Effects of Rincon Bayou Pipeline Inflows on Salinity Structure Within the Nueces Delta, Texas

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Effects of Rincon Bayou Pipeline Inflows on Salinity Structure Within the Nueces Delta, Texas

Introduction

This project represents the third year monitoring of hydrological effects from the Rincon Bayou Pipeline (RBP) in the Nueces Delta near Corpus Christi, Texas (Fig. 1). As stated in the 2001 Agreed Order, the City of Corpus Christi (City) is required to provide freshwater inflows into the Nueces Estuary. Each month the City is required to "pass through" to the Nueces Estuary an amount of water equal to the measured inflow into the Choke Canyon Reservoir/Lake Corpus Christi Reservoir System (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).

Typically, a river flows through a delta prior to making its confluence with a receiving water body. The Nueces River differs in that it flows directly into Nueces Bay, and completely bypasses the Nueces Delta. Only during times of severe flooding that causes over-banking of the river, or locally heavy rainfall, does freshwater make it into the delta proper (BOR 2000; Pulich et al. 2002). In an attempt to provide freshwater during normal flow conditions, the City has built a pump station and pipeline to divert up to the first 3,000 acre-feet of required pass throughs to the upper Rincon Bayou in the Nueces Delta.

Primary project objectives are to monitor freshwater inflows coming into the delta via the RBP by measuring salinity at various stations downstream of the pipeline and calculating spatial and temporal environmental affects to determine the amount of freshwater needed to manage a healthier estuary. This report provides a descriptive analysis for the six inflow events that have occurred since data collection began in May 2009.

Methods

The Conrad Blucher Institute for Surveying and Science (CBI) at Texas A&M University - Corpus Christi (TAMU-CC) installed and maintained a network of salinity monitoring stations in the Nueces Delta under contract with the Coastal Bend Bays & Estuaries Program (CBBEP). Monitoring stations were installed downstream of the RBP outfall (Fig. 2) with locations selected to capture the spatial extent of freshwater flow in the Rincon Bayou and Nueces Bay.

Salinity monitoring stations consist of a single piling jetted into the mud and positioned in the deepest part of the Rincon Bayou channel. NUDE01 (Fig. 3) is located in the upper reach of the Rincon Bayou (27.889444, -97.591389) and NUDE02 (Fig. 4), which is maintained by the University of Texas Marine Science Institute, is located in the middle reach of Rincon Bayou (27.888611, -97.569444). NUDE03 is located in the lower tidally influenced reach of Rincon Bayou (27.883611, -97.533056) and Salt08 is located in the lower Rincon Bayou at the interface of Nueces Bay (27.870428, 97.517090) (Fig. 5). Salinity data from Salt08 provides confirmation of RBP freshwater reaching the interface of Nueces Bay.

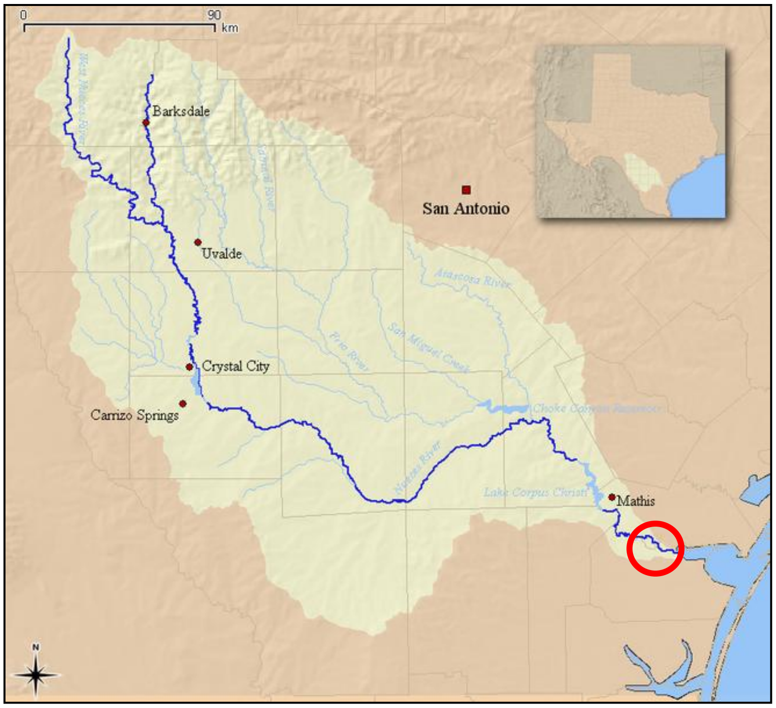

Fig. 1. Location of the Nueces Delta in relation to Texas and the Nueces Watershed.

Fig. 2. Map of the Nueces Delta and locations of salinity monitoring stations. RBP = Rincon Bayou Pipeline.

A tide gauge (NUEBAY 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 (mm). The primary water level data from this tide gauge was used to determine tide cycles during RBP events. The weather station, NUDEWX (see Fig. 2; Fig. 6), located on Rincon Bayou is located downstream from the RBP outfall and upstream of NUDE01. The NUDEWX measures wind speed (mph), wind direction, barometric pressure (mm), rainfall (in.), relative humidity (%), and solar radiation (cal/cm^2/min). The CBI performed monthly maintenance to the weather station that included a rain gauge calibration check and the tide gauge was serviced once every 6 months.

The salinity monitoring stations consist of either a Hydrolab® or YSI® water quality datasonde interfaced with line of sight spread spectrum radios aimed back to TAMU-CC. Stations are radio polled by an automated computer program designed and implemented by the Information Technology staff at CBI. Data are stored in the Division of Nearshore Research (DNR, a part of 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. Instruments are exchanged monthly with freshly calibrated units. 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 DNR Environmental Database http://lighthouse.tamucc.edu/RinconSalinity.

Fig. 3. Field personnel exchanging a datasonde at NUDE01.

Fig. 4. NUDE02 at the railroad crossing. The datasonde is under the railroad bridge in the deepest part of the channel.

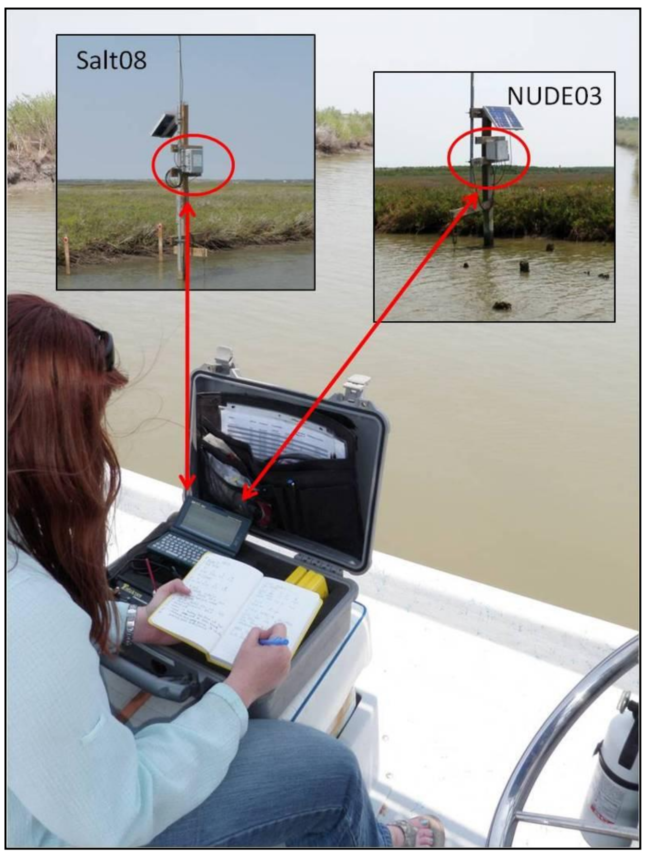

Fig. 5. NUDE03 and Salt08 stations located in the lower delta in the Rincon Bayou. CBI field personnel utilize a radio and computer to poll stations before and after datasonde exchange to ensure instruments are accurately measuring salinity. All field data are recorded in a logbook.

Fig. 6. Real time NUDEWX weather station serviced by CBI field personnel.

The RBP was funded by the City of Corpus Christi and became operational in November 2007. The design criteria of the RBP pumping station includes three 350 horsepower mixed flow submersible pumps capable of transferring up to 60,000 gallons per minute with all three pumps operating (Table 1; Fig. 7). The number of days to deliver a given volume of freshwater through the RBP varies on the number of pumps used.

Table 1. Summary of Rincon Pipeline pump criteria.

	Number of Rincon 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

A)

B)

Fig. 7. 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.

Results and Discussion

Initially funded in September 2008, first year monitoring for this project did not begin until May 2009. By the end of the first year in August 2009, no RBP pumping events had occurred due to drought affecting the region, which resulted in no inflows to the Reservoir System. However, second year data collection from September 2009 through August 2010 covered the wettest period on record for South Texas, with the National Weather Service at Corpus Christi International Airport recording 109.1 cm (42.9 in) of rainfall (NWS 2010).

Regional rainfall variability is evident as only 39.5 cm (15.6 in) of rainfall was recorded at NUDEWX located 18.0 km (11.0 mi) northwest of the Corpus Christi International Airport (CRP). However, the amount of rainfall recorded at NUDEWX was not indicative of rainfall within the lower Nueces watershed, as 126.5 cm (49.8 in) of rainfall was recorded at Wesley Seale Dam at Lake Corpus Christi located 30.0 km (18.5 mi) west northwest of NUDEWX (NCDC 2010; http://www.nueces-ra.org). Rain falling on the downstream side of the dam has the potential to flow into the delta and provide valuable freshwater inflows. The variability in rainfall amounts at these three locations emphasizes the patchiness in rainfall distribution over short distances, which is common within this area.

In contrast, data collected in year-three from September 2010 through August 2011 took place during record drought conditions that occurred statewide. A total of 64.2 cm (25.3 in) was recorded at the CRP, 20.0 cm (7.9 in) of rainfall was recorded at the NUDEWX, and 56.9 cm (22.4 in) was recorded at Wesley Seale Dam (NCDC 2010; http://www.nueces-ra.org). While rainfall recorded at CRP and Wesley Seale dam are approximately 12.7 cm (5.0 in) and 20.3 cm (8.0 in) less than the annual average rainfall respectively, 62.7% and 61.8% of the total respectively, occurred in the first month of the sampling year (September) before drought conditions began.

The rainfall differences between the two years gave a unique opportunity to study the diverted freshwater inflows in Rincon Bayou during different climate conditions of wet versus dry. These data will identify the effects of the RBP on salinity and show if differences in spatial extent and retention time occur between wet and dry periods. This data interpretation based on wet and dry year data is important for several reasons, including:

1. All three pumping events that took place during year-two coincided with either localized heavy rain events or moderate volumes of water coming over the Calallen Dam. This dampened identification of salinity effects and recovery time from the RBP as the only source of inflow. Year-two provided the opportunity to study the effects of freshwater inflows into the Rincon Bayou via the RBP during a **wet year**.

2. In May 2010, 3,000 acre-feet that was scheduled for "pass-through" to the Nueces Delta was "banked" in Lake Corpus Christi because salinity in Nueces Bay and Nueces Delta was <10 ppt and reservoir storage capacity was approximately 90% full. The "banked" concept is to not pump the 3,000 acre-feet to the Rincon Bayou until salinity reaches a threshold (currently a threshold has not been defined) and can be used to determine the effects of pumping freshwater into the delta.

3. The 3,000 acre-feet of water banked during May 2010 was allocated into three 1,000 acre-feet amounts and released during March 2011, May 2011, and June 2011. The Nueces Watershed had not received any significant rainfall since fall 2010, which raised salinity in Nueces Bay and Nueces Delta. This provided the opportunity to utilize the banked water to study the effects of RBP during a **dry year**.

As of August 2011, there have been six pumping events since the RBP became operational in late 2007, with 9,014 acre-feet pumped into the upper Rincon Bayou (Table 2). Drought conditions that occurred in late 2008 and persisted until fall of 2009 permitted only one pumping event of 2,987 acre-feet in 2009. Currently, based on the data collected during the six pumping events, freshwater from the RBP does not appear to influence the middle of Nueces Bay. Salinity data from Salt03 was used to identify the RBP spatial extent into Nueces Bay (Fig. 8).

However, at Salt08, located at the interface of Nueces Bay and the Nueces Delta, salinity changes did occur during the pumping events. The change in salinity at Salt08 from the RBP was likely contingent on season, wind strength and direction, tide, and quantity of water being pumped. Since salinity was lowered at Salt08 in response to the RBP inflow and not in Nueces Bay proper, this suggests that the RBP is a good management tool for changing salinity in the Rincon Bayou, in localized areas of the Nueces Delta, and at the interface of Nueces Bay. The inflow from the RBP can provide important salinity relief for flora and fauna during low inflow years and during drought conditions in the Nueces Delta.

Table 2. All six pumping events recorded during this project for the three years with; dates, duration, tide, acre-feet pumped, and classification.

Year	Pumping Event	Dates of Event	Duration (days)	Tide	Acre-Feet Pumped	Wet/Dry Period
1	-	No pumping occurred	-	-	-	-
2	1	September 28 to October 21, 2009	24	High	2,987	Wet
	2	January 6 to January 14, 2010	9	Low	742	Wet
	3	May 10 to May 31, 2010	21	High	2,288	Wet
3	4	March 21 to March 30, 2011	10	Moderate	1,001	Dry
	5	May 3 to May 12, 2011	10	High	1,002	Dry
	6	June 13 to June 22, 2011	10	Moderate	994	Dry

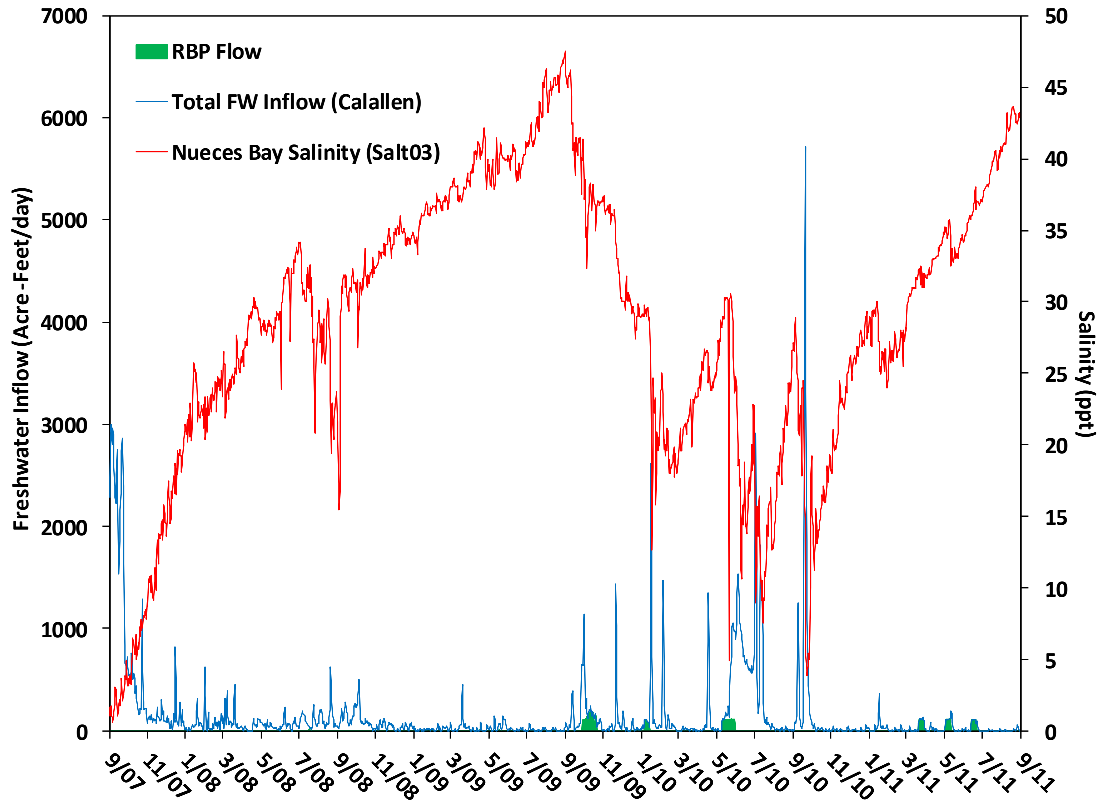

Fig. 8. Freshwater inflows through the RBP, over the Calallen Dam, and salinity at Salt03 in Nueces Bay.

If the "banking" concept was implemented into a permanent inflow regime so that during dry years the delta would still receive a small amount of water (~1,500 acre-feet) each month or season to keep salinity below extreme conditions (salinity > 35 ppt), this would be ideal for the flora and fauna in the Rincon Bayou. The ideal salinity for vegetation and macro benthic infauna in the delta is approximately 16 ppt to 25 ppt according to the Nueces River Basin and Bay Expert Science Team (BBEST). The BBEST further determined that a salinity of 18 ppt was essential for indicator species during critical seasonal time periods (Nueces BBEST 2011).When salinity reaches 25 ppt there is a decrease in productivity from certain species, and at 55 ppt vegetation and other species are displaced or begin to die off (Webb 1983; Nueces BBEST 2011).

A technical advisory committee, Nueces Inflow Pipeline Advisory Committee (IPAC), was formed out of the Nueces Estuary Advisory Council (NEAC) to advise the City on when to pass-through the "banked" water. The IPAC is a three member committee that consists of Dr. Paul Montagna of the Harte Research Institute for Gulf of Mexico Studies, Dr. Jim Tolan of the Texas Parks and Wildlife Department, and Ray Allen of the Coastal Bend Bays & Estuaries Program. All three of these members are active NEAC members and have been involved in freshwater inflow studies in the Nueces Estuary since the early 1990s. This committee provides the City with information on quantity and duration of water needed (based on water available for pass through) in order to achieve the greatest benefit under certain seasonal situations.

Water is typically confined within shallow channels of the Rincon Bayou during normal flow conditions (Fig. 9). However, storms, strong wind, and seasonal high tides can cause water to spread out of the shallow banks and onto the tidal flats. Based on aerial photography and site visits, the observed RBP spatial coverage during a 1,000 acre-feet pumping event was identified to extend downstream to Salt08. In addition, salinity data collected by the Center for Coastal Studies (CCS) identified freshwater began spreading out onto flats in the lower delta (Fig. 10).

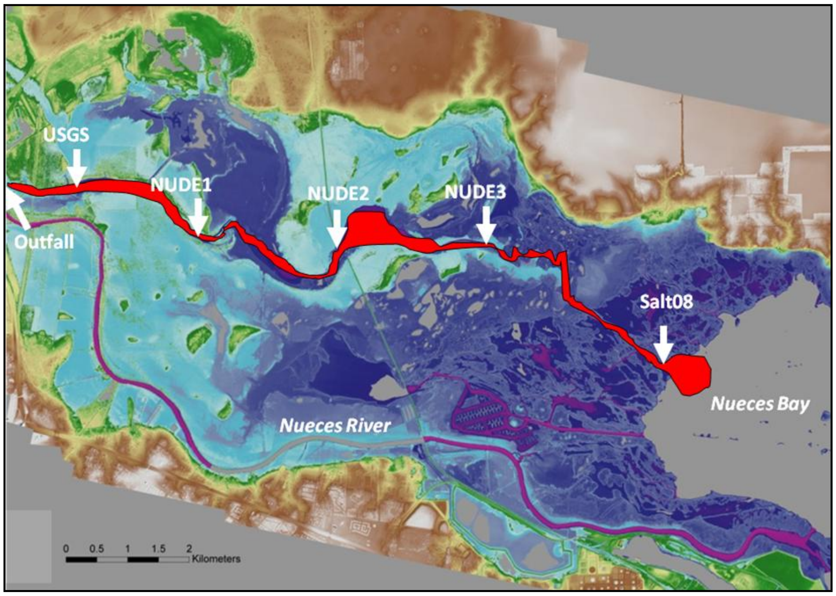

Fig. 9. Light Detection and Ranging, or LiDAR, image of the Nueces Delta showing typical water coverage (in red) in the Rincon Bayou during normal conditions.

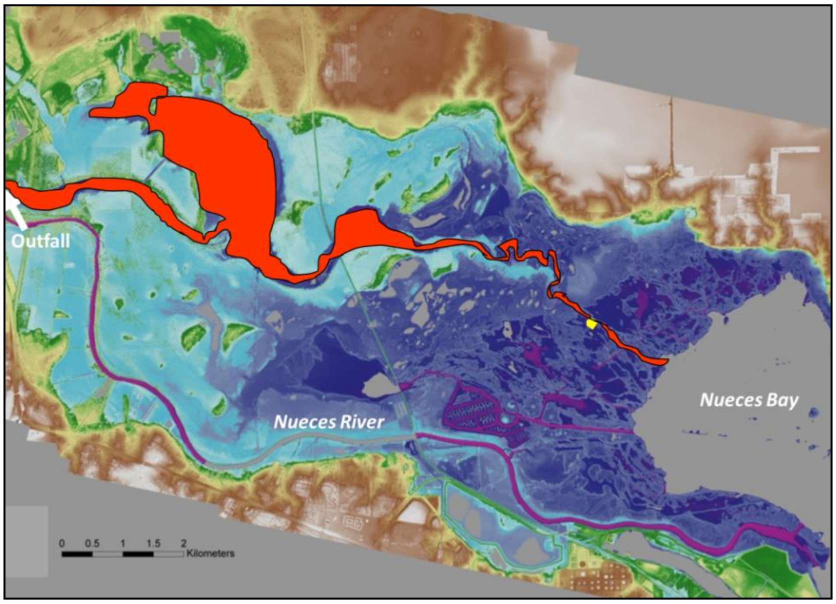

Fig. 10. The red polygon is the area observed to have freshwater coverage during pumping events. The yellow polygon identifies the CCS location where RBP freshwater spread in the lower delta.

As described by Adams and Tunnell (2010), the salinity effects during 2009 and 2010 pumping events were highly influenced by seasonal tides. Similar tidal influence was experienced during the May 2011 pumping event when seasonal high tides pushed Nueces Bay water against the RBP freshwater. Not only did seasonal high tides create a slower displacement of saltwater in the delta, but also exacerbated the daily high tides to where salinity levels would spike down during daily low tide and then back up during high tide. Salinity spikes continued until enough water was pumped into the area to fully displace the saltwater near the station being monitored (i.e. NUDE02, NUDE03, or Salt08).

The variation in salinity at NUDE02 during a high tide showed an oscillating trend during the September 2009 pumping event compared to the downward trend observed during the low tide event of January 2010 (Fig. 11). This data may help to understand the timing and magnitude of freshwater needed to reduce salinity in the lower delta complex via the RBP.

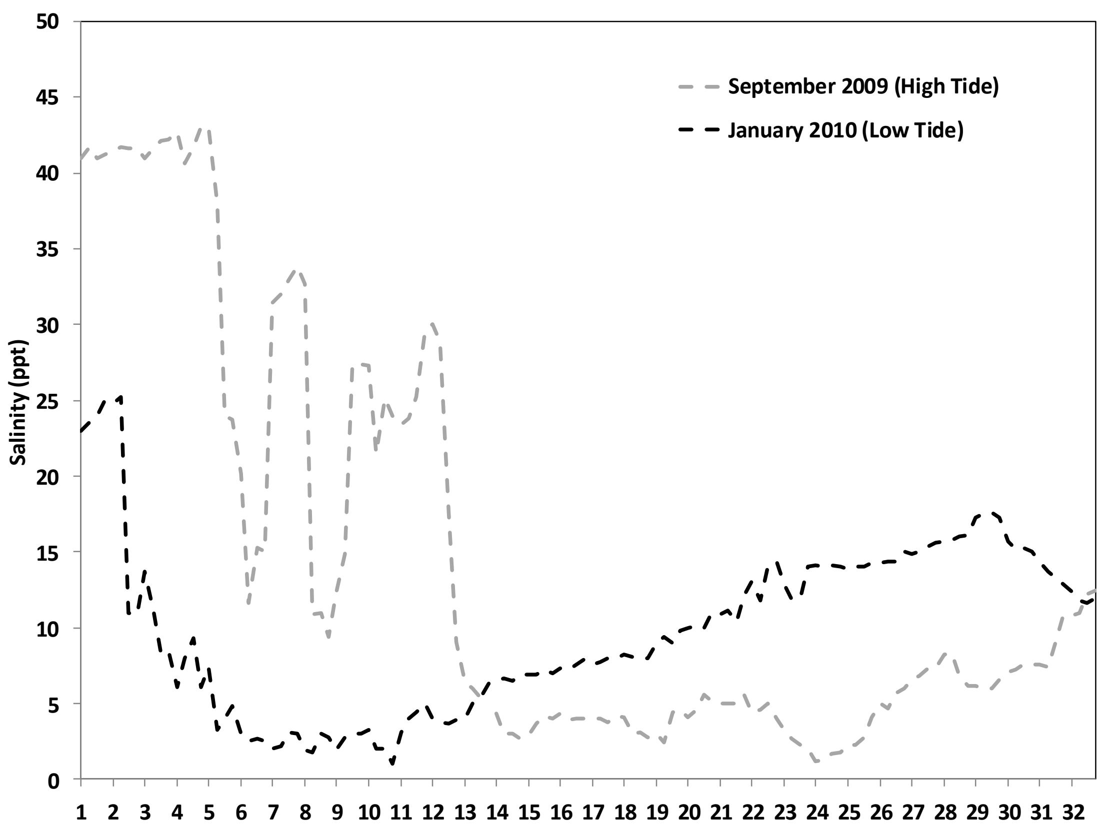

Fig. 11. Range of salinity at NUDE02 during a high (September 2009) and low (January 2010) tide pumping event. The X-axis number represents the number of days pumps were operated.

The Rincon Bayou has no distinct elevation gradient at the RBP outfall and water flows both downstream and backflows upstream to the Nueces River naturally. During the RBP operational testing phase, the City installed a swing gate that could be shut during pumping events to stop the upstream flow, but the structure was not entirely effective. The force of pumping eroded the bank around the gate and allowed water to continue to backflow towards the river.

Attempts to reinforce the banks using sandbags reduced backflow flow to the Nueces River to approximately 10 to 30% in year-two. This backflow intensified during pumping events and continued until pumping ceased and the natural flow resumed (Fig. 12 A). A United States Geological Survey gauge (USGS 08211503) has been in operation since 1996 upstream of the RBP outfall and measures discharge rates of both the RBP and natural flows through the bayou. Data from this USGS gauge was used to calculate the percentage of RBP backflow to the Nueces River.

In preparation for year-three pumping events, additional modifications were made to the RBP outfall. In addition to the swing gate, a temporary bulkhead was constructed to not only prevent backflow of the RBP water but also to control erosion around the outfall and swing gate area. This modification reduced the volume of backflow to the Nueces River from 30% to 10% for the 2011 pumping events (Fig. 12 B).

Adams and Tunnell (2010) concluded that salinity, tide cycles, number of pumps used to pump freshwater through the pipeline, and duration of the pumping events were the best indicators in comparing pumping events. Year-three conclusions also identified, wind velocity, wind direction, evaporation, and rainfall as additional important indicators in explaining RBP dynamics.

As cited in Adams and Tunnell (2010), NUDE02 appeared to be an appropriate reference station for monitoring changes in salinity within the Rincon Bayou. NUDE02 is centrally located in the Rincon Bayou between Nueces Bay and the Nueces River. If RBP freshwater reached NUDE02 for an extended period of time, then much of the freshwater pumped beyond that period would flow into the lower Rincon Bayou and possibly extended out into the lower delta and into Nueces Bay. There was a distinct drop in salinity at NUDE02 when freshwater pumping began and a subsequent slow increase in salinity when pumping ended (Fig. 13).

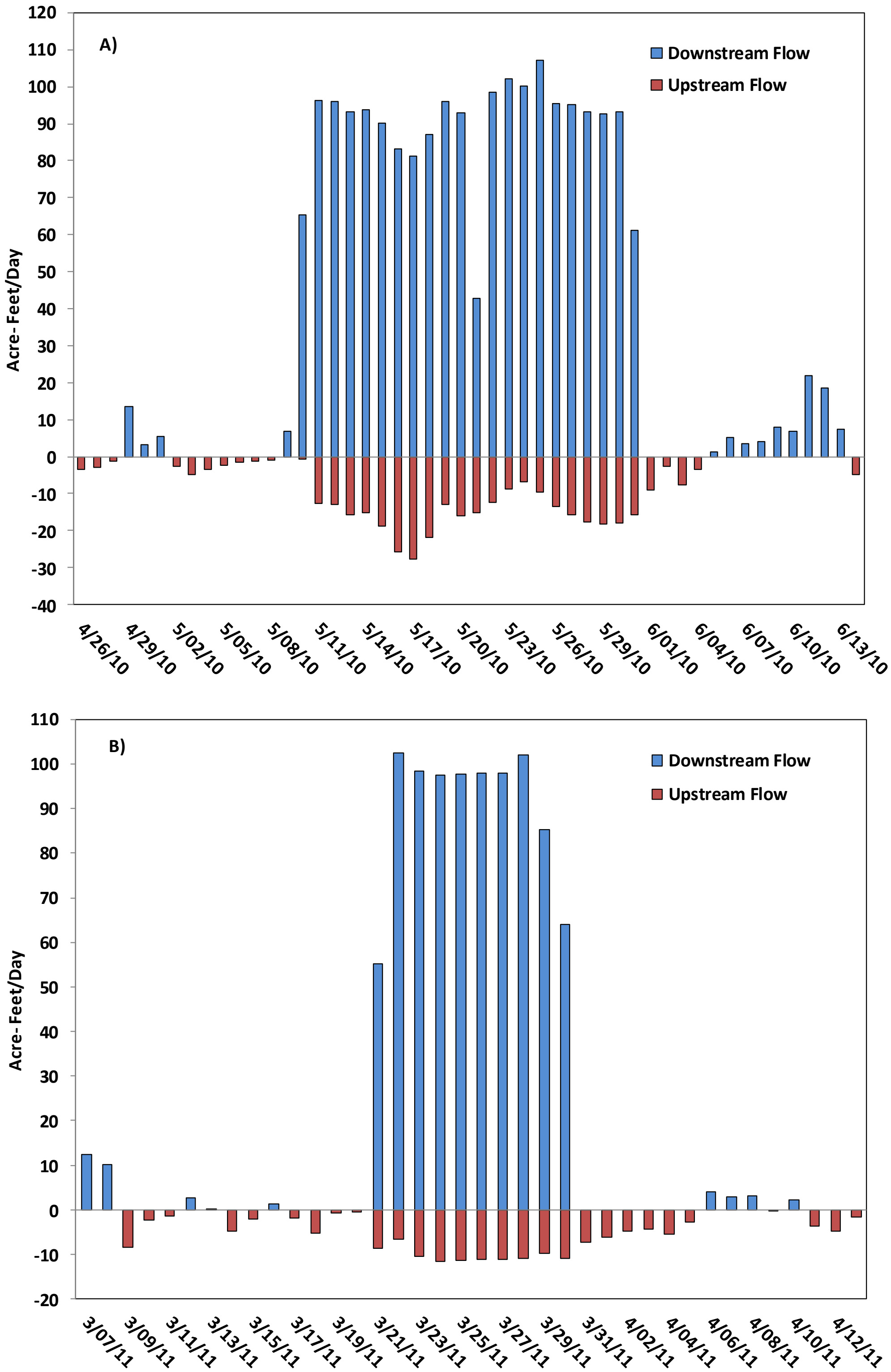

Fig. 12. Discharge rates of freshwater through the RBP during the A) May 2010 pumping event and B) March 2011 pumping event showing the amount of RPB water following downstream through the Rincon Bayou or the loss upstream to the Nueces River with upstream flow as measured at USGS Gauge 08211503.

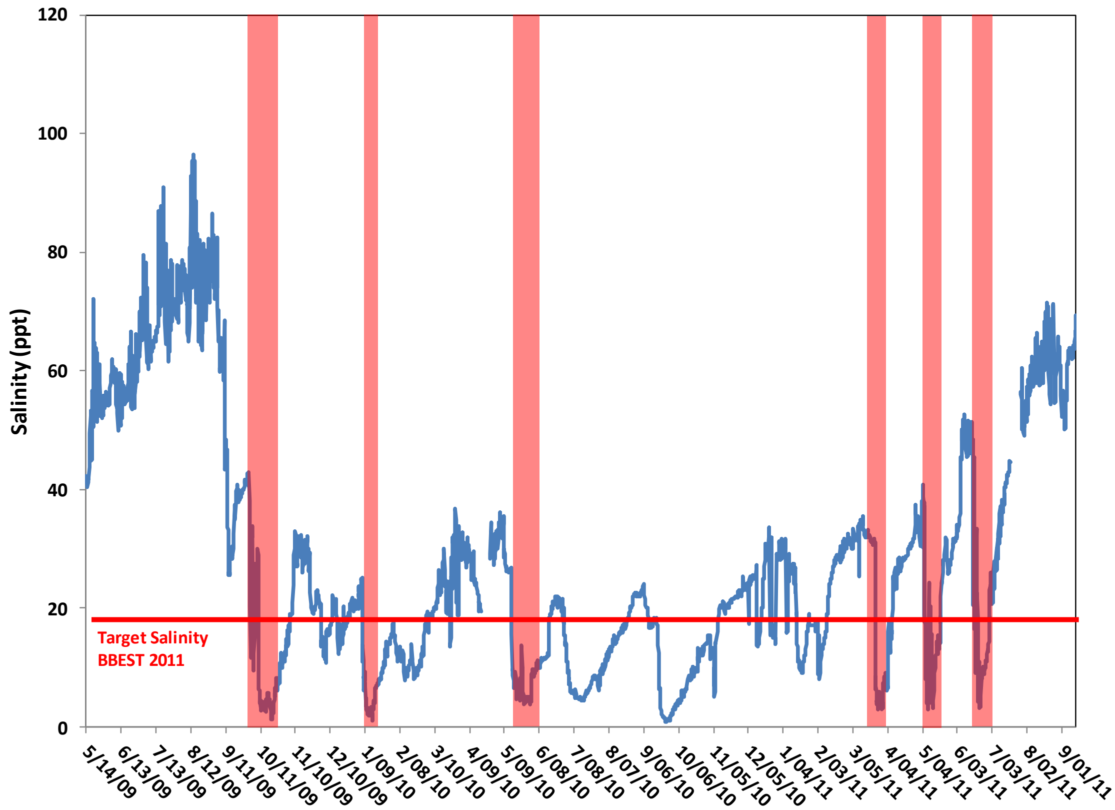

Fig. 13. NUDE02 salinity during the six pumping events with the target salinity value recommended by BBEST shown at 18 ppt. Shaded areas denotes the six pumping events that have occurred for the project.

When analyzing all pumping events over the three-year period, there was a clear distinction between low, moderate, and high tide events in terms of how long it took for freshwater to reach NUDE02. When flow was graphed to describe pumping events during different tidal conditions, events occurring during low and moderate tides showed a faster drop in salinity at NUDE02 compared to high tide events (Fig. 14; see Table 2).

For example, the January 2010 event was during a low tide period that allowed freshwater from the RBP to reach NUDE02 within two days, compared to the high tide event in September 2009 where it took freshwater from RBP approximately one week to reach NUDE02. Both pumping events used one pump at 55 cfs or 109 acre-feet per day to deliver the freshwater to the Rincon Bayou. It appears during low tide events there is a better chance of surface water displacement in the lower delta. This may be due to less resistance of the RBP freshwater against Nueces Bay water. Tidal influence on the RBP will be useful in determining the quantity of water needed to change salinity in the lower delta during different seasons.

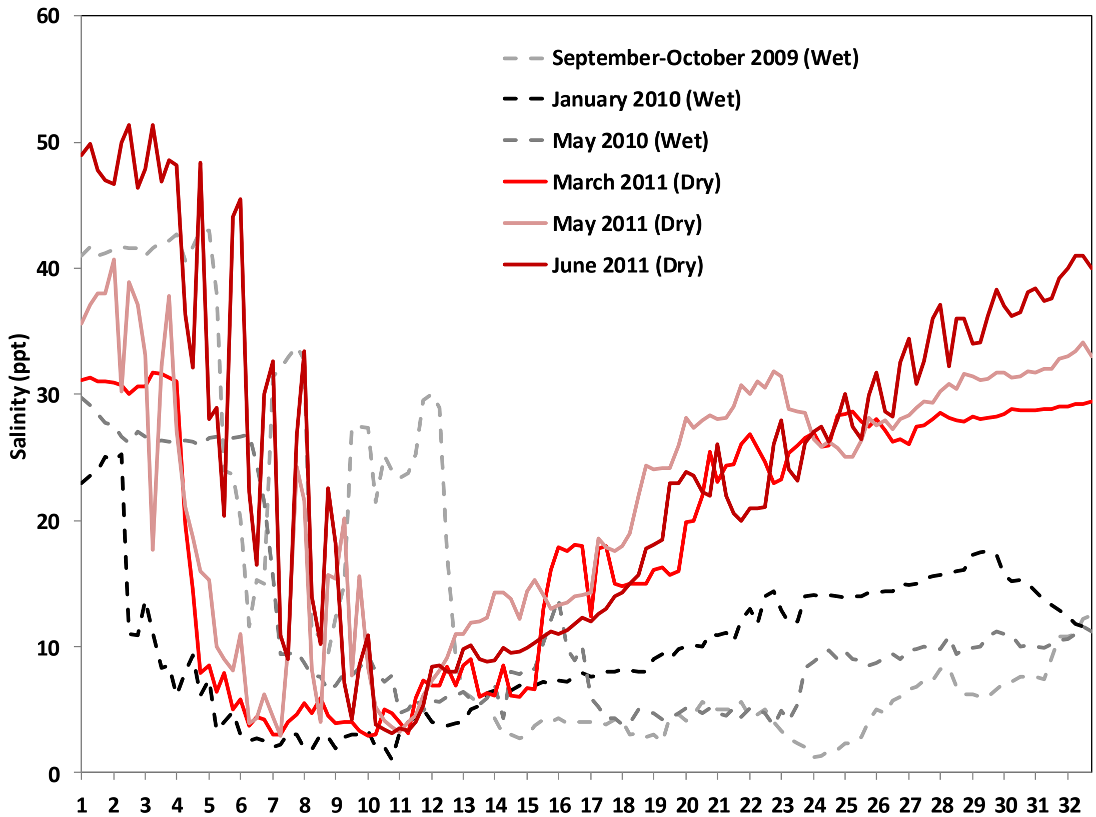

Fig. 14. NUDE02 salinity during all six pumping events based on the number of days after pumps were turned on (Day 1 = 1st day pumps were turned on). This figure can be crossed referenced with Table 2 to see the tidal influence on movement of freshwater through the delta.

The same concept of graphing flow by pumping event was used to determine the time it took salinity to rebound at NUDE02 after the pumps were turned off (Fig. 15). For year-two (September 2009 through August 2010), salinity took approximately 20 days to rebound to within 5 ppt of Nueces Bay salinity during the low and high tide events, except for the May 2010 event that occurred during a period of low salinity in Nueces Bay. Year-two pumping events were considered a wet period. Meaning, each of the 3 pumping events preceded rain, were followed by rain, or occurred during inflow events over the Calallen Dam.

During year three (September 2010 through August 2011) pumping events, the region was in a dry period and the only salinity changes in the Rincon Bayou related directly to RBP inflows. Salinity data from year-three showed it took approximately 10 to 18 days to rebound to within 5 ppt of Nueces Bay salinity during the dry period. These data help to understand the lasting effects of freshwater displacement in the Rincon Bayou and assist in developing the RBP operational plan for both dry and wet periods typical of this region.

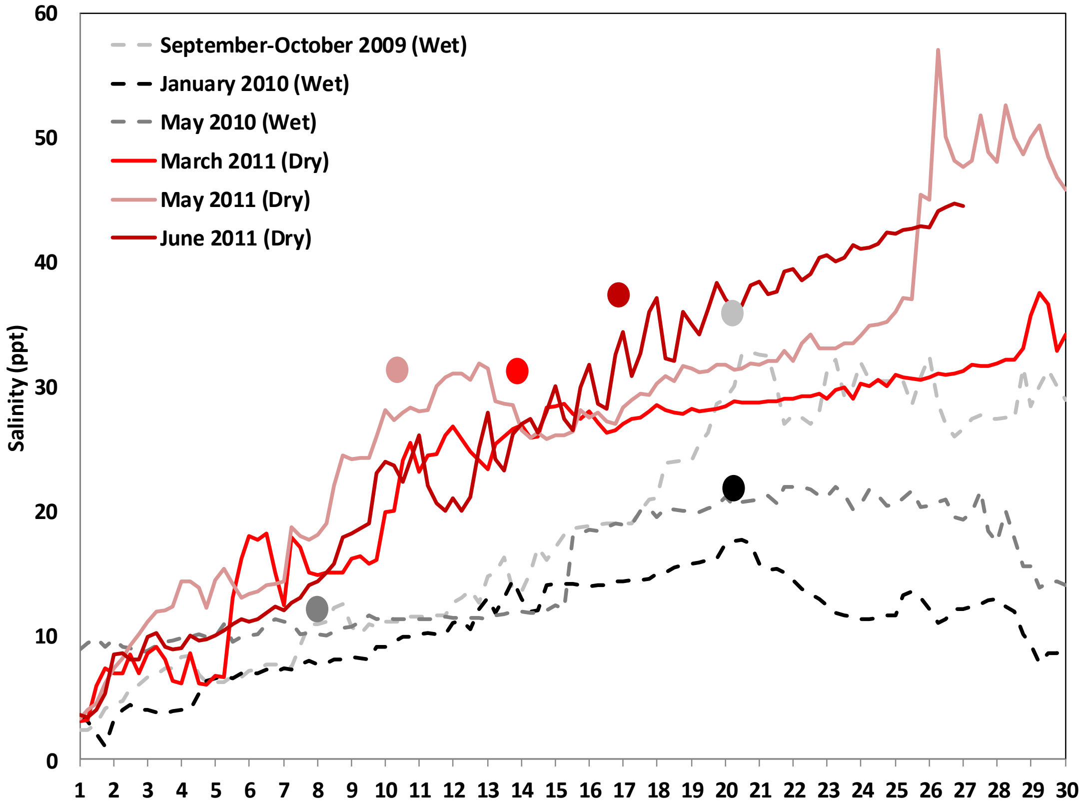

Fig. 15. NUDE02 salinity from all six pumping events based on the number of days after pumping stopped (Day 1 = 1st day pumps were turned off). Colored dots represent Nueces Bay salinity at Salt03.

Reduced freshwater inflows into the Nueces Delta resulting from reservoir construction have created a high salinity environment that effects primary production and alters vegetation communities (Palmer et al. 2002; Forbes and Dunton 2006). Reduced inflows into the estuary have also decreased sediment loads that have exacerbated the erosion process of the delta (BOR 2000; Ockerman 2010). Coupled with wind, wave, and sea level rise, approximately six to ten acres per year are being lost in the delta and bay interface due to the lack of sediment deposition (Rasser 2009).

The salinity gradient that influences the zonation of communities found in a typical estuary is usually absent in the Nueces Delta. Salinity comparisons between the Nueces River, Rincon Bayou, and Nueces Bay illustrate the effectiveness of the RBP and address the salinity gradient issue. The salinity gradient from freshwater in the river, to brackish water in Rincon Bayou, and then to marine water in Nueces Bay occurred during the March 2011 event (Fig. 16). When the RBP is in operation, it effectively changes the Rincon Bayou channel by establishing a salinity gradient more typical of an estuarine system.

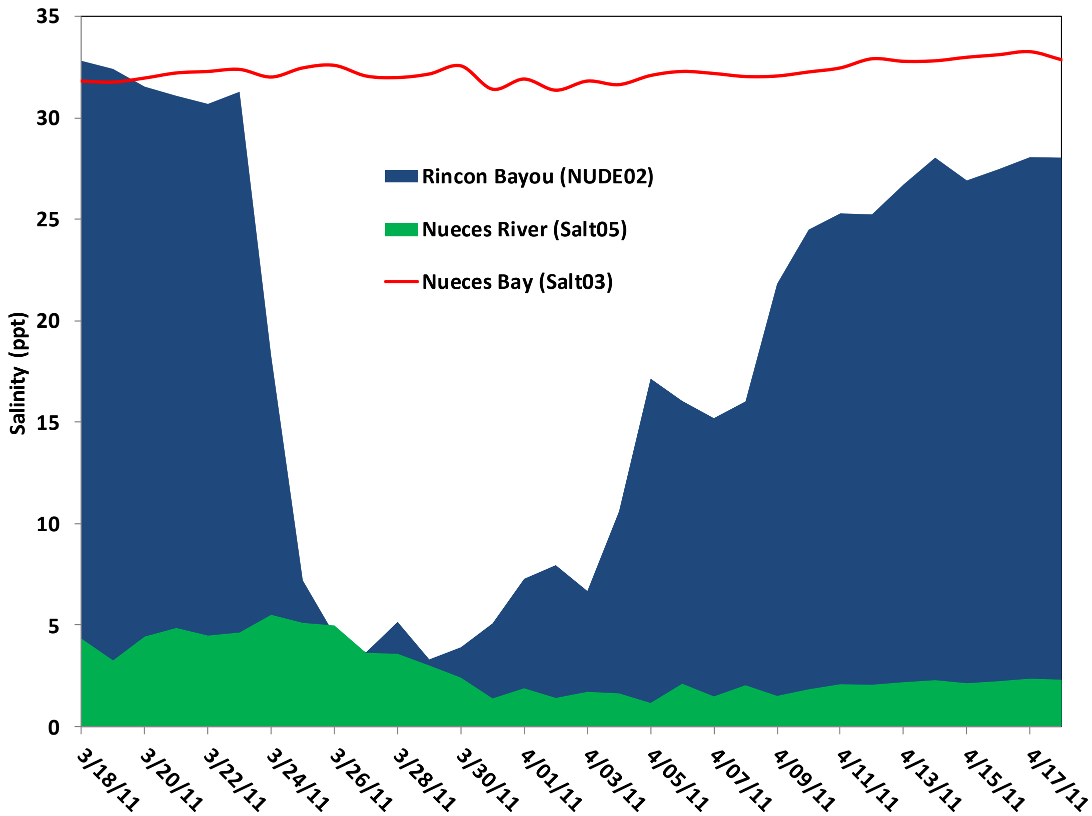

Fig. 16. Graph showing mean salinities in the Nueces River (Salt05), Rincon Bayou (NUDE02), and Nueces Bay (Salt03) during the March 2011 pumping event.

Conclusions and Recommendations

Since RBP pumping began in 2009, various weather conditions and tidal regimes have occurred during RBP events in the Rincon Bayou but the data analysis in determining the spatial and temporal effects of the RBP has only been with the use of one pump to deliver the freshwater. The Nueces Delta Hydrodynamic Model by Ryan and Hodges (2011) demonstrates using two or three pumps to deliver the water has a greater effect on spatial water coverage outside of the Rincon Bayou channel. Based on this report, and on Ryan and Hodges (2011) model, it is recommended that future pumping events use two or three pumps to provide an accurate spatial assessment prior to developing the finalized RBP operational plan.

Development of a permanent operational plan will require additional pumping scenarios and data analysis. However, based on the current data collected and analyzed, several key elements have emerged that will assist in plan development:

- As determined by Adams and Tunnell (2010), salinity station NUDE02 is an appropriate location for monitoring freshwater inflows from the RBP because of its mid-point position on Rincon Bayou in relation to the RBP outfall and Nueces Bay. **Based on data collected, and through an adaptive management process, it is recommended that**

NUDE02 become the controlling monitoring station for future pumping decisions until further data suggest a more appropriate datasonde location.

- During 2011, only 10% of the freshwater pumped through the RBP was calculated to backflow upstream to the Nueces River, compared to 10 to 30% of backflow during 2009 and 2010. **Efforts are currently underway to design and construct a permanent structure that would allow uninterrupted water flow within the main stem of Rincon Bayou near the RBP outfall during normal conditions. The structure should be designed so that it can be temporarily closed during pump operations to maximize 100% of the freshwater flow being delivered downstream.**

- Flow data from the six pumping events showed approximately 1,500 acre-feet of water is needed to lower salinity at NUDE02 below 5 ppt, under low or high tide conditions. This is important in defining the quantity of water needed to impact salinity in the lower delta marsh complex.

- It takes approximately 10 days to pump 1,000 acre-feet using one pump at a rate of 109 acre-feet per day, and about 27 days to pump 3,000 acre-feet. **We suggest that future pumping events operate more than one pump so that the timing and magnitude of water needed for the RBP operational plan is understood.**

- During regional wet periods, salinity at station NUDE02 takes approximately 20 days to rebound to within 5 ppt of Nueces Bay salinity after the pumps are turned off. Alternatively, during regional dry years it may take approximately 15 days for salinity to rebound to within 5 ppt of Nueces Bay salinity. **It is important that various scenarios be investigated under wet and dry conditions to refine the understanding of short-term salinity responses in the delta so an operational plan can be developed.**

- Banking water during regional wet periods for future use during regional dry periods is a beneficial tool for studying effects of the RBP in the Nueces Delta during low flow or drought. Banking water may also provide an opportunity to create a refuge for flora and fauna during dry periods within the Nueces Delta by releasing small quantities of water on a monthly or seasonal basis. **It is recommended that the concept of banking water for use during dry times in the Nueces Delta as a permanent management tool be adopted.**

- The Nueces BBEST completed a final report in October 2011 and recommended the target salinity within the Nueces Delta be set at 18 ppt. This salinity target was based on flora and fauna requirements in order to sustain a sound ecological environment within the Nueces Delta and Nueces Bay. **It is recommended that 18 ppt be set as the target salinity goal for operating the pumps and used as a tool for developing the future RBP operational plan.**

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 of Reclamation, Oklahoma-Texas Area Office, Austin, Texas.

Forbes, M.G. and K.H. Dunton. 2006. Response of a subtropical estuarine marsh to local climatic change in the southwestern Gulf of Mexico. Estuaries and Coasts 29, pp. 1242-1254.

Montagna, P.A., E. Hill, and B. Moulton. 2009. Role of science-based and adaptive management in allocating environmental flows to the Nueces Estuary, Texas, USA. WIT Transactions on Ecology and the Environment, Vol 122: 559-570.

National Climatic Data Center. 2011. http://www.ncdc.noaa.gov/oa/ncdc.html

National Weather Service. 2010. http://www.srh.noaa.gov/images/crp/docs/stwj/STWJFall10.pdf

Nueces River Authority. 2011. http://www.nueces-ra.org/CP/CITY/month.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.

Ockerman, D.J. and F.T. Heitmuller. 2010. Simulation of streamflow and suspended-sediment concentrations and loads in the lower Nueces River watershed, downstream from Lake Corpus Christi to the Nueces Estuary, South Texas, 1958–2008: U.S. Geological Survey Scientific Investigations Report 2010–5194, 50 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. Estuaries 25 pp. 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.

Rasser, M. 2009. The role of biotic and abiotic processes in the zonation of salt marsh plants in the Nueces River Delta, Texas. Dissertation. University of Texas at Austin, Austin, Texas.

Ryan, A.J. and B.R. Hodges. 2011. Modeling Hydrodynamic Fluxes in the Nueces River Delta. Draft Report submitted to the Coastal Bend Bays & Estuaries Program for project number 1001. The University of Texas at Austin, Center for Research in Water Resources, 98 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 Christ, et al., April 28, 1995.

Webb, J.W. 1983. Soil water salinity variations and their effects on *Spartina alterniflora*. *Contributions in Marine Science.* 26: 1-13.