3 (bottom image) are being exchanged with a newly calibrated device which will last for approximately 4 weeks until another sonde will be exchanged again.

RESULTS AND DISCUSSION

Eighteen pumping events have occurred since the RBP became operational in late 2007. 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) of freshwater pumped to the Rincon Bayou. Three pumping events in year three (2010-2011) totaling 2,997 acre-feet (3,696,745 m^3) of freshwater were pumped to the Rincon Bayou. Four pumping events occurred during year four (2011-2012) during which 5,695 acre-feet (7,024,679 m^3) of freshwater were delivered to the Rincon Bayou. Four pumping events occurred in year five (2012-2013) during which 3,991 acre-feet (4,921,592 m^3). So far, five pumping events totaling 11,694 acre-feet (17,799,143 m^3) of freshwater were delivered to the Rincon Bayou during year six as of July 31, 2013 (Table 2).

Local rainfall varied spatially between the National Weather Service 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 regularly 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.

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 current 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 as of July 31, 2014. Drought conditions across the Texas watershed have not been as persistent as the previous year causing the Choke Canyon and Lake Corpus Christi reservoirs to have a higher combined average capacity than the 2012-2013 year (Figure 6). 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 2013). 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 2013). Reservoir water levels were generally greater during the 2013-2014 year with Lake Corpus Christi ranging between 23.6% and 100.0% with an average of 74.5% and the Choke Canyon Reservoir ranging between 29.3% and 36.8% with an average of 33.5%.

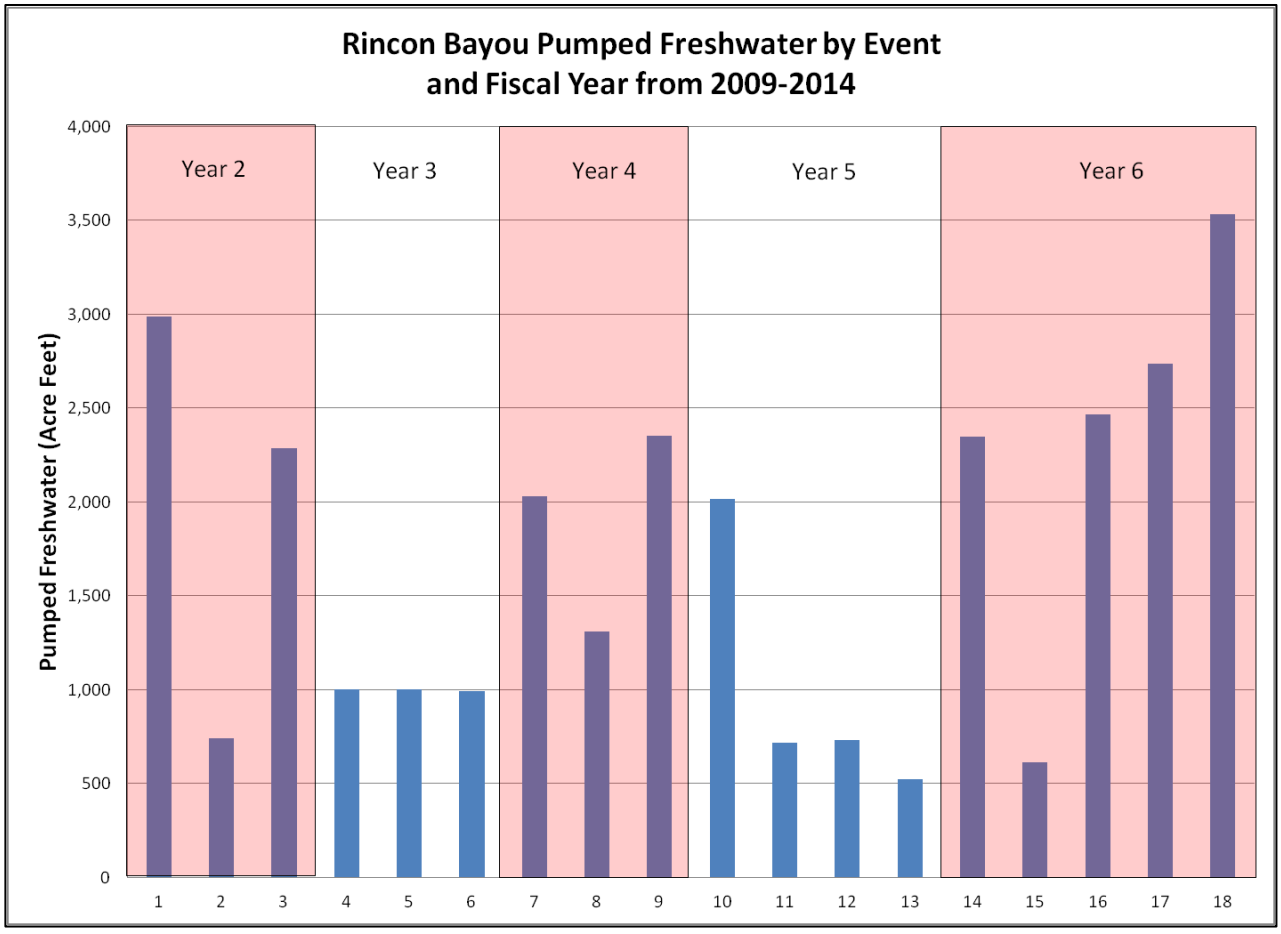


Figure 6. Rincon Bayou pumping events by fiscal year from 2009-2014.

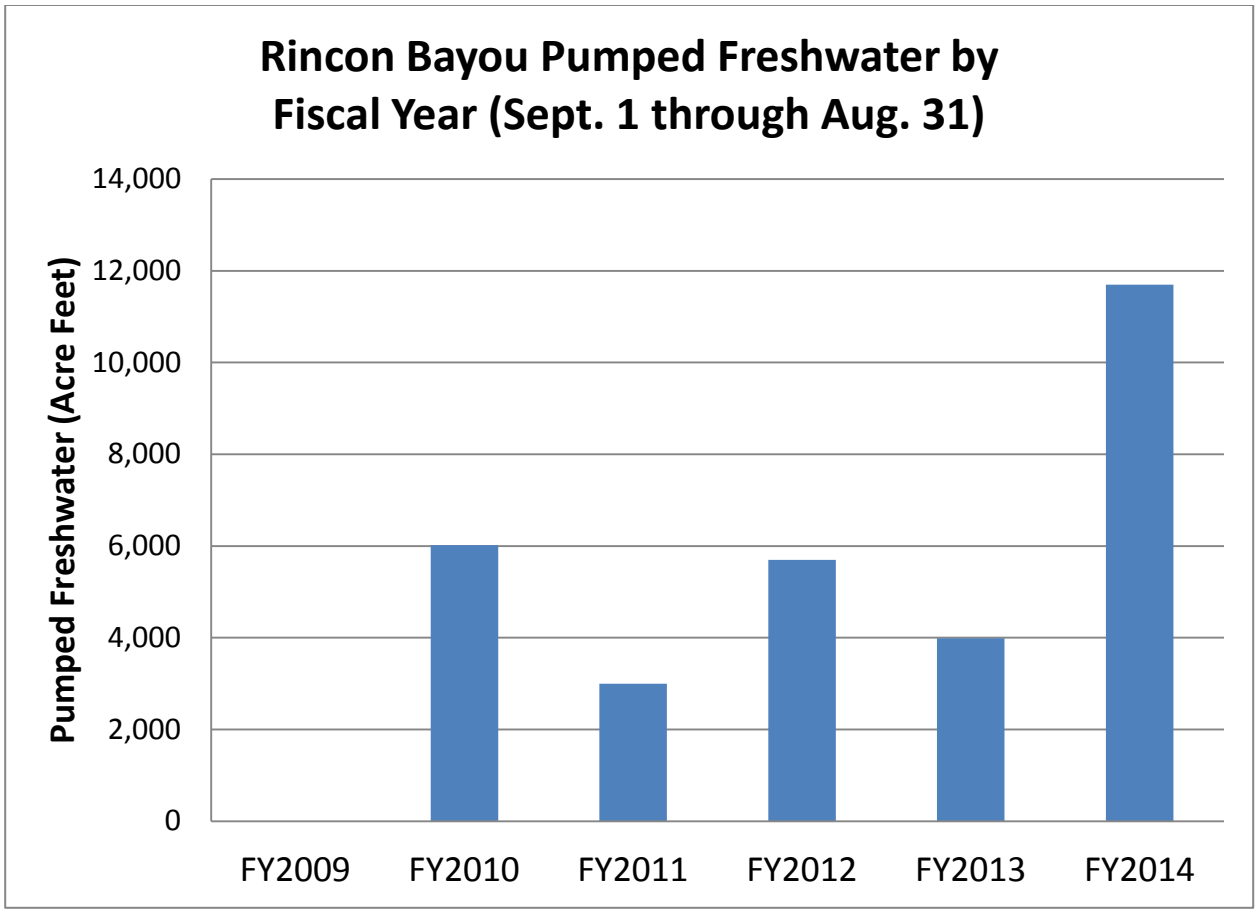


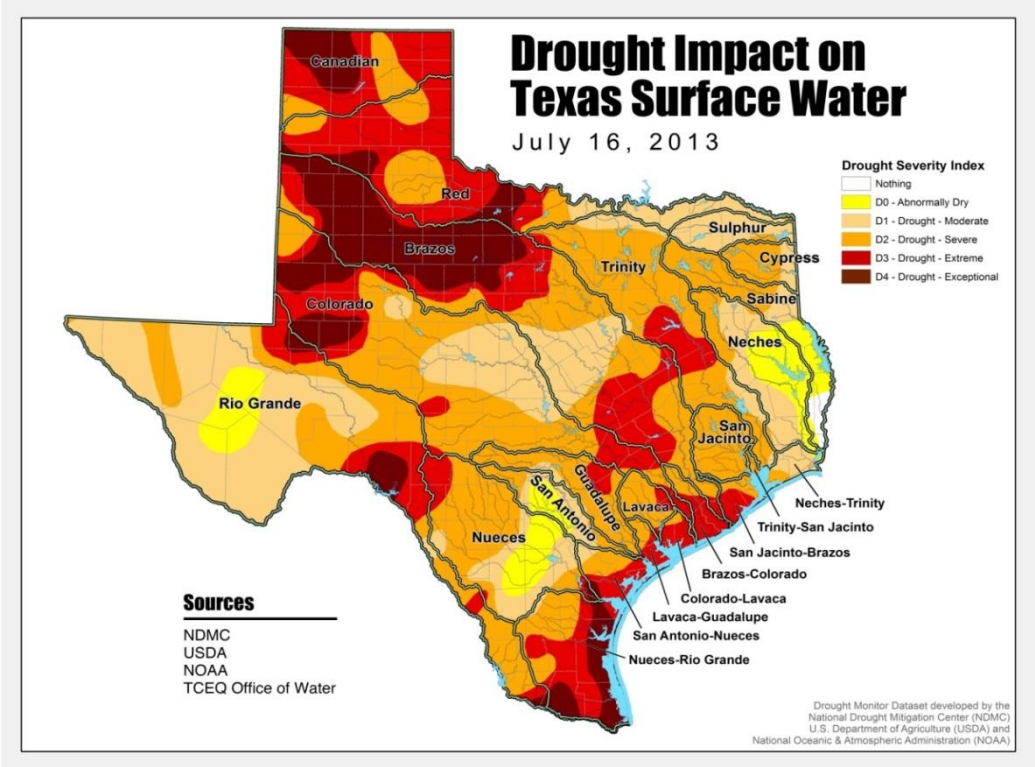
Figure 7. Total amount of freshwater pumped for each fiscal year (Sept. 1 through Aug. 31).

Table 2. RBP pumping events including pumping dates, duration, and acre-feet pumped.

Year	Pumping Event	Dates of Event	Duration (days)	Tide	Acre-Feet Pumped	Wet/Dry Period
1	-	No pumping occurred	-	-	-	-
2	1	Sep. 28 to Oct. 21, 2009	24	High	2,987	Wet
	2	Jan. 6 to Jan. 14, 2010	9	Low	742	
	3	May 10 to May 31, 2010	21	High	2,288	
3	4	Mar. 21 to Mar. 30, 2011	10	Moderate	1,001	Dry
	5	May 3 to May 12, 2011	10	High	1,002	
	6	Jun. 13 to Jun. 22, 2011	10	Moderate	994	
4	7	Nov. 2 to Nov. 22, 2011	21	Moderate	2,031	Dry
	8	Mar. 7 to Mar. 19, 2012	13	Moderate	1,310	
	9	Jun. 21 to Jul. 13, 2012	23	High	2,354	
5	10	Oct. 5 to Oct. 18, 2012	13	Moderate	2,017	Dry
	11	Jun. 1 to Jun. 10, 2013	10	High	717	
	12	Jun. 24 to Jul. 2, 2013	9	Moderate	731	
	13	Jul. 17 to Jul. 21, 2013	5	High	526	
6	14	Oct. 21 to Nov. 9, 2013	16	High	2,348	Dry
	15	Nov. 22 to Dec. 8, 2013	12	Moderate	613	
	16	Feb. 3 to Feb. 15, 2014	13	Low	2,466	
	17	May 9 to Jun. 3, 2014	24	Moderate	2,736	
	18	Jun. 23 to Jul. 15, 2014	23	Moderate	3,531	

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

	2008-2009	**2009-2010**	**2010-2011**	**2011-2012**	**2012-2013**	**2013-2014**
NUDEWX	3.0 in. (7.62 cm)	15.6 in. (39.62 cm)	7.9 in. (20.01 cm)	N/A – sensor removed	7.13 in. (18.11 cm)	19.29 in. (49.00 cm)
CRP	8.81 in. (22.38 cm)	42.9 in.(108.97 cm)	25.3 in.(64.26 cm)	18.68 in. (47.45cm)	14.16 in. (35.97 cm)	18.69 in. (47.47 cm)



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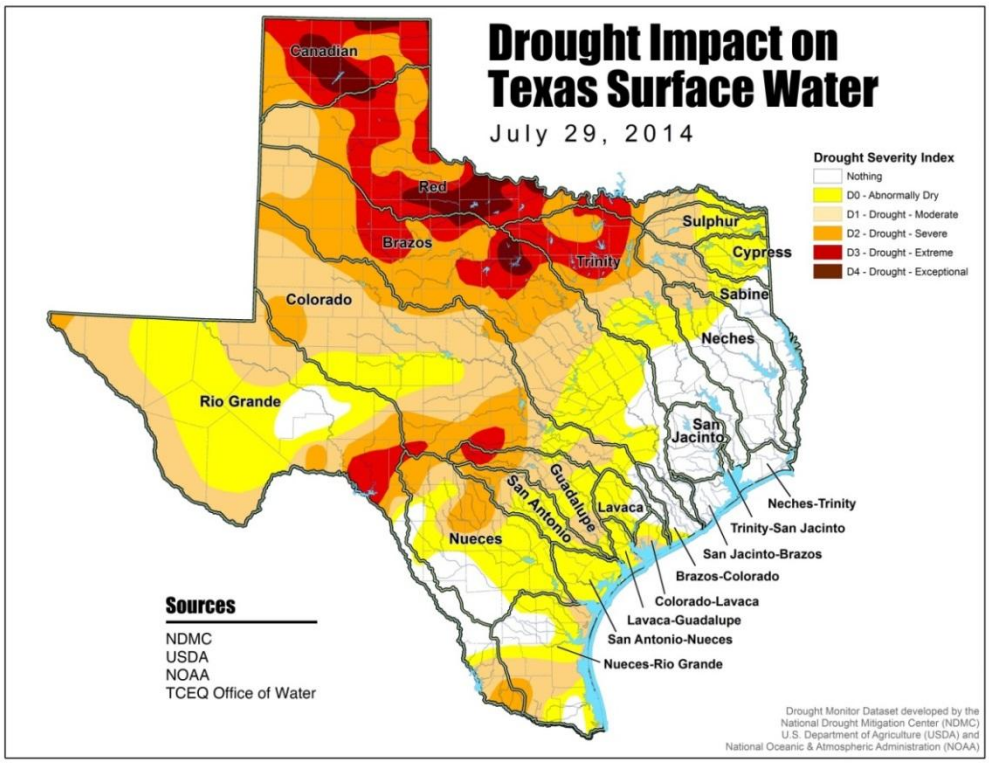


B)

Figure 8. Drought condition throughout the state of Texas on July 16, 2013 (A) and on July 29, 2014 (B)

Difference in rainfall from year to year gives an opportunity to study the pumping events during wet versus dry conditions to better understand their delivery efficiency.

Salinities during event 14 (October-November 2013) at NUDE2 followed patterns typical of past pumping events with salinities dropping from 24ppt to below 5 ppt within 4 days of pumping and gradually raising back to above 20 ppt 13 days after pumping ended (Figures 7 and 8). A total of 2,348 acre-feet of water were pumped over 16 days. Pumping event 15 (November – December 2013) was the lowest event during the 2013-2014 year at 613 acre-feet and resulted in salinities dropping from 21 ppt to below 5 ppt in 3 days after the pumps were activated. Salinity levels gradually raised to above 5 ppt4 days after the pumps were deactivated.

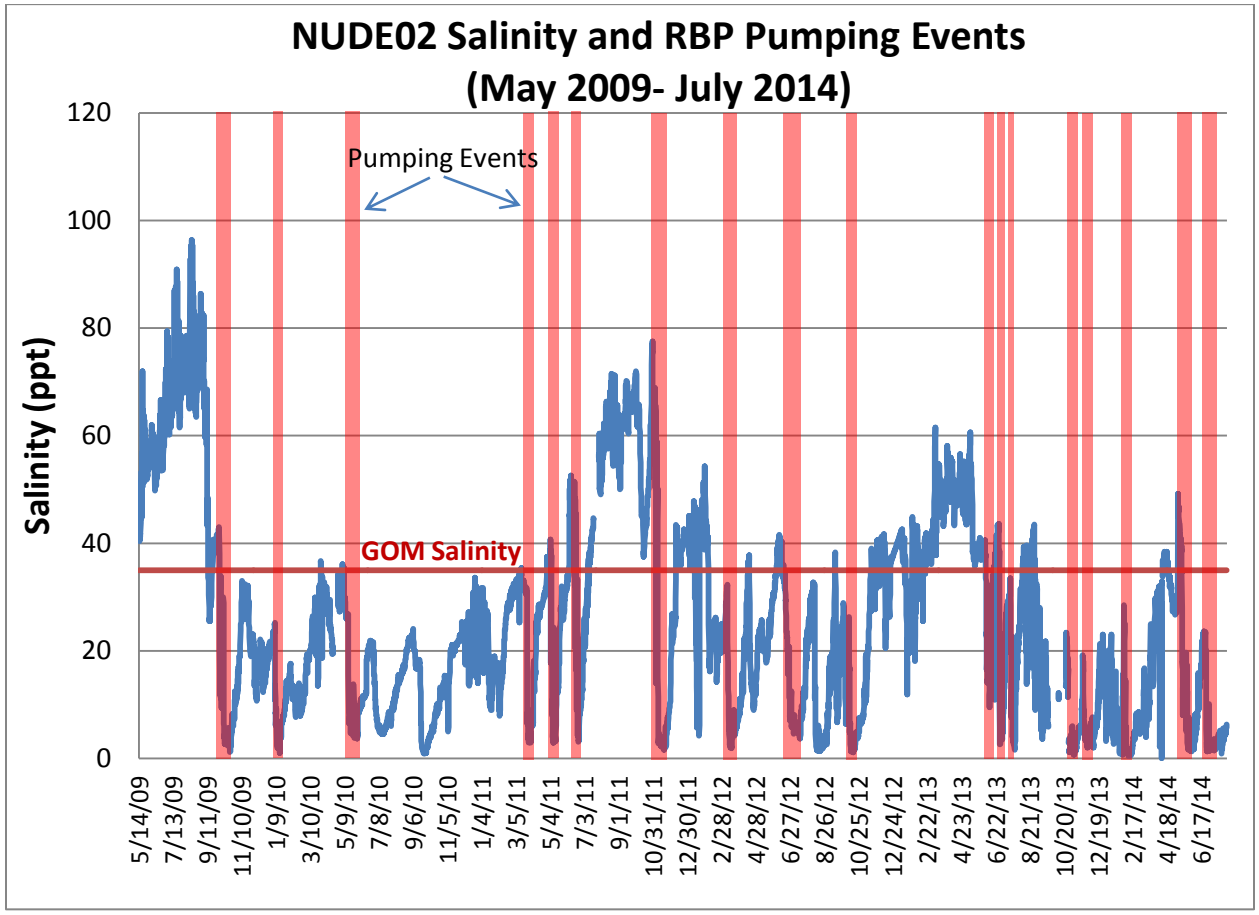


Figure 9. NUDE2 salinity during the eighteen pumping events relative to35ppt, which is typical Gulf of Mexico (GOM) salinity seen on the horizontal red line. Shaded areas denotes the pumping events that have occurred for the project during the period of May 2009 to July 2014. Thickness of each shaded area represents duration (days) of pumping.

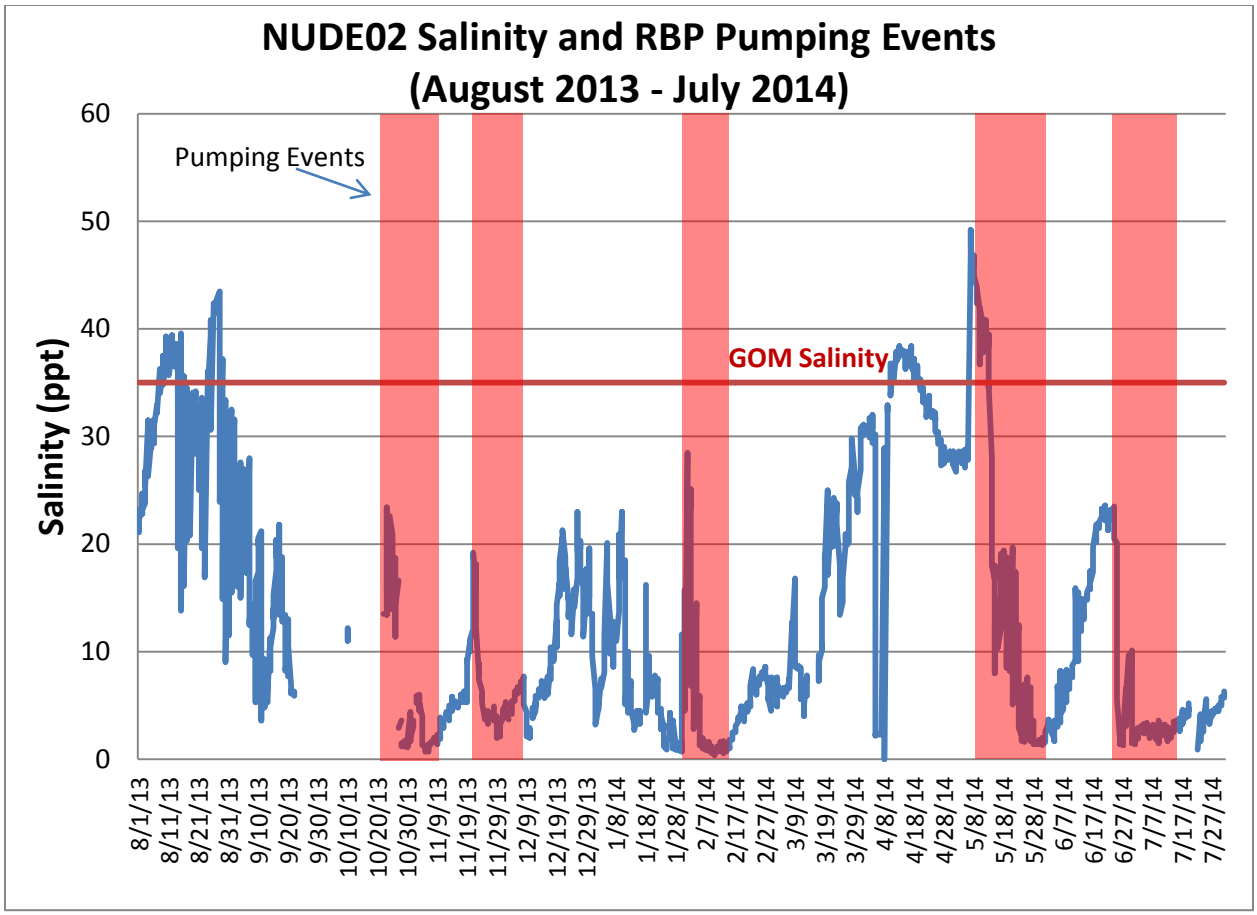


Figure 10. NUDE2 salinity during the four pumping events relative to35ppt, which is typical Gulf of Mexico (GOM) salinity seen on the horizontal red line. Shaded areas denotes the pumping events that have occurred for the project during the period of August 2013to July 2014. Thickness of each shaded area represents duration (days) of pumping.

Pumping events 16 (February, 2014), 17 (May – June 2014) and 18 (June – July 2014) represent the fourth, third and first highest pumping events, respectively, in terms of acre-feet pumped. A total of 2,348 acre-feet was pumped during event 16 resulting in salinities dropping from 13 ppt to below 5 ppt in 2 days and gradually increasing to above 5 ppt in 5 days after the pump were deactivated. Pumping event 17 occurred during the highest salinities of the sampling period with a value of 43 ppt when the pumps were activated. A total of 2,736 acre-feet were pumped over 24 days resulting in salinities dropping to under 5 ppt 14 days after the pumps were activated and raising back to above 5 ppt 5 days after the pumps were deactivated. Pumping event 18 represents the highest pumping event to date at 3,531 acre-feet which resulted in salinities dropping from 24 ppt to under 5 ppt in 3 days and raising back above 5 ppt 14 days after the pumps were deactivated.

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 9).

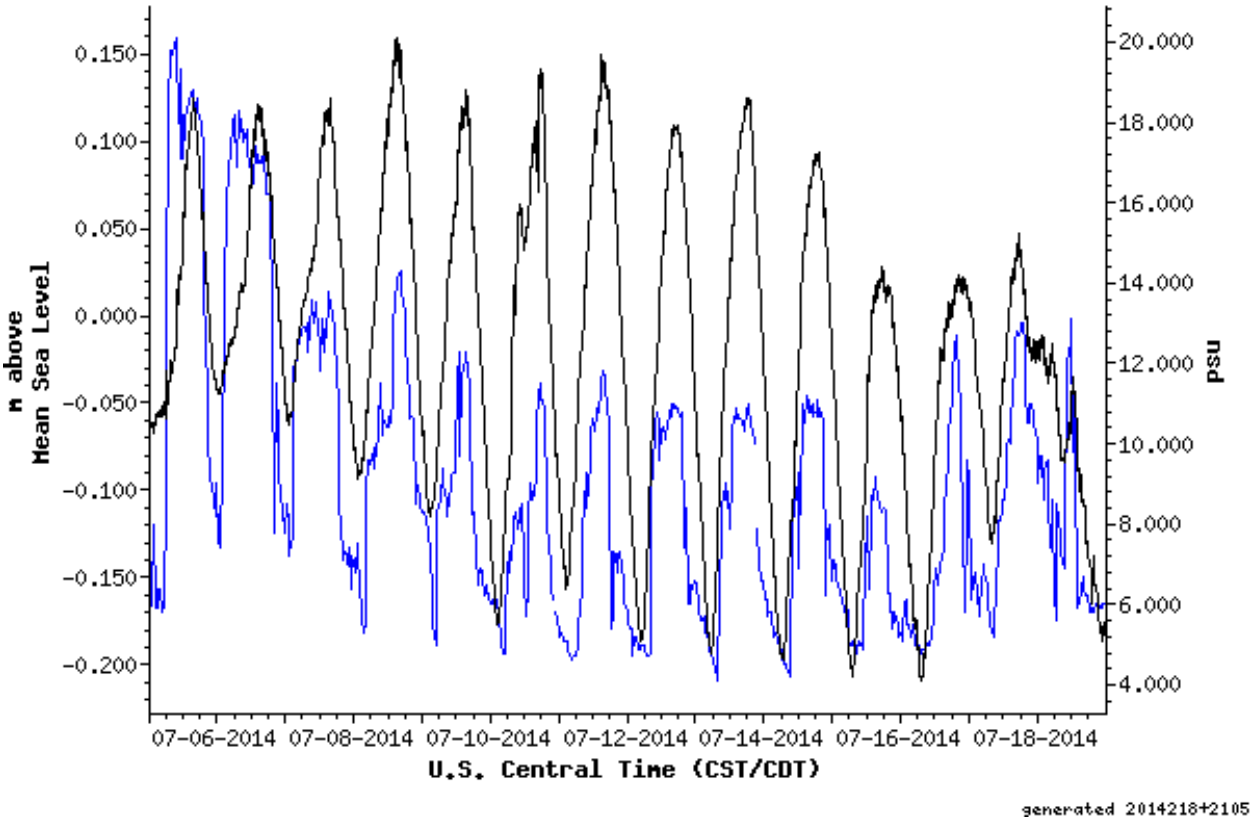
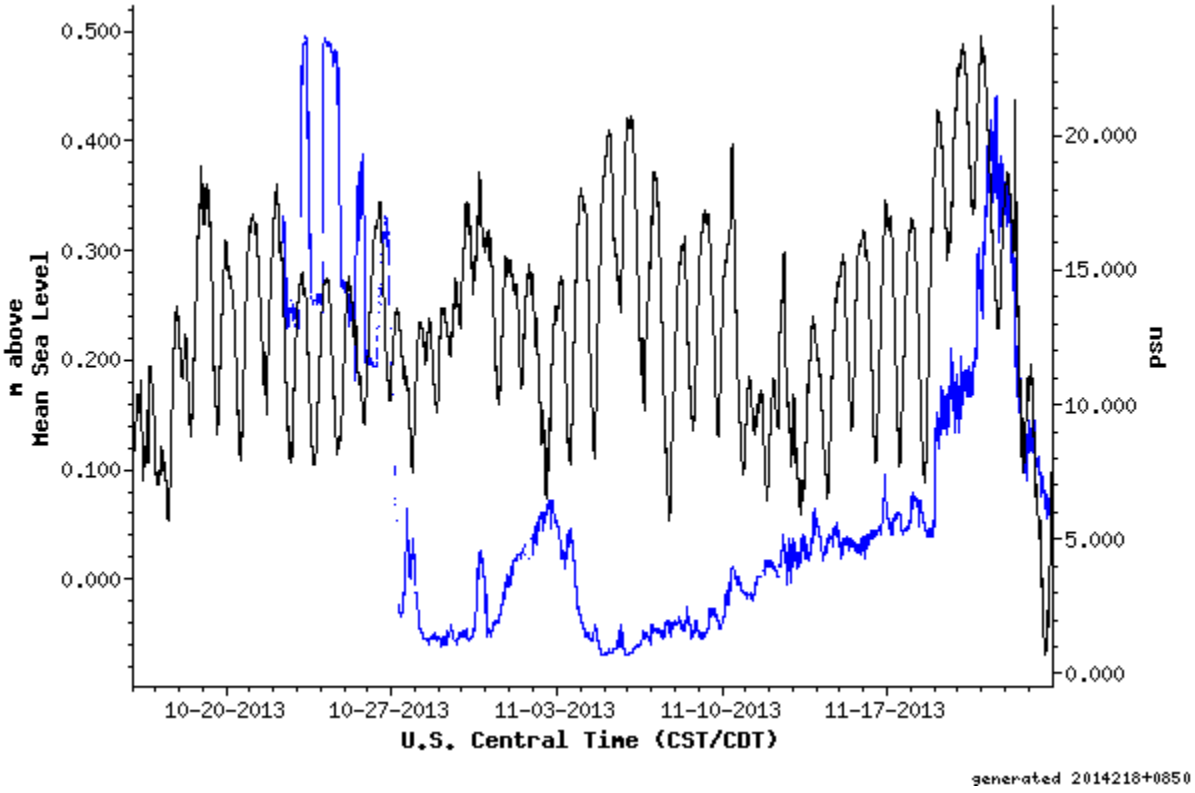


Figure 11. Salinity (blue line) and water level (black line) at SALT08 at the end of pumping event 18.

At least some tidal influence on salinity levels appeared to be present during periods of all pumping events during the 2013-2014 sampling year (Figure 10). Diurnal tidal variation appeared to have little to no effect on salinities at NUDE2 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).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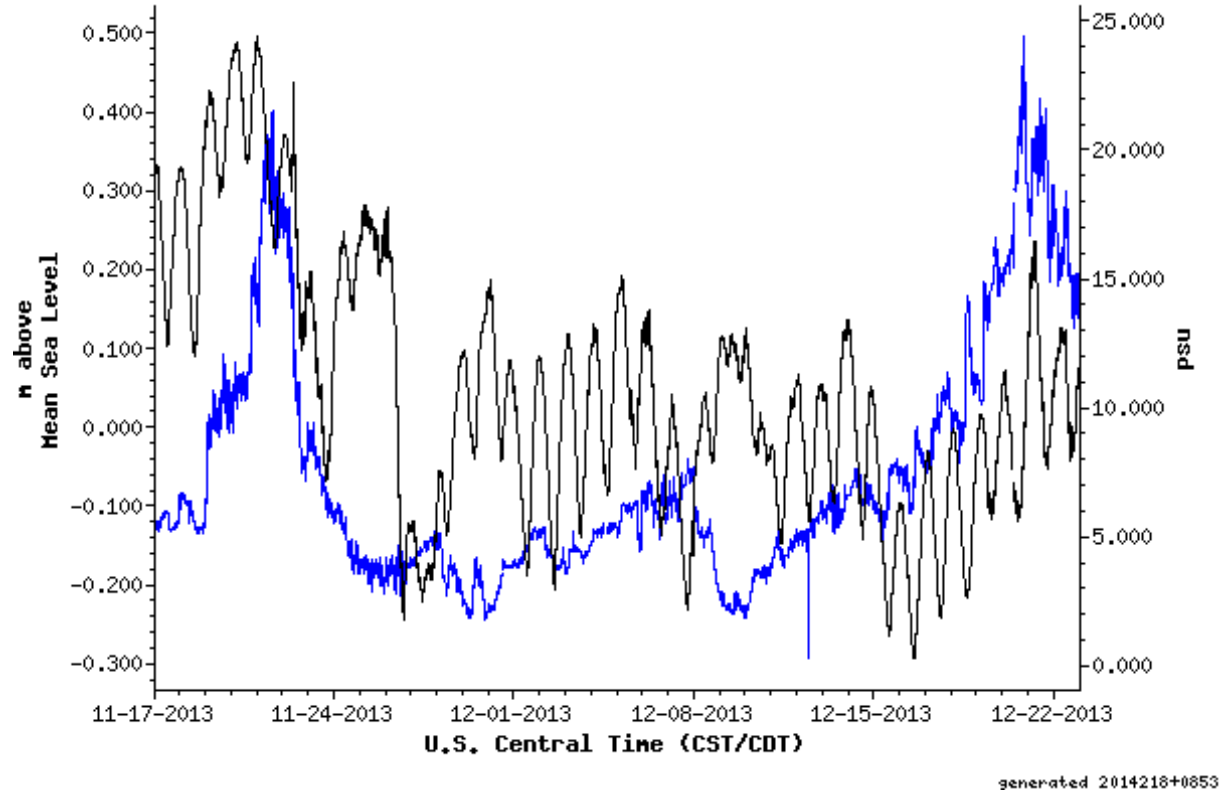
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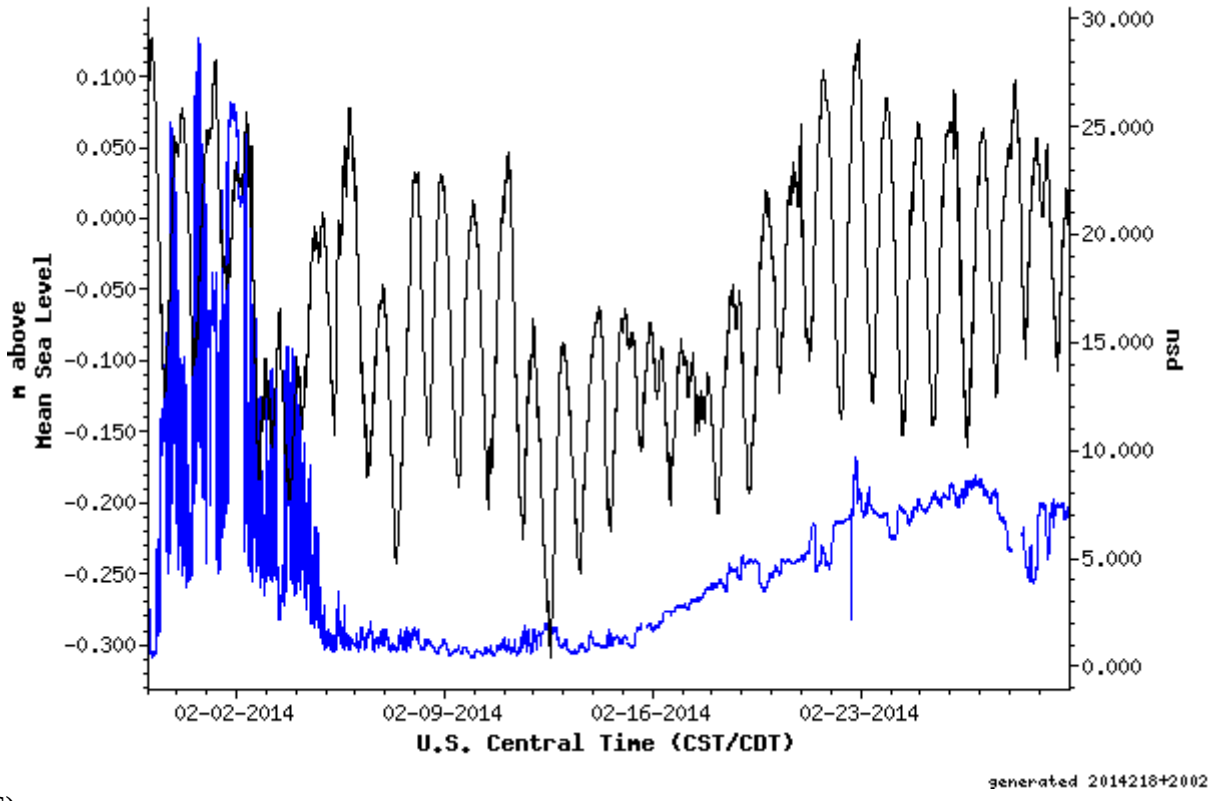
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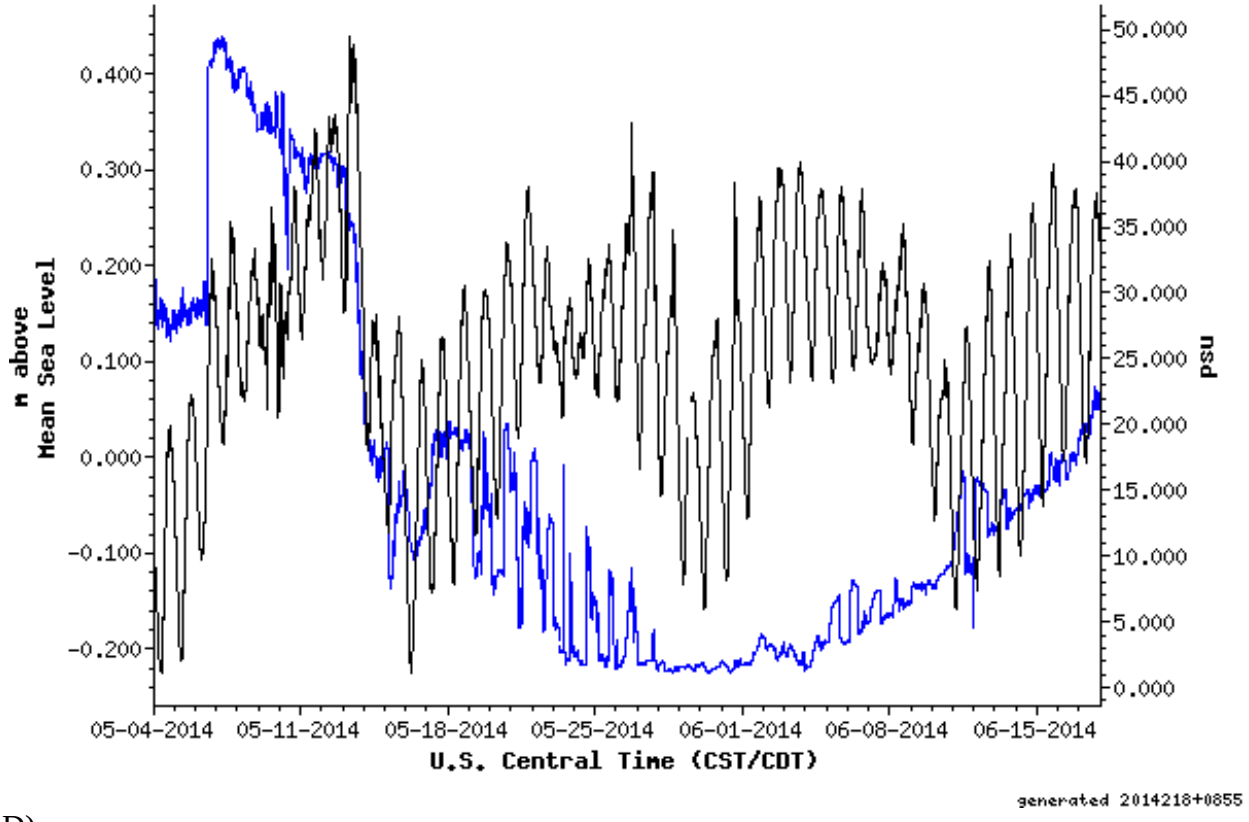
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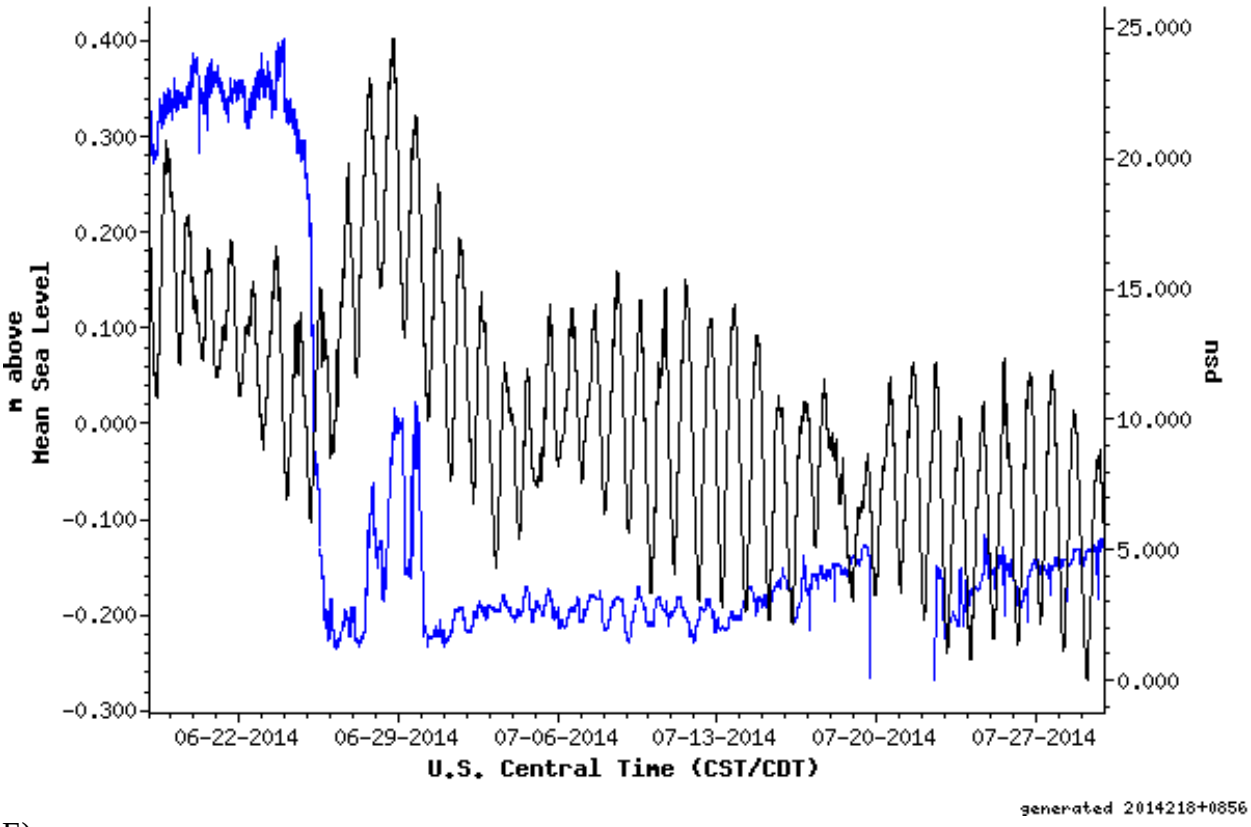

E)

Figure 12.Individual pumping events during the 2013-2014 year.Blue lines represent salinity at NUDE2 and black lines represent water level at NUDEBAY 185. Each graph represents 5 days before the pumping event and 14 days after the pumping event for A) event 14, B) event 15, C) event 16, D) event 17, and E) event 18.

CONCLUSIONS

The most recent sampling year gave an opportunity to study pumping events in the Nueces Delta during a year following one of the worst droughts in Texas history (Nielsen-Gammon 2012). The 2013-2014 sampling year also had the most water pumped at a total of 11,694 acre-feet than any other sampling year, nearly twice the amount of the next closest year (year 2 at 6,017 acre-feet). Four of the five highest volume pumping events occurred during the most recent sampling year as well as the most pumping events (five) and the most days of pumping (88 days) of any other sample year. The high volume of water pumped during the 2013-2014 sampling year is mainly attributed to higher instances of freshwater passthrus from October 2013, when Lake Corpus Christi filled and spilled and from high passthrus from May and June of 2014.

All of the pumping events from the 2013-2014 sampling year were relatively typical with salinities dropping below 5 ppt in 2-5 days of pumping with the exception of pumping event 17 taking longer, likely due to higher tides and the challenge of freshwater displacing bay water. The most recent sampling year attributes data representing management strategies indicative of a relatively large amount of available freshwater in comparison to previous sampling years.

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.

REFERENCES

Adams, J.S. and J.W. Tunnell. 2010. Rincon Bayou Salinity Monitoring. Final Report submitted to the Coastal Bend Bays & Estuaries Program for project number 0921, Coastal Bend Bays & Estuaries Program, Publication No. CBBEP-66, 18 pp.

Bureau of Reclamation (BOR).2000. Concluding Report: Rincon Bayou Demonstration Project.Volume II: Findings.United States Department of the Interior, Bureau ofReclamation, Oklahoma-Texas Area Office, Austin, Texas.

Dunton, K. H. and H. D. Alexander. 2000. Chapter Six: Vegetation Communities. In Bureau of Reclamation.Concluding Report: Rincon Bayou Demonstration Project.Volume II: Findings.UnitedStates Department of the Interior, Bureau of Reclamation, Oklahoma – Texas Area Office, Austin, Texas.

Hill, E. M., B. A. Nicolau, and P. V. Zimba.2011. Habitat Management History of the Nueces Estuary, Texas, USA.Texas Water Journal (2)1: 97-111.

Hodges, B.R., K.H. Dunton, P.A. Montagna, and G.H. Ward.2012.Nueces Delta Restoration Study. Final Report to the Coastal Bend Bays & Estuaries Program, Project 1001. Publication No. 84. Corpus Christi, Texas. 133 pp.

Matthews G. A. andA. J. Mueller.1987. Freshwater inflow requirementsof a Texas estuary.Coastal Zone 1987. WW Div./ASCE, Seattle Washington, 26-29 May 1987: 15 p.

Montagna, P.A., R.D. Kalke, and C. Ritter.2002. Effect of Restored Freshwater Inflow on Macrofauna and Meiofauna in Upper Rincon Bayou, Texas, USA. Estuaries 25:1436–1447.

Montagna, P. A., E. M. Hill and B. Moulton. 2009. Role of science-based and adaptive management in allocating environmental flows to the Nueces Estuary, Texas, USA. In: Brebbia, C.A. and E. Tiezzi (eds.), Ecosystems and Sustainable Development VII, WIT Press, Southampton, UK, pp. 559-570.

Nielsen-Gammon, J. W. 2012. The 2011 Texas Drought.Texas Water Journal3(1): 59-95.

Nueces River Authority. 2013. http://www.nueces-ra.org/CP/CITY/day.php

Nueces River and Corpus Christi and Baffin Bays Basin and Bay Expert Science Team (BBEST). 2011. Environmental Flows Recommendations Report. Final Submission to the Environmental Flows Advisory Group, Nueces River and Corpus Christi and Baffin Bays Basin and Bay Area Stakeholder Committee, and Texas Commission on Environmental Quality, 285 pp.

Nueces River and Corpus Christi and Baffin Bays Basin and Bay Area Stakeholder Committee (BBASC).2012.Environmental Flow Standards and Strategies Recommendations

Report.FinalSubmission to the Environmental Flows Advisory Group, and Texas Commission on Environmental Quality, 112 pp.

Palmer, T.E., P.A. Montagna, and R.D. Kalke, 2002.Downstream effects of restored freshwater inflow to Rincon Bayou, Nueces Delta, Texas, USA.Estuaries25pp. 1448-1456.

Pulich Jr., W. J. Tolan, W. Y. Lee, and W. Alvis.2002.Final Report.Freshwater inflow recommendation for the Nueces Estuary.Texas Parks and Wildlife Department. Austin, Texas. 69 pp.

Texas Commission on Environmental Quality (TCEQ). 1995. Agreed Order Establishing Operational Procedures Pertaining to Special Condition B, Certificate of Adjudication No. 21-3214, Held by City of Corpus Christi et al., April 28, 1995..

Whitledge T. E. and D. A. Stockwell. 1995. The effects of mandatedfreshwater releases on the nutrient and pigment environmentin Nueces Bay and Rincon Delta: 1990–1994. In:Jensen R, editor.Proceedings of the 24th Water for TexasConference.1995 Jan 26-27; Austin. College Station(TX): Texas Water Resources Institute. p. 47-51.