State of Louisiana

Coastal Protection and Restoration Authority of Louisiana (CPRA)

2020 Operations, Maintenance, and Monitoring Report

for

Black Bayou Culverts Hydrologic Restoration

State Project Number CS-29
Priority Project List 9

DEC 2020
Calcasieu and Cameron Parishes

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Preface

The Black Bayou Culverts Hydrologic Restoration (CS-29) project was funded through the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) on the 9th Priority Project List with the Natural Resources Conservation Service (NRCS) as the federal sponsor and the Coastal Protection and Restoration Authority (CPRA). The 2020 OM&M Report format combines the Operations and Maintenance annual project inspection information with the Monitoring data and analyses for the project. This report includes monitoring data collected through December 2019, and annual Maintenance Inspections through October 9, 2019.

The 2020 report is the 1st report in a series of OM&M reports. For additional information on lessons learned, recommendations, and project effectiveness please refer to the additional materials available from the CPRA web site at (http://lacoast.gov/new/Projects/Info.aspx?num=CS-29).

I. Introduction

The Black Bayou Culverts Hydrologic Restoration Project (CS-29) is located in north-central Cameron Parish and southern portions of Calcasieu Parish. The project area is bordered by the Gulf Intracoastal Waterway (GIWW) for a significant distance either to the north or south, from the Mermentau River in the east, and ending near the large project water control structure in the northern reaches of Calcasieu Lake (Figure 1 and 2). The project area encompasses the Sweet Lake/Willow Lake area north of the GIWW (Area 2A, 5,725 ac), large areas of the Mermentau Lakes sub-basin to the south of the GIWW and west of the Mermentau River ending at Highway 27 (Area 2B, 23,558 ac and Area 3, 39,173 ac). There are also some smaller areas including tidal creeks north of the Town of Grand Lake (Area 1, 5,200 ac) and east and west of Deatonville (Area 4, 1441 ac) (Figure 3 and 4). The total project area is approximately 72,378 acres (29,290 ha) and is comprised of a vast majority of fresh to intermediate marsh in the Mermentau Lakes sub-basin and of brackish to saline marsh in the much smaller Area 4 west of the Black Bayou culverts water control structure and the U.S Army Corps of Engineers (USACE) Calcasieu locks. The marshes in the project area are dominated in large part by fresh flood tolerant species such as *Typha latifolia* (broadleaf cattail), *Sagittaria lancifolia* (bulltongue arrowhead), *Zizaniopsis miliacea* (giant cutgrass), and *Cladium jamaicense* (sawgrass) with more intermediate species mixed in at higher elevations with less flooding such as *Spartina patens* (saltmeadow cordgrass) and *Phragmites australis* (Roseau cane). Some locations within the project area are exposed to extreme long term flooding conditions with a cohort of species adapted to floating marshes consisting of, *Panicum hemitomon* (maidencane), *Ludwigia grandiflora* (large-flower primrose-willow), and *Eleocharis sp.* (spikerush) (Mouledous et al. 2016).

Historically, a majority of the Black Bayou culverts project area was in the southern watershed of the approximately 3,000,000 acre Mermentau River basin, receiving overland sheet flow from the surrounding uplands during periods of high rainfall and river discharge. Drainage was predominantly north-south from the upper basin through the Lakes sub-basin

and finally into the Chenier sub-basin via the Mermentau River. The Mermentau River provided a freshwater head to the project area and, to a lesser extent, the Calcasieu River and the Vermilion River to the West and East, respectively. Beginning in the late 1800s, significant hydrologic changes in the Chenier Plain began affecting water level fluctuation and water circulation patterns in the project area. This has inhibited the freshwater head from flowing north to south and has diverted it to a bidirectional east and west flow via the Gulf Intracoastal Waterway (GIWW) (LCWCRTF 2002). Hydrologic alteration first began with the construction of the Old Intracoastal Waterway in 1912 to provide navigation to the Mermentau River from Franklin, La. The channel was dredged through Schooner Bayou and Grand and White Lakes, linking the two lakes together and allowing water to flow east/west through the Basin. The construction of the GIWW between 1925 and 1944 continued this pattern. Drainage improvements on the upper Mermentau River and its four major tributaries took place throughout the 1900's, facilitating rapid transport of storm water and agricultural runoff into the Lakes sub-basins, and further altering historic flow patterns. Dredging of the lower Mermentau River in the 1950's and again in the 1970's allowed significant saltwater intrusion and marsh loss within the region.

Modifications to Calcasieu Pass such as the removal of the Calcasieu Pass oyster reef (1876) and maintenance of a deep (40 ft) and wide (400 ft) Calcasieu Ship Channel has increased the magnitude and duration of tidal fluctuations causing higher salinity and a broader range of water level fluctuations throughout the lake and the surrounding marshes (LDNR 1993). Construction of the Gulf Intracoastal Waterway established an east-west hydrological connection between the previously distinct Calcasieu and Mermentau basins, disrupting the natural north-south flow and allowing the saline waters of the Calcasieu Basin to encroach on the fresher Mermentau Basin. The U.S. Army Corps of Engineers (USACE) constructed three major water control structures in the 1950's. The Calcasieu lock, Catfish Point control structure, and Schooner Bayou control structure were constructed for water level control and to prevent saltwater intrusion, but are also periodically operated for flood water evacuation and to allow estuarine ingress, when conditions permit. Two additional control structures were added in later years. The Freshwater Bayou lock and Leland Bowman lock were constructed in 1968 and 1985, respectively, and are operated in conjunction with the other three control structures to maintain the Lakes sub-basin as a freshwater reservoir for primarily agricultural and navigation interests. The structures are operated collectively to achieve a target water level of 2.0 ft Mean Low Gulf (MLG). Louisiana Highway 82 was constructed in 1958 from Pecan Island to Grand Chenier, creating a barrier between the two Sub-basins and further altering the historic sheet flow pattern. Water level fluctuations are also highly influenced by local meteorological factors. A strong north wind can cause drastic de-watering of marshes, while a strong sustained southerly wind can result in drastic increases in water levels and salinities blown in from the Gulf of Mexico outside of the Lakes sub-basin. The extensive system of navigation channels, locks, and expanded river channels, have allowed increased water level fluctuations and salinities outside of the project area, while causing extensive long term fresh water flooding inside the project area (USDA 1997). Most of the land loss in the project area and surrounding marshes occurred between 1956 and 1978 (Barras et al. 2008), as both large and small scale changes have resulted in basin wide hydrologic alterations.

The Black Bayou Culverts Hydrologic Restoration Project includes structural measures designed to allow elevated levels of freshwater from the Mermentau Lakes sub-basin to be released through the GIWW, near its confluence with Calcasieu Lake and the Calcasieu River, when the receiving basin's hydrologic conditions allow, both independently of and additional to the Calcasieu locks, which was previously the only westward drainage component of the Mermentau Lakes sub-basin. The culverts reconnected the historic Black Bayou channel to the Calcasieu Lake Basin. Black Bayou Culverts structural features construction was completed in January 2010 and became fully operational as repairs were completed in May of 2016. Structural features and their intended functions are listed below:

As Originally Constructed:

1. Ten - 10 ft. x 10 ft. concrete box culverts with aluminum flapgates were constructed at HWY 384, between the Calcasieu basin and the Mermentau Lakes sub-basin, to increase drainage during high water events or lock closures. A hinged flap gate was installed over each culvert on the Calcasieu side of the structure with buoyancy capabilities to increase the flow rate under low head differentials.

2. 11,825 SF of steel sheet bulkhead constructed along the Southwest bank of Black Bayou to secure this area from additional erosion occurring from increased velocities.

3. 1,500 tons of rock rip rap was installed on both sides of the structure to prevent undermining and erosion of the structure and roadbed.

As Repaired:

1. Ten (10) - 10 ft. x 10 ft. concrete box culverts equipped with aluminum flapgates on the west side and trash racks with a receiving slot for a sluice gate on the east side of the structure. The box culverts are supported by 110, 12 in butt diameter timber piles 50ft in length (to elevation -60 ft.) and 128, 4.5 in (transitioned to 3.5 in. below the top 15ft.) diameter push piers to an elevation -70 ft.

2. At approximately 17 ft from the headwall, a steel sheet pile cutoff wall was constructed on the West side of the structure to an elevation -35 ft and steel sheet pile toe wall on the East side of the structure to an elevation -25 ft was constructed with a tie-in concrete slab to the culvert structure.

3. Rock rip rap (R-700) channel lining was placed 25 feet east and 50 ft west of the structure. Rock rip rap (R-300) wingwall revetment was placed on either side of the structure.

4. 11,825 SF steel sheet pile bulkhead (approx. 550 LF) with a galvanized steel pile cap was constructed along the southwest channel bank of Black Bayou.

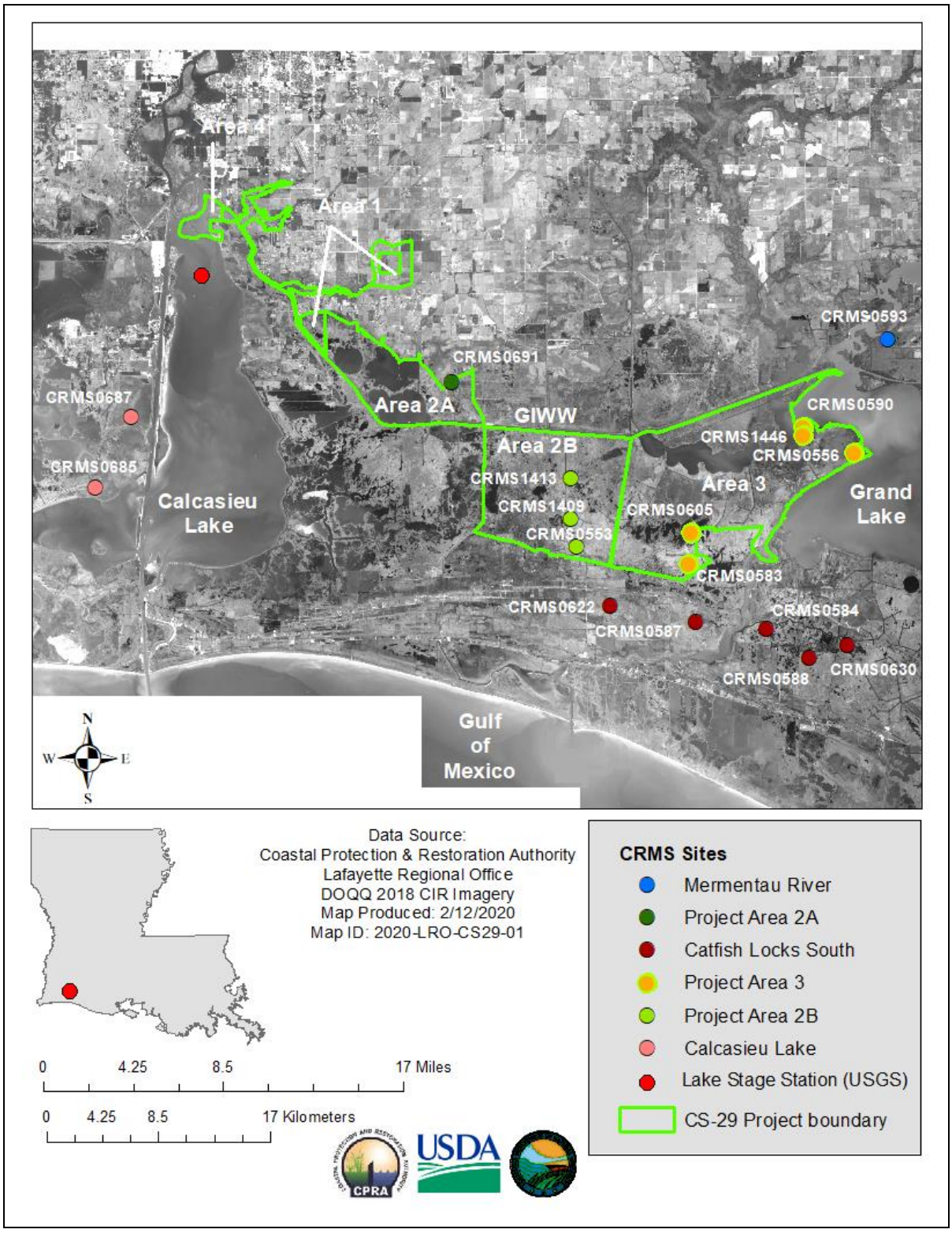


Figure 1. Black Bayou Culverts project area and boundaries, along with associated CRMS sites, color coded by project sub-areas and reference locations.

Figure 2. Black Bayou culverts project structure flowing rapidly, from east to west, out of the Mermentau Lakes sub-basin into the Calcasieu basin.

II. Maintenance Activity

a. Project Feature Inspection Procedures

The purpose of the annual inspection of the Black Bayou Culverts Hydrologic Restoration Project (CS-29) is to evaluate the constructed project features to identify any deficiencies and prepare a report detailing the condition of project features and recommended corrective actions needed. Should it be determined that corrective actions are needed, CPRA shall provide, in the report, a detailed cost estimate for engineering, design, supervision, inspection, and construction contingencies, and an assessment of the urgency of such repairs. The annual inspection report also contains a summary of maintenance projects, if any, which were completed since completion of constructed project features and an estimated projected budget for the upcoming three (3) years for operations, maintenance and rehabilitation. The three (3) year projected operation and maintenance budget is shown in Appendix B.

An inspection of the Black Bayou Culverts Hydrologic Restoration Project (CS-29) was scheduled for October 9, 2019 where it was found the water level was too high to see the gate hinges. In attendance were Jody White, Stanley Aucoin of CPRA, Richard Evely and Cody Lefleur of NRCS. Subsequent drive-by visits were made by CPRA, NRCS, and the USACE checking water levels and site conditions. Weld issues and movement of the gate hinge nuts were noted which warranted a gate inspection. The gate inspection was scheduled with the Contract Operator and held on January 16, 2020 under partly cloudy skies and cool temperatures. In attendance were Jody White and Stanley Aucoin of CPRA, Carol Clement and Cody Lefleur of NRCS, and the Contract Operator, Chris Simon of Simon and Delany, with four individuals for traffic control and boat operation. Crane Services were provided by Crane Ceaux. The gate inspection began at 10:00am at the culvert structure on Hwy 384.

The field inspection included a complete visual inspection of all features. Staff gauge readings, where available, were used to determine approximate elevations of water, rock armor, earthen embankments, steel bulkhead structures and other project features. Photographs were taken at each project feature (see Appendix A) and Field Inspection notes were completed in the field to record measurements and deficiencies (see Appendix C).

b. Inspection Results

<u>Concrete Box Culverts w/ Flapgates</u>

The flapgates were free flapping as intended; however, seven gates have broken locking rings and/or stop plates which require repair. See attached Inspection Report in Appendix C. All but Gate No. 4 can be locked down when necessary with the remaining intact rings. A 10ft piece of steel drill pipe was found in the headwall locking rings in an attempt to prevent the gate from closing. However, the pressure of the water on the gate at high tide crushed the aluminum rings. There are stop plate welds that are broken which could be the result of a pipe

being inserted behind the gate arm where it connects to the hinge. (Photos: Appendix A, Photos 1, 5, & 6)

Trash Screen
The trash screens on the east side of the structure were working as intended. There was floating vegetation and debris collecting at the trash screens. During additional visits, it was found the debris does migrate back into the GIWW or pass through the structure as the hydraulic conditions fluctuate. (Photos: Appendix A, Photo 7)

Steel Sheet Pile Bulkhead
The steel sheet pile bulkhead was in good condition. (Photos: Appendix A, Photo 3)

Rock Rip Rap Along Channel
The visible rock rip rap was in good condition. (Photos: Appendix A, Photos 1, 2, 5, 6 & 7)

c. Maintenance Recommendations

i. Immediate/ Emergency Repairs

Estimates are being obtained to repair Gate No. 4 and any additional locking rings permissible within the project budget. Repairs are required to be sequenced in groups of three gates per one event in order to use the sluice gates to isolate the culverts while the flapgates are removed from the structure.

ii. Programmatic/ Routine Repairs

- Flapgate repairs extend into FY21.
- The respective gate numbering should be repainted on the side of the guardrail.

d. Maintenance History

General Maintenance: Below is a summary of completed maintenance projects and operation tasks performed since January 2010, the construction completion date of the Black Bayou Culverts Hydrologic Restoration Project (CS-29).

May-2010 Simon and Delany: This maintenance project included providing a boom truck to lift Gate No. 2 for inspection on May 5, 2010. During a prior operation on April 15, 2010, this gate was not able to be pinned closed with the other nine gates. The gate was found to be in good condition. Bent eyelets had prevented from closing and once corrected it was pinned closed. With all gates closed, it was noted that water was still flowing at the structure. The costs associated with this event are as follows:

Provide Boom Truck and Crew: (Coordination handled by OCPR)	$2,200.00
TOTAL COST:	**$2,200.00**

June-2010 Simon and Delany: This maintenance project included providing a two man dive team to perform an underwater inspection of all ten gates on June 1, 2010. Undermining of the structure was confirmed between Gates No. 1 & 2, and at Gates No. 5 and No. 8. The costs associated with this event are as follows:

Provide two man dive team and perform inspection: (Coordination handled by OCPR)	$1,850.00
TOTAL COST:	**$1,850.00**

June-2010 American Contractor and Technology, Inc (ACT): This maintenance event included furnishing and placement of 240 supersize sand bags (approx. 1 CY per bag) in front of the flapgates on the lake side of the structure to reduce flow into the basin at high tide conditions as a result of undermining that has occurred. This work began on June 15, 2010 and was completed on June 23, 2010. Saltwater infiltration into the basin was reduced by this action. The costs associated with this event are as follows:

Construction Costs: (Coordination handled by NRCS)	Approximately $99,081.91
TOTAL COST:	**$99,081.91**

June- 2010 NRCS Investigation Committee: A committee was authorized by the NRCS State Conservationist to review and investigate the failures experienced at the structure. The committee began a design and construction review of the compiled records. A preliminary engineering report was prepared and a physical inspection was recommended.

April- 2011 Healtheon: This contract included construction of two earthen cofferdams on each side of the structure with clay fill. The intent was to dewater the interior to allow for a physical inspection and re-flood the site once complete. Work began on April 26, 2011 and was completed September 2, 2011. The physical inspection by the NRCS National Design Center Committee out of Fort Worth, TX occurred August 24-25, 2011.

TOTAL COST: (Coordination handled by NRCS)	**$1,096,322.93**

June- 2015 Tarpan:
Once funds were approved by the CWPPRA task force, a repair project was led by NRCS. Lonnie Harper and Associates were tasked with the design. The structure was repaired by constructing a steel sheet pile cutoff wall with wing walls on the west side of the structure and a steel sheet pile toe wall with wing walls on the east side of the structure. Existing timber piles were inspected for damage and flowable fill grout was pumped into the voids beneath the structure. The sheet pile was capped with a concrete tie-in slab to the structure sill (approximately 17ft from the structure headwall). For additional structural support, push piers were driven through the box culverts and fastened with stainless steel mounting plate assemblies. A concrete chamfer was installed over the mounting plates to form a smooth bottom surface. The trash racks were refurbished and slots were added to accept a sluice gate. The flapgates and frames were refurbished and coated with coal tar epoxy. The box culverts were cleaned and refurbished. Two 6 in. vents were installed near the west side in each box culvert. R-700 stone lined the channel bottom 50 feet on the west side and 25 feet from the sheet pile wall on the east side. R-300 stone was used as revetment on the wingwall embankments. The inlet and outlet channels were dredged. The work was completed July 7, 2016.

E&D and Construction S&I	$616,747
Construction Contract (Tarpan)	$6,900,963.61
TOTAL COST:	**$7,517,710.61**

April 2017 Simon and Delany: This maintenance event included parts and labor to replace the stainless steel nuts on the flapgate anchor rods with Teflon stop nuts to prevent the nuts from loosening and backing off the anchor rod.

TOTAL COST: $1,625.00

August 2018 Sealevel Construction: The Contract included fabrication of three aluminum sluice gates measuring 10’4” x 12’ 5 ¼”, for use on the East side of the structure. The gates were test fit and stored at the NRCS Lake Charles Field Office at 5417 Gerstner Memorial Drive.

TOTAL COST: $63,250.00

III. Operation Activity

a. Operation Plan

CS-29 BLACK BAYOU CULVERTS HYDROLOGIC RESTORATION

WATER MANAGEMENT PLAN/OPERATIONAL SCHEDULE
PROPOSED WATER CONTROL STRUCTURE IN THE
BLACK BAYOU AREA
CALCASIEU PARISH, LOUISIANA

With the construction of Louisiana Highway 384, the Black Bayou drainage path to the Calcasieu River was effectively blocked. In conjunction with the poor water relief offered by the Calcasieu Lock, the barrier created in Black Bayou has hindered the release of flood waters from the Mermentau Basin. Coupled with upstream drainage improvements, clearing of adjacent lands, subsidence, and relative sea level rise, the area is experiencing even longer periods of inundation from flood waters.

This project would re-open Black Bayou and alleviate some of the high water levels in the Mermentau Basin, as well as reduce water velocities through the Calcasieu Lock resulting in safer navigation. The removal of excess water in this area would allow an increase in emergent vegetation, while decreasing stresses on existing vegetation. The proposed flap gated structure would also maintain the deterrence of saltwater intrusion from the Calcasieu River.

Elevation observations in the marshes located near the project site revealed that the average mud line elevations were approximately +0.8 feet NAVD88. The top of the marsh plant root crown mass ranged in elevation from +0.9 feet NAVD88 to +1.2 feet NAVD88 (survey data as per On Target Surveying, Inc. and referenced in the 'Hydrologic Investigation of the Louisiana Chenier Plain' report dated October 2002). The applicant proposes to allow the structure to operate without human intervention, i.e. flap gates operating without restriction, unless the water level upstream of the structure reaches the previously stated average mud line elevation (+0.8 feet NAVD88). If this condition occurs, flow through the structure would be eliminated by manually locking closed the flap gates. A tide gauge referenced to the NAVD88 datum will be maintained upstream of the structure and the water surface elevation at this gauge will be used to determine the appropriate time for restriction of flow through the structure. The structure will remain closed until the water surface elevation at the gauge is +1.0 feet NAVD88; at which time the pins will be removed from the flap gates and the structure will be allowed to operate as designed.

STRUCTURE OPERATION SCHEDULE:

DATE	WATER LEVEL	STRUCTURE OPERATION
Jan. 1 – Dec. 31	above +0.8 ft*	Normal operation, i.e. unrestricted flap gates
Jan. 1 – Dec. 31	below +0.8 ft*	Structure closed, i.e. no flow through structure

*In the event that the water level upstream of the structure drops below +0.8 ft NAVD88 the flap gates will be closed in order to eliminate flow through the structure. After such an event, the structure will remain closed until the water level increases to +1.0 ft NAVD88, at which time the flap gate restriction will be removed and the structure will operate as designed.

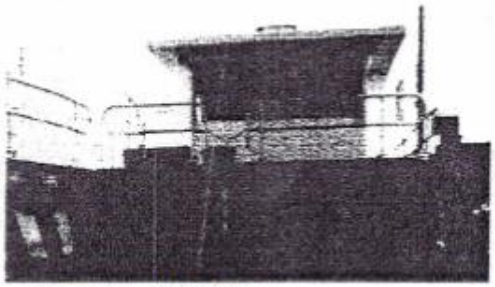
5/7/2004

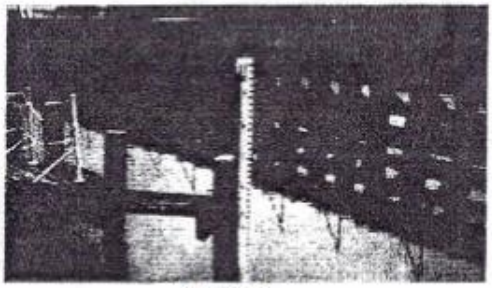

USACE
Calcasieu Lock
Calcasieu Ship Channel
Bazile Rd
Calcasieu Lock Rd
Calcasieu Lock East Gauge
GIWW
Hwy 384
384
CS-29 Black Bayou
Culverts Structure
Black Bayou
© 2016 Google
N
Tour Guide
1998
Imagery Date: 3/13/2017 30°04'55.60" N 93°17'16.69" W

Calcasieu Locks Gauge Data Sheet (2005) in NAVD88
Conversion from MLG to NAVD88 – Subtract 1.293ft

VICINITY MAP

Reproduced from USC&GS "MOSS LAKE" Quadrangle





WEST
STAFF GAUGE 3
(EXISTING)

Adjusted NAD 83 (1992) Geodetic Position (RTK)
Lat. 30°05'19.78129" N
Long. 93°17'41.39782" W

Adjusted NAD 1983 Datum(1992)
LSZ (1702) Feet (RTK)
N = 583,105.13
E = 2,660,539.46

Elevation of 7.0 foot mark on
Gauge No. 3(NAVD 88) (Feet) (RTK)
Elevation = + 5.707

EAST
STAFF GAUGE 4
(EXISTING)

Adjusted NAD 83 (1992) Geodetic Position (RTK)
Lat. 30°05'12.32111" N
Long. 93°17'28.38764" W

Adjusted NAD 1983 Datum(1992)
LSZ (1702) Feet (RTK)
N = 582,332.08
E = 2,661,669.33

Elevation of 6.0 foot mark on
Gauge No. 4 (NAVD 88) (Feet) (RTK)
Elevation = + 4.707

NGS Monument F226
(SEE ATTACHED NGS DATA SHEET)

Adjusted NAD 83 (1992) Geodetic Position (RTK)
Lat. 30°05'11.62589" N
Long. 93°17'11.66667" W

Adjusted NAD 1983 Datum(1992)
LSZ (1702) Feet (RTK)
N = 582,236.79
E = 2,663,136.84

Adjusted NAVD88 (Feet)(RTK)
Elevation = +3.377

b. Actual Operations

Structure Operations: CPRA Engineering staff monitor water levels at the Calcasieu Lock and within the Mermentau Basin to make recommendations to the project stakeholders, i.e. NRCS, CPRA, and USACE, with respect to locking or unlocking the flapgates. A trend in water level elevations of 2.09ft MLG (0.8ft NAVD88) at the Calcasieu Lock East Gauge is the target for locking/closing the flapgates.

CPRA currently contracts gate operations through a public bid process. Simon & Delany LLC. is the current Operations Contractor through the end of the contract period in June 2021. Upon agreement from the project stakeholders to lock or unlock flapgates, CPRA contacts the Contract Operator to prepare equipment and traffic control devices needed for the operation. When traffic lanes are interrupted, CPRA is required to submit a project permit to DOTD for those operations.

April 15, 2010	9 of 10 gates pinned closed, Gate No. 2 could not be pinned (Joint effort between OCPR, NRCS and USACE)
May 5, 2010	Lifted Gate No. 2, found bent eyelets, pinned closed (performed by Simon and Delany)
May 12, 2016	Removed cofferdams, removed pins, all gates free flapping (performed by Tarpan under NRCS contract)
March 7, 2017	Lifted gates No. 4 & 5 with crane truck, removed board from support bracing on gate no. 5. Board was jammed under gate no. 4 preventing it from closing and gate no. 5 from opening. Board broke locking ring on gate no. 4. (performed by Simon and Delany with Crane Ceaux)
May 11, 2018	Closed all Flapgates
September 11, 2018	Opened all Flapgates
January 16, 2020	Lifted all 10 gates for inspection and found Gate No. 1, 3, 4, 6, 8, & 9 with broken locking rings. Gates No. 6 & 8 have broken welds on stop plates. Gate No. 7 had a missing stop plate.

IV. Monitoring Activity

The CS-29 project represents a large spatial area and the necessary reference conditions are equally expansive, therefore leveraging of the CRMS network is beneficial for monitoring. There are many CRMS sites located in the CS-29 project area, and many positioned outside the project area which can be used for references locations in generally hydrologically separated habitats (Table 1).

Table 1. Project areas and reference locations with the associated CRMS sites, all project areas were compared to all reference locations when congruent data was available.

Location/Area	**CRMS Sites**				
Project Area 1	NA				
Project Area 2A	0691				
Project Area 2B	0553	1409	1413		
Project Area 3	0556	0583	0590	0605	1446
Project Area 4	NA				
Reference North -Mermentau River	0593				
Reference West - Calcasieu Lake	0685	0687			
Reference South - Catfish Locks	0584	0587	0588	0622	0630

a. Monitoring Goals

The following goals will contribute to the evaluation of the project objectives:

1. Reduce flood duration within the project area.
2. Increase percent cover, stem height, and species richness of emergent vegetation.

The goals will be assessed by:

1. Evaluating duration of flooding in the project area.
2. Evaluating percent cover, stem height, and species richness of emergent vegetation.

b. Monitoring Elements

Aerial Photography

High resolution aerial photography (1 m, color infrared, CIR) and satellite imagery (30 m, Landsat Thematic Mapper, TM) are collected every three years for the entire coast through the CRMS program. The aerial photography is used to classify land and water within the square kilometer that surrounds each CRMS site. The satellite imagery is analyzed to evaluate changes in land and water areas within the CS-29 project area at a coarse (30m) resolution. The CRMS spatial viewer provides historic data for land water quantification in the project

area starting in 1985. Land values are displayed for available cloud free Landsat images during the late fall for 1985-2016. The data provided by this tool is at a large spatial scale and is designed to show trends in land loss, not exact acreages or locations.

Water level:
CRMS continuous hourly water level monitoring in the project area began in November, 2006 and seventeen CRMS sites were used to monitor project and reference water levels. All water level and marsh elevation data in this report are reported in GEOID 12A to compare between locations.

Salinity
CRMS continuous hourly salinity monitoring in the project area began in November, 2006 and seventeen CRMS sites were used to monitor project and reference salinities conditions.

Emergent Vegetation:
Beginning in 2006 vegetation was monitored at seventeen CRMS sites inside and outside of the project boundaries. Individual species' cover data from CRMS stations were summarized according to species cover, total cover, height of dominant species, and sum of individual species cover (Visser et al. 2002). The CRMS percent cover and layer height vegetation data were transformed into a three dimensional vegetation volume and then indexed by marsh type to generate a 0-100 score for the vegetation volume present (Wood et al. 2015). This metric focuses on the quantity of vegetation present irrespective of species and can aid in the separation of similar marsh types with different growth potential.

Hydrologic Index
The Hydrologic Index (HI) assesses the relationship between the combined effect of mean salinity and percent time flooded on vegetation primary productivity for five different marsh classifications in coastal Louisiana (swamp, fresh, intermediate, brackish, and saline). The index score ranges from 0 - 100, representing the percent of maximum vegetation productivity expected to occur if the separate effects of salinity and inundation on productivity interact in a multiplicative fashion.

Soil Properties
Soil cores were collected to describe major soil properties such as bulk density and percent organic matter. Three, 4" (10.16-cm) diameter cores were collected to a depth of 24 cm and divided into 6, 4-cm sections at each site. The soil was processed by the Department of Agronomy and Environmental Management at Louisiana State University. Soil cores were only collected at the project and reference CRMS sites during station establishment in 2005-2007 and the second series of samples has been collected, but not made available. Cores were collected at nine sites inside the project area, and reference conditions were collected from eight sites outside the project area.

Soil Surface Elevation Change
Soil surface elevation change utilizing a combination of sediment elevation tables (RSET) and vertical accretion from feldspar marker horizons are being measured twice a year at each of

the project and reference CRMS sites. These data will be used to describe the general trends in elevation change. The RSET was surveyed to a known elevation datum (ft, NAVD 88) so it could be directly compared to other elevation variables such as water level. Data collected over at least 5 years was used to calculate rates for the project and reference conditions; therefore the displayed elevation change rates are an estimation of that temporal trend.

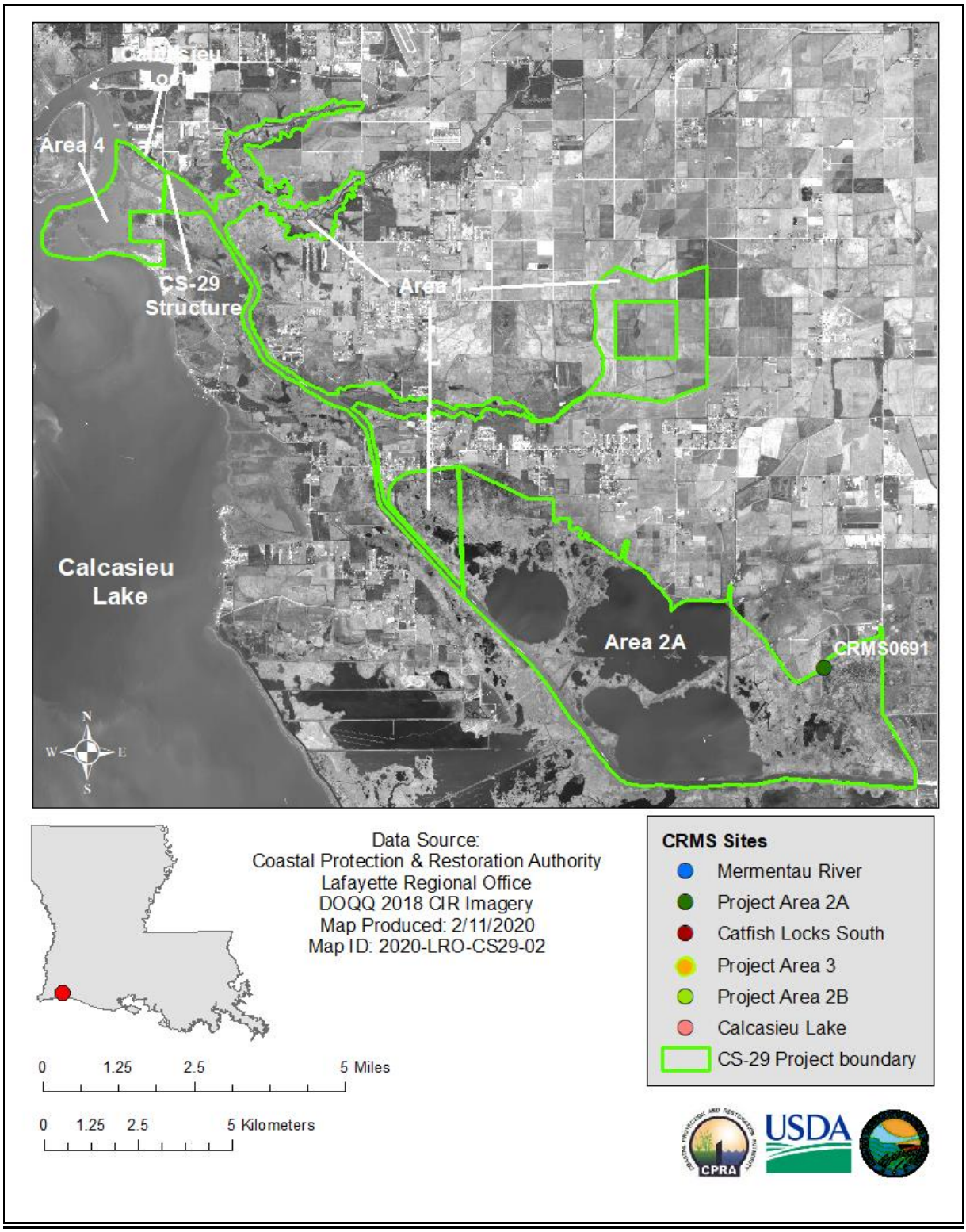


Figure 3. CS-29 sub areas 1, 2A, and 4 along with associated CRMS sites located within the project and reference areas. Not all locations have represented CRMS sites, displaying the relative information density.

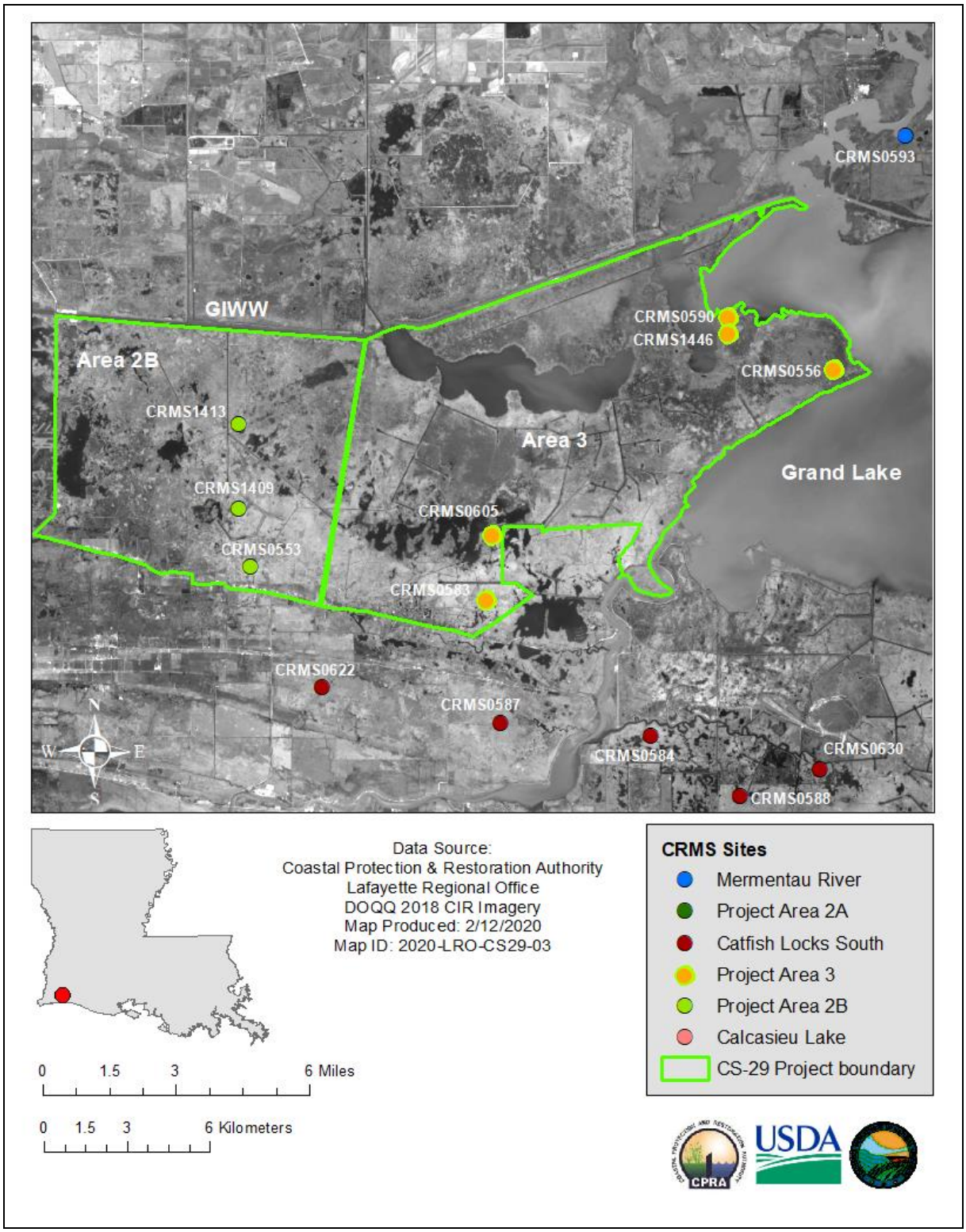


Figure 4. CS-29 sub areas 2B and 3 along with associated CRMS sites located within the project and reference areas. Not all locations have represented CRMS sites, displaying the relative information density.

IV. Monitoring Activity (continued)

c. Monitoring Results and Discussion

Aerial Photography

Overall, from 1984-2016, there was a slight increase in the project area's percent land, although the project was not operational as designed until May of 2016; the Mermentau Basin as a whole showed a minimal reduction in percent land over the same time frame. The larger scale CRMS coastal satellite TM land water analysis shows the overall stability of the project area, even as water elevations are consistently well above marsh elevation, especially in 2016 and again in 2019 (Figure 5) (Couvillion et al. 2017). These high flood years, along with invasive floating aquatic plants, have shown the ability to smother and drown large areas of project marsh, though these areas would be expected to recover during a lower water cycle, revegetating in fresh flood tolerant vegetation (Figure 6). The area rebounded well from the hurricane damage of 2005 and 2008, recovering to pre storm conditions, and due in part to the strict control of salinity and tidal scour in the Mermentau Lakes sub basin.

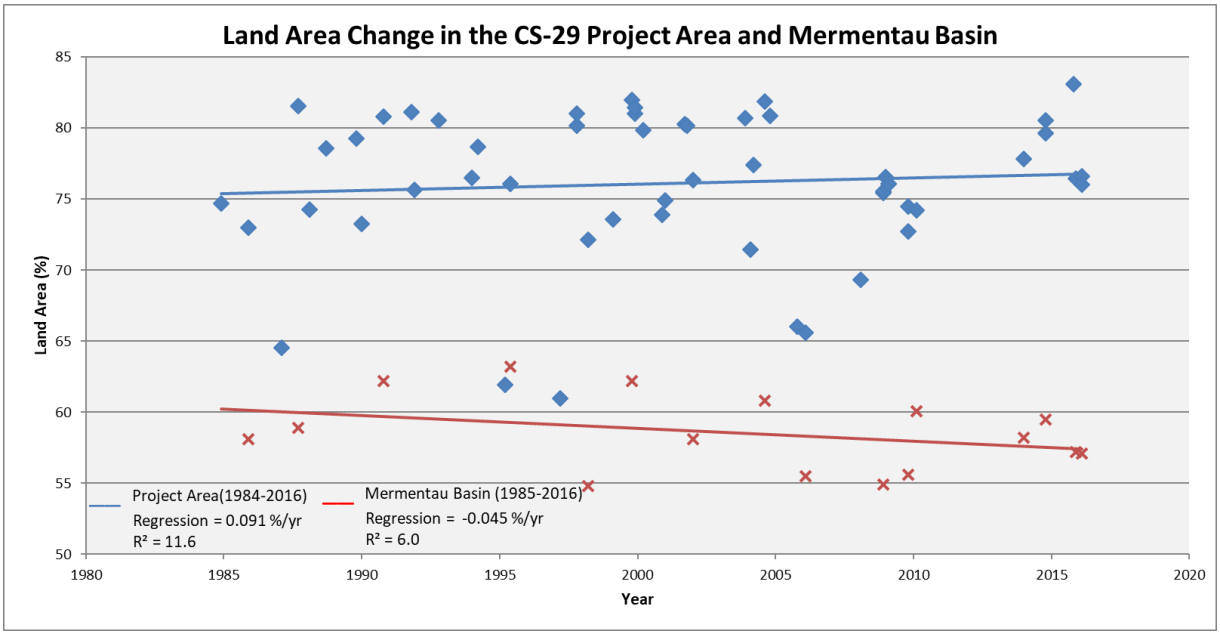


Figure 5. Project and basin scale percent land analysis for years 1985 to 2016 of cloud free Landsat images, CRMS spatial viewer land/water.

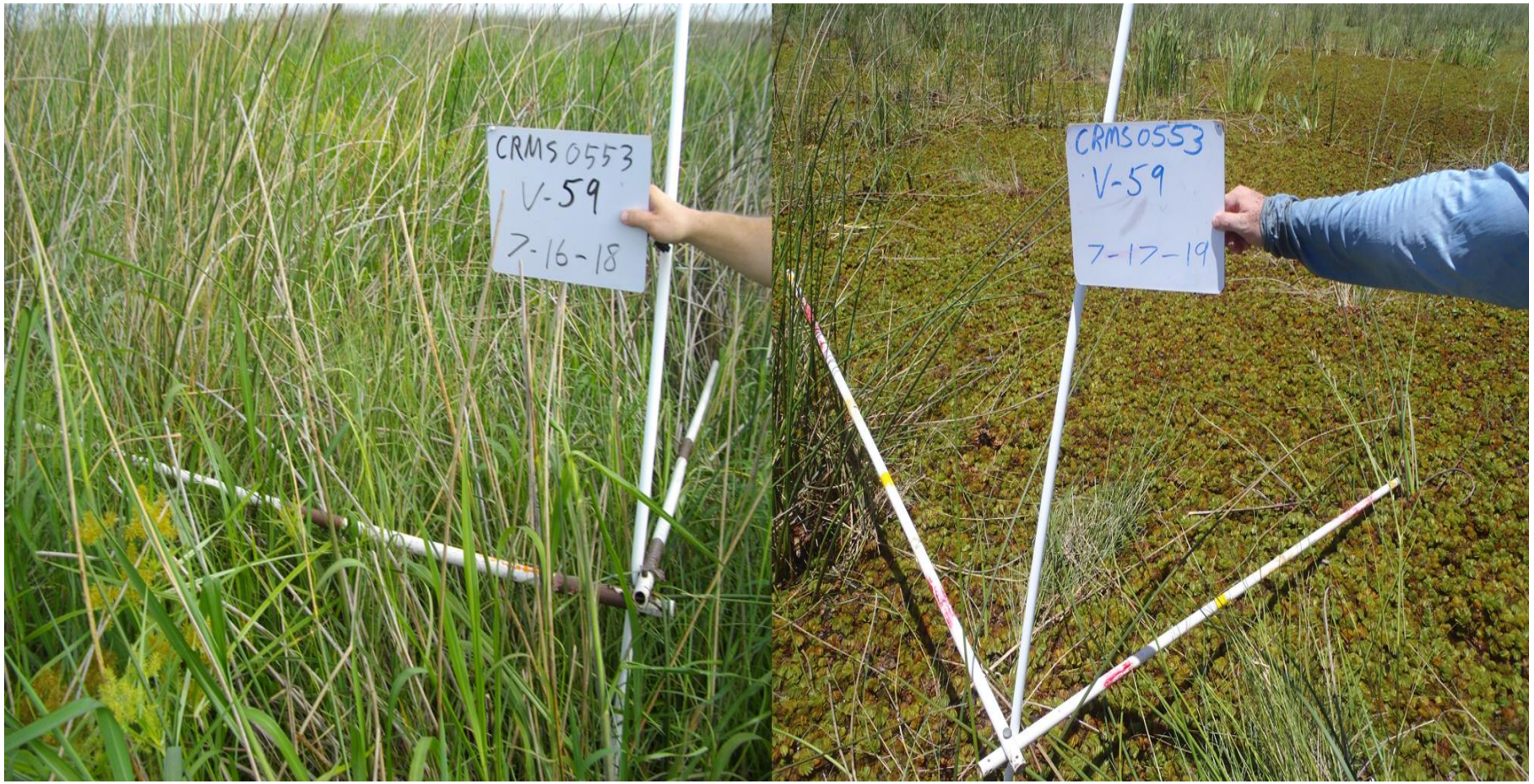


Figure 6. Area of marsh possibly converting to open water through the combination of invasive *Salvinia Molesta* and prolonged elevated water levels at CRMS0553 in Area 2B of CS-29 between 2018 and 2019.

Water Level:

The project hydrologic control structure on Black Bayou near Calcasieu Lake separates the Mermentau Lakes wetlands east of the lake from the frequently saline waters of the Calcasieu Lake, while allowing for additional gravity drainage under favorable conditions, and when the Calcasieu locks are closed. A consequence of this dependence on gravity drainage is the reduced hydrologic capacity for drainage under heavy upland rainfall conditions and the dependence on external receiving basin water levels for drainage opportunities. The USACE management target, which is consistent with the water elevation management target at the project structure, was to maintain a water level at or above 0.27 feet NAVD 88 GEOID 12A (0.8ft NAVD88), which is consistent with marsh elevation in the area (Project Operations Plan 1992, LCWCRTF 2002, and Mouledous et al. 2016). The overall marsh inundation trend from 2014 through 2019 shows that the three project areas and the Mermentau River are routinely flooded greater that 80% of the time, while Calcasieu Lake and the Catfish locks south reference sites are flooded far less often (Figure 7). A two way ANOVA on weekly percent inundation from 2014-2019 of the three project areas and three reference locations was performed. The model tested the effects of location and pre or post project construction to isolate and identify the major sources of variability in marsh inundation. Both main effects along with the interaction were significant with location being vastly more influential than pre or post project and the interaction, as local marsh elevation is a critical component of flooding along with drainage potential ($F_{5, 5555} = 406.85$, $p < 0.0001$). The Calcasieu Lake marshes were flooded significantly less than all other locations (53.0%), with the Catfish locks south locations being intermediate and distinct (82.8%); all other locations including all project locations were flooded more than 94% of the time. The pre post project effect was much less influential on marsh inundation but still significant, as flooding typically rose and fell across the region in tandem. This similarity is attributable to the Gulf of Mexico water level variability and regional precipitation cycles affecting the region in concert ($F_{1, 5555} = 45.58$, $p < 0.0001$). These results indicate that pre project flooding from 2014 - May 2016 was less (84.2%) than post project marsh inundation from June 2016-2019 (89.1%) across all locations. The interacting relationship of the two main effects of location and pre post project construction ($F_{5, 5555} = 13.13$, $p < 0.0001$) is statistically meaningful, but almost certainly not due to project impacts, as the major interaction result was that the Calcasieu Lake location increased in flooding post (61.7%) project compared to pre project (44.3%) which is not a project induced effect. Irrespective of marsh elevation which drives inundation, water levels do show a relationship within the project areas and among the outside reference conditions with proximity to drainage.

In general water level at the Mermentau River reference site was higher than all other areas but was not distinct from project Area 3. Project Areas 2A and 2B are lower and typically very close to Calcasieu Lake water levels, with the exception of drought conditions as experienced in 2018, which saw those project areas drop below lake levels for a significant portion of the year. To date, the 2018 drought is the only time the structures have been closed to maintain water level. At an annual scale, the project areas in closer proximity to the structure and the locks have lower water levels than those more distal. The water levels south of the Catfish locks are markedly lower than all other locations due to more efficient drainage, lower water volume inputs, and a shorter distance to the Gulf of Mexico; these locations are also hydrologically managed. The average marsh elevations in the project sub areas are low

but similar to the rest of the Mermentau lakes sub-basin, between 0.32 feet in Area 3 and -0.13 feet in Area 2A (NAVD 88 GEOID 12A) which is near or below the USACE minimum management water level goal. This results in the project area marshes being submerged a significant portion of each year, along with the management goal being difficult to impossible to obtain depending on receiving basin conditions under gravity drainage.

At a larger spatial scale, the reference conditions of the project area are consistent, relative to one another, from 2014 through 2019, with the Mermentau River sites remaining higher than all others, as it is the furthest from a drainage opportunity and received upland waters from southcentral Louisiana. The Gulf of Mexico, as measured by CRMS0600 south of Rockefeller Refuge, is rarely lower than Calcasieu Lake at most monthly increments, generally matching the elevation of the Lake. This, under all but drought conditions, is the lowest possible gravity drainage potential of any location in the project area, and the Gulf rarely reaches the target minimum water level of the project and only in the late winter months (Figure 8). Within the project sub areas, water levels are generally lower in closer proximity to the structure. Project Area 3 has only slightly lower water levels than the Mermentau River reference site, and being 20-30 miles from the project structure, the minimal water level difference between locations is probably not meaningful to marsh vegetation in near permanent flooding. Project Areas 2A and 2B have similar monthly average water levels to one another and both have lower water levels than Project Area 3 and the Mermentau River reference, as they are both closer to the project structure and further from substantial sources of upland runoff (Figure 9). These areas are still well above the project water level minimum threshold, but so are the receiving basins these locations depend upon for drainage. Combined with low average marsh elevations in the project area, approximately 0.25ft NAVD88 GEOID 12A (CPRA CIMS 2020), this leads to near permanent fresh, flooded conditions and the selection of flood tolerant vegetation in the project area.

During the drought of spring and summer 2018, both the Black Bayou Culverts and the Calcasieu locks were closed for an extended period of time in order to maintain fresh conditions and minimum water levels in the Mermentau Lakes sub-basin. The Calcasieu locks were closed near constantly from 3/15/2018 to 9/15/2018, 96.1% of the time, while the CS-29 project structure closed approximately two months later, being 100% closed from 5/11/2018 to 9/11/2018. This staggered closure offered the opportunity to examine the effects on water levels with both structures operating simultaneously compared to only the CS-29 structure flowing, and finally to a complete closure of both locations. The hourly water level data from this drought period inside the project area reveals the project area's response to low receiving basin water levels under differing operational configurations (Figure 10). During February and early March with both structures open and operational, CS-29 project areas respond repeatedly to low Calcasieu Lake water levels by dropping between 0.4-0.6 ft, specifically around 3/3/2018 and 3/19/2018; this affected water level as far away as the Mermentau River. After the Calcasieu locks were effectively sealed on 3/29/2018, the receiving basin water levels again dropped to a level well below the project area, and with only the CS-29 structure operating, water levels again dropped close to 0.5 feet in response to this head differential illustrating that the CS-29 structure does have a far reaching effect on water level in the Mermentau Lakes sub-basin (Table 2). As drought conditions worsened, the project area dropped below the minimum water level target due to the CS-29 structure continuing to drain

water opportunistically; correspondingly the project structure was closed (Figure 11) (NOAA Drought Index 2020). Water levels in the Mermentau River and project Area 3 then stabilized around 0.0 ft NAVD GEOID 12A, and only dropped another one to two tenths of a foot over the ensuing month, while in project Area 2A water level continued to drop due to a loss of connectivity with surrounding water bodies, eventually reaching approximately negative one foot. As the water level over the marsh was reduced and surface waters became more channelized, similar drainage opportunities reduced water levels in the project area more, even with less cross sectional area of drainage; this is likely due to a reduced overall volume of water in the project area. Also, as the Calcasieu locks transitioned from 50% openings to zero percent openings, it appears that the CS-29 structure was more than capable of handling the drainage capacity at low project water levels. However, it is likely that a 0.4 ft. drop in water level at 1.2 feet project area water elevation is a higher total volume of water than a 0.6 ft. drop at 0.5 feet project area water elevation (NAVD88 GEOID12A) due to a reduced overall water storage capacity once the water level is below the average marsh surface. With the structures closed and Calcasieu Lake running over 0.5 ft above the project area, the CS-29 structure and the Calcasieu locks prevented a major saltwater intrusion event in the project area and the larger Mermentau Lakes sub-basin as a whole, preserving its unique marsh vegetation and fresh water reservoir for agricultural usage.

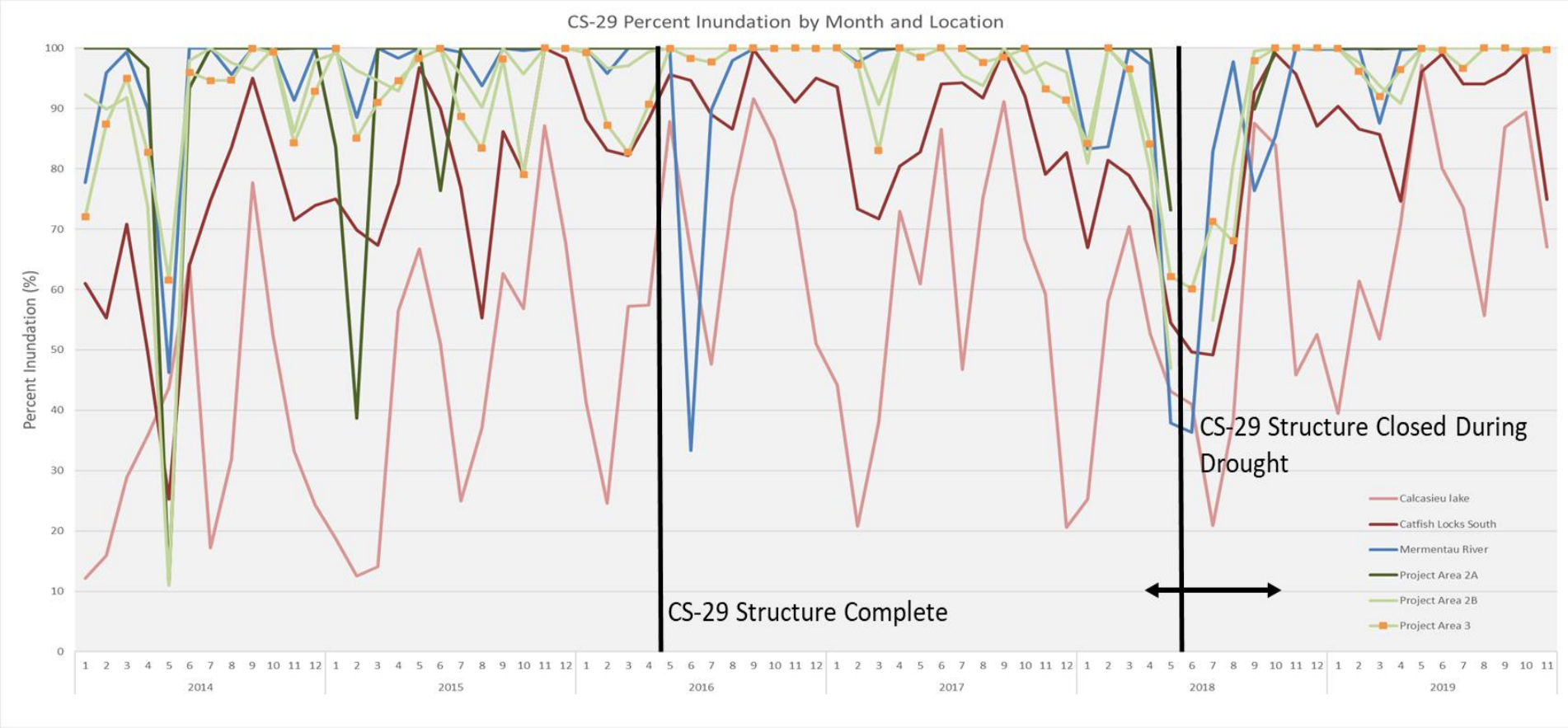


Figure 7. Percent Inundation inside the project subareas and the local reference conditions outside the project area showing near permanent flooded conditions from 2014-2019 in most areas except Calcasieu Lake. At the monthly scale, only Calcasieu Lake and Catfish locks south have water levels routinely below marsh elevation.

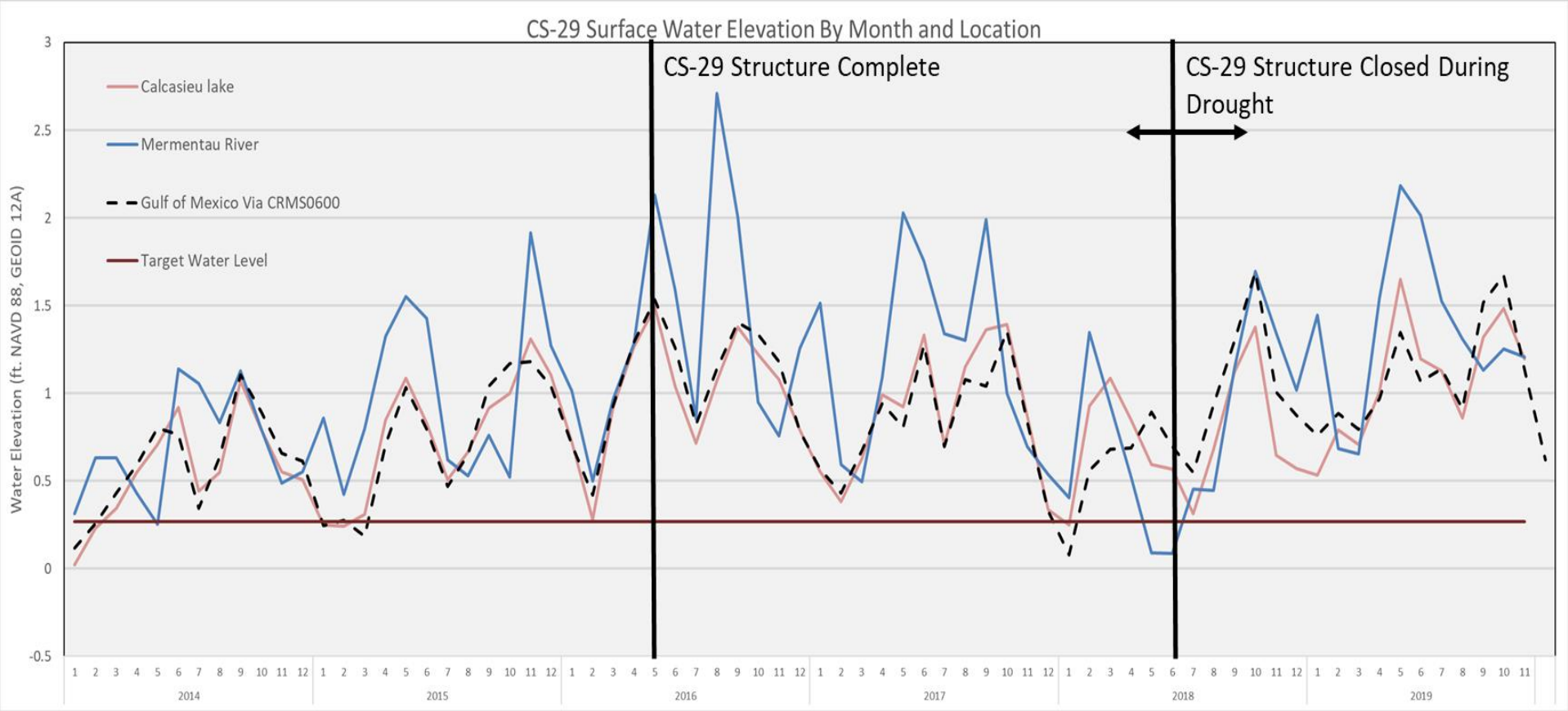


Figure 8. Monthly mean water levels outside the project area in the Mermentau River, Calcasieu Lake, and Gulf of Mexico (CRMS0600). These three locations generally track similarly to one another except during extreme events. The 2016 flooding shows the hydraulic separation of the northern Mermentau Lakes sub-basin and limited drainage as water levels remained elevated for much of the year.

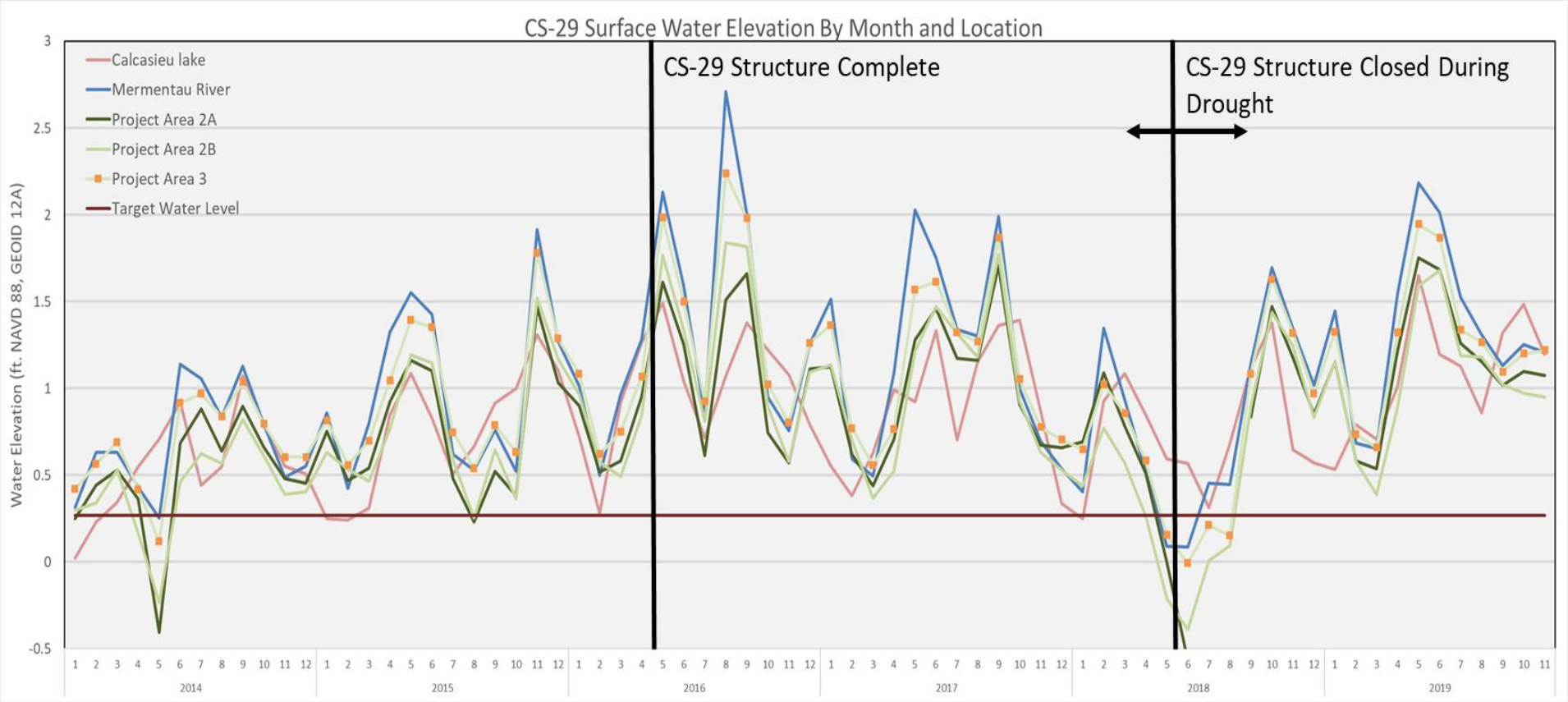


Figure 9. Monthly mean water levels inside and outside the project area in CS-29, the Mermentau River, and Calcasieu Lake. The project sub areas fall into a narrow range between the higher Mermentau River and the lower Calcasieu Lake, striated based on distance from the structure and locks; this relationship only breaks down during drought conditions, with the project area water elevation dropping below Calcasieu Lake.

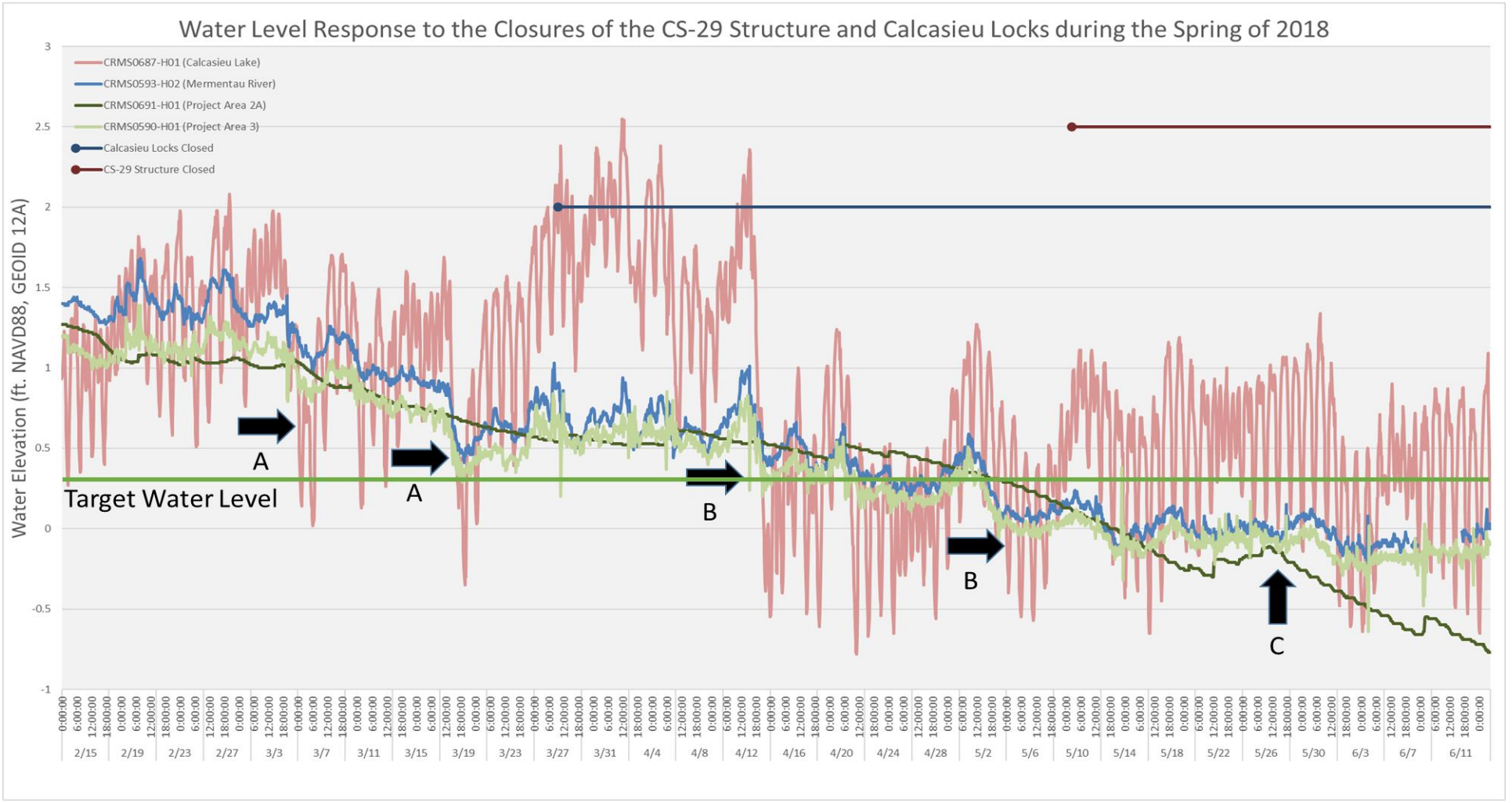


Figure 10. Hourly water levels inside and outside the project area in CS-29, the Mermentau River, and Calcasieu Lake. The drought of 2018 prompted the closure of both the CS-29 structure and the Calcasieu locks for an extended period. The closures were staggered and shows the effect of both structures in operation (A), only the CS-29 structure (B), and interior marsh evapotranspiration (C).

Table 2. Water level trends during brief drainage events inside and outside the project area. The drought of 2018 prompted the closure of both the CS-29 structure and the Calcasieu locks for an extended period. The closures were staggered and shows the effect on water level (NAVD88 GEOID12A).

Location of Water Level Recorder	Date Range Spring 2018	Structures	Percent Open	Starting Water Level (ft)	Ending Water Level (ft)	Maximum Change (ft)
Calcasieu Lake	3/2-3/9	Calcasieu Locks	56	2.0	0.0	-2.0
Project Area 3	3/2-3/9	CS-29 Culverts	100	1.2	0.8	-0.4
Calcasieu Lake	3/18-3/22	Calcasieu Locks	17	1.7	-0.3	-2.0
Project Area 3	3/18-3/22	CS-29 Culverts	100	0.8	0.3	-0.5
Calcasieu Lake	4/12-4/16	Calcasieu Locks	7.5	2.3	-0.5	-2.8
Project Area 3	4/12-4/16	CS-29 Culverts	100	0.8	0.2	-0.6
Calcasieu Lake	5/2-5/7	Calcasieu Locks	0	1.3	-0.5	-1.8
Project Area 3	5/2-5/7	CS-29 Culverts	100	0.5	-0.1	-0.6
Calcasieu Lake	5/30-6/3	Calcasieu Locks	0	1.3	-0.7	-2.0
Project Area 3	5/30-6/3	CS-29 Culverts	0	0.0	-0.3	-0.3

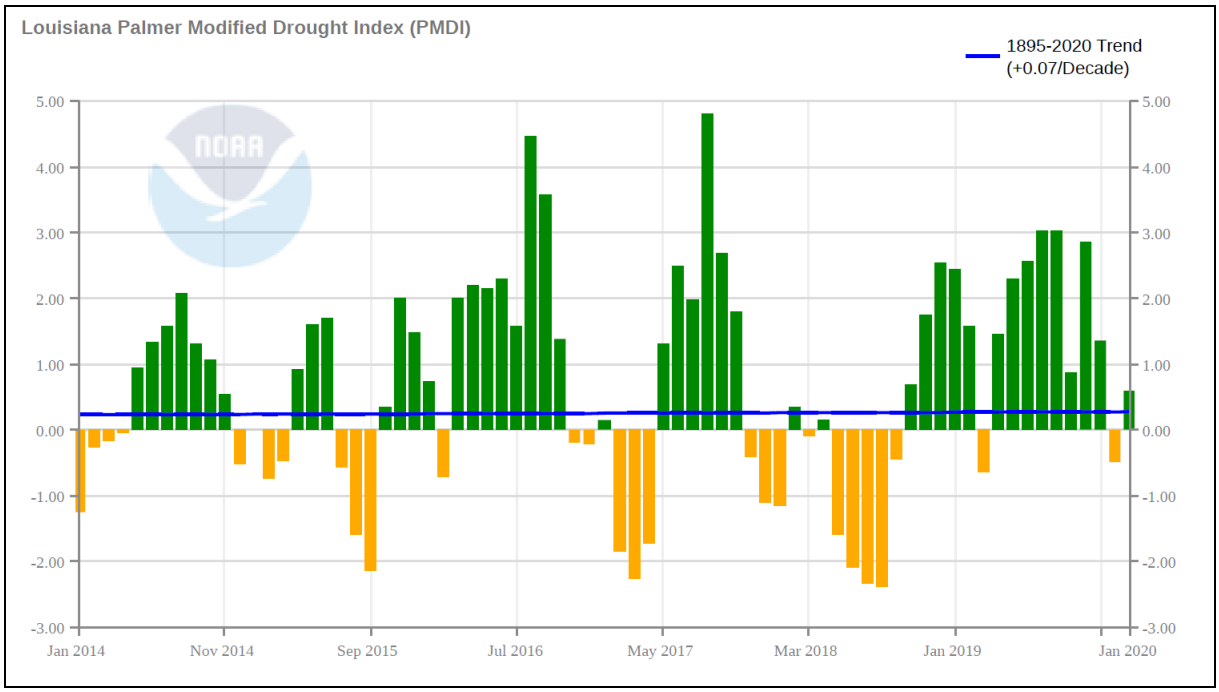


Figure 11. U.S. Drought Monitor Palmer Modified Drought Index data for Louisiana from 2014-2019. Most instances of the project area nearing or falling below the minimum water management threshold coincides with drought conditions (in yellow).

Salinity

The project areas CRMS continuous salinity stations have generally measured very low average annual salinity values from 2014-2019, rarely exceeding one part per thousand (ppt) and never two ppt. This is an effective indicator that the project is successfully maintaining the separation between the Calcasieu and Mermentau basins as designed, while still allowing drainage under applicable water levels. This is obvious when examining salinity data from the reference conditions to the south and west. The marshes south of the Catfish locks experience higher annual salinity levels on average, often approximately double that of the CS-29 project area. Because of the salinity introduced via the Calcasieu Ship Channel (CSC) this is specifically the salinity entry point the project structure was designed to block, while still allowing opportunistic drainage; salinities in the CSC routinely exceed 10 ppt as a yearly average, episodically much higher (Figure 12).

At the monthly time scale, project Area 3 is the only location to experience salinities over 2 ppt from 2014-2019. This minor salinity introduction is likely in the vicinity of the ME-11 water control structure and the nearby Gravity Drainage District structure via the lower Mermentau River during the drought conditions of 2018 (Wood et al. 2019). In contrast, the waters of Calcasieu Lake are repeatedly higher than the 10 ppt monthly average and occasionally closer to 20 ppt for months at a time (Figure 13). These high salinity waters are successfully kept separate from project Areas 2A and 2B due to project design and operation of the Calcasieu locks. Overall, the project has added drainage potential to the Mermentau Lakes sub-basin while maintaining the salinity separation, which, given the water elevation relative to marsh elevation, is critical for maintaining vegetative growth and cover.

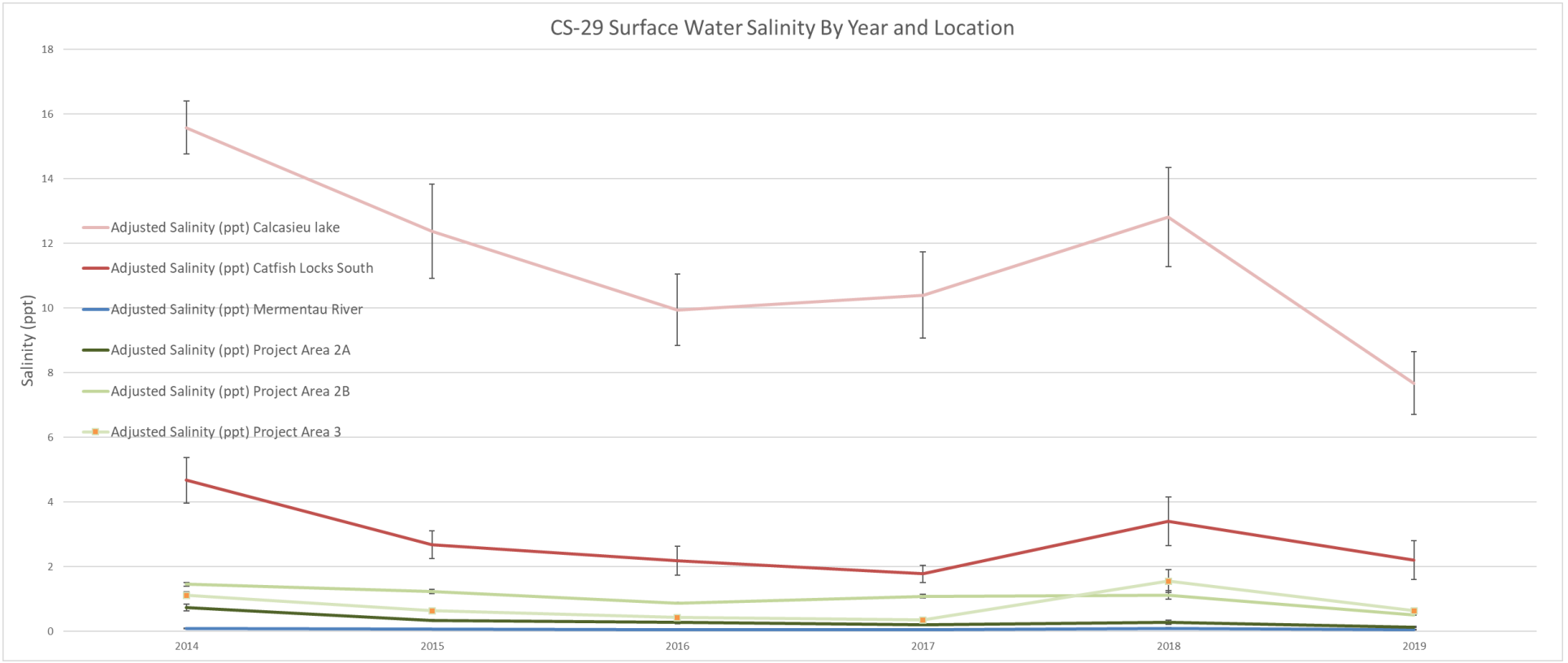


Figure 12. Yearly means and standard errors of surface water salinity collected in the project and reference locations from 2014-2019.

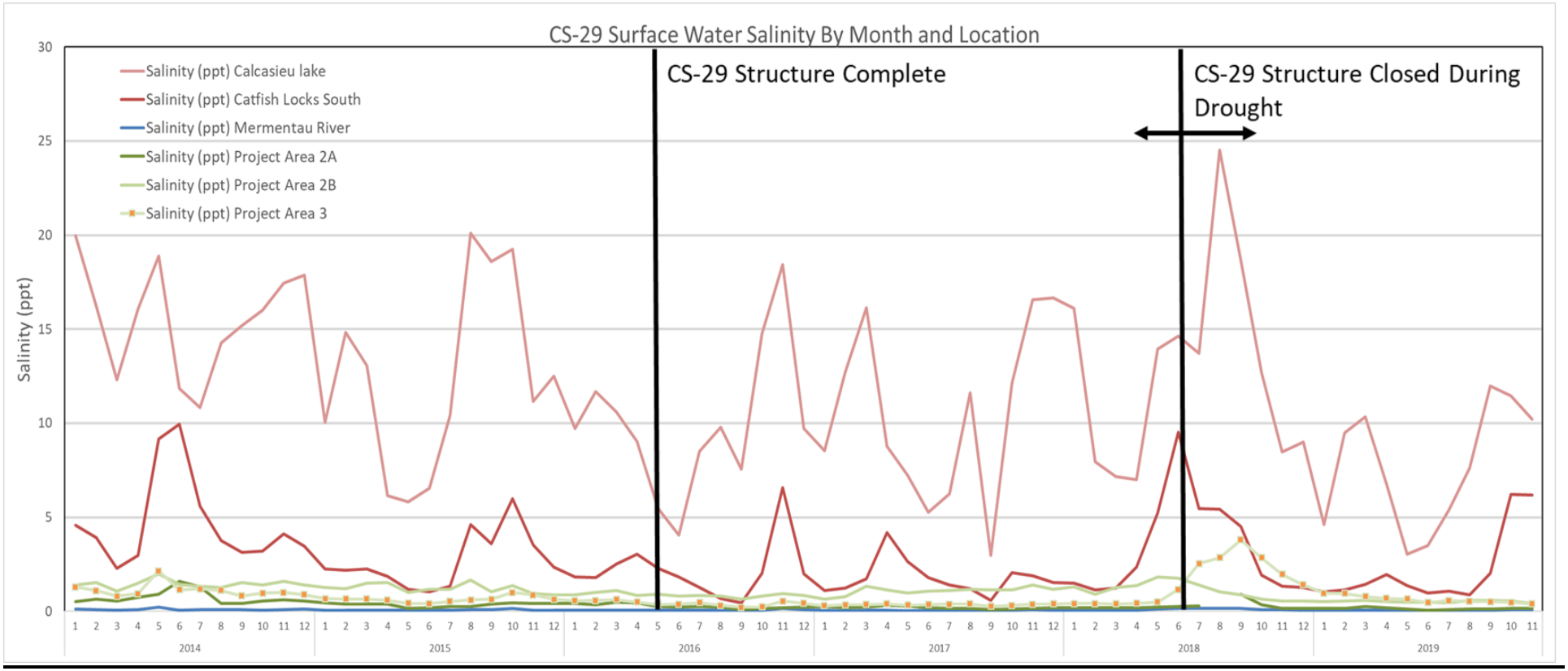


Figure 13. Monthly means of continuous salinity collected at stations in the project areas and reference conditions from 2014-2019.

Vegetation

The vegetation of the CS-29 project and reference areas is heavily influenced by salinity and water level, along with current marsh elevations. The separation maintained by the project structure and the Calcasieu locks keeps the saline waters in Calcasieu Lake from reaching the project area, causing distinct vegetation differences across the region. This separation along with high water levels in the receiving basin leads to high water levels and flooded conditions a majority of the time in the project area. These overarching environmental factors influence many of the vegetative parameters as measured at CRMS sites throughout the project and reference areas such as, height of the dominant species present, species richness, sum of species percent cover, and species assemblages.

The height of the dominant species present in the project and reference areas can vary depending on landscape scale regional factors such as hurricanes, floods, and droughts, causing shifts among all areas simultaneously. However, localized site specific factors can also influence the height of plants, like species, nutrient availability, salinity regime, flood stress adaptation, and others. There were no statistical differences of dominate species height pre (168.7 cm) and post (161.9 cm) project construction in any of the project sub areas based in a two way ANOVA of data collected between 2014-2019. There was however a location effect, with project Area 2A (201.7 cm) having significantly taller vegetation than the other project locations, Area 2B (155.7 cm) and Area 3 (138.7 cm), which did not differ from one another ($F_{2, 50} = 6.80$, $p = 0.0006$). These differences are based on the complex interplay of multiple factors as mentioned above, and not solely the project structure. The project areas generally maintain taller vegetation than all the reference areas on an annual basis, irrespective of marsh type.

The project Area 2A vegetation was generally substantially taller than the rest of the locations measured, often exceeding 200 cm; this is likely due to a combination of larger species assemblages, proximity to upland agricultural runoff containing nutrients, very low salinities, and flood stress adaptation causing plants to emerge further out of the water for gas exchange. The five remaining project and reference areas were typically similar to one another with salinity and flood regimes separating heights by area, with project Area 2B maintaining the second tallest plants and Calcasieu Lake the shortest. The Mermentau River, project Area 3 and Catfish locks south were intermediate (Figure 14). This relationship changed somewhat in 2019 as the lengthy deep flooding conditions increased the height of the vegetation in the Calcasieu Lake areas while reducing height at Catfish and project Area 2B, causing Calcasieu Lake to increase compared to all locations except project Area 2A (Figure 9).

The conditions affecting vegetation height also have a large impact on species richness and number of species present in the various project and reference locations. Higher salinity generally selects for fewer species as the adaptation to these higher salinities are present in fewer species overall. Not surprisingly, Calcasieu Lake (4.5) has a significantly lower number of overall species present than any of the other areas, averaging below five species during the summer ($F_{5, 91} = 46.1$, $p < 0.0001$), based on a two way ANOVA testing location and year from 2014-2019. Alternatively, more flooded fresh conditions can lead to a higher numbers of species, especially in floating marshes as the variable growing conditions lead to high competition at very small spatial scales. This is evident with the Mermentau River area, exhibiting 27.5 distinct species annually on multiple occasions, with the majority of the

project areas averaging between 20-25 species during each CRMS summer vegetation survey. Among the project sub areas, based on a two way ANOVA of data collected between 2014 and 2019 by project area, there was no change in species richness pre (19.8) vs. post (20.4) project construction, however there was a marginally significant effect by project area with Area 2A (17.0) harboring fewer species than Area 2B (21.9) and Area 3 (21.3) ($F_{2, 50} = 3.42$, $p = 0.040$) (Figure 15). Large disturbance events like droughts and hurricanes can cause a temporary change in species richness and this is evident in the project area. Much of the time, species are simply replaced as conditions change to favor one species over another; shifts in dominant species are present while previously abundant plants are pushed to niches.

These ever shifting species assemblages are surprisingly stable in terms of total cover and the sum of species cover across project and reference areas. All areas, except the Mermentau River, behaved fairly similarly and occupied the same range of total species cover near 80% annually (Figure 16). Values higher than this rough average are typically only found under drought conditions, during the beginning of the growing season in fresh locations such as project Areas 2A, 2B, and 3; along with the Mermentau River. A two way ANOVA testing project Area and pre and post project construction was preformed to specifically address this effect ($F_{1, 50} = 8.4$, $p < 0.0056$). These results indicate there was significantly more total species cover post construction (87.7%) than pre construction (73.8%) from 2014-2019. This effect is likely driven by the drought of 2018, as ponds dry up, soils become aerobic and species expand and compete for resources. The more established and dominant marsh species are resistant to change and short term variations in local environmental parameters. As such, these species are conserved through time, though the quantity (%) may vary. There was no differences among the project areas 2A (80.0%), 2B (78.1%), and 3 (84.0%) with regards to total species cover as they all general maintain near 80% cover.

In fresher, more frequently flooded conditions, such as project Area 2A, the dominant species over the last decade are *Schoenoplectus californicus* (California bulrush), Zizaniopsis miliacea (giant cutgrass), and *Sagittaria lancifolia* (bulltongue arrowhead), varying in percent cover as conditions dictate (Figure 17). This species assemblage reveals the area to be very fresh and typically inundated for long periods of time during the growing season. Project Area 2B shows a slightly less fresh and less flooded species assemblage, along with higher diversity. The area is predominantly composed of *Spartina patens* (saltmeadow cordgrass), *Schoenoplectus californicus* (California bulrush), and a mix of other niche species, depending on if high or low waters are prevalent, such as *Echinochloa walteri* (coast cockspur grass) or *Ipomoea sagittata* (saltmarsh morning-glory) (Figure 18). This suggests an intermediate to fresh marsh, with seasonal but variable flood stress. Project Area 3 maintains a similar species combination to Area 2B, with the exception of *Sagittaria lancifolia* (bulltongue arrowhead) as codominant with *Spartina patens,* due to the similar environmental factors acting upon both areas, correspondingly, and maintaining a more flood tolerant species assemblage through time as the project area has received higher water levels for longer in recent years due to external forces (Figure 19). This trend is also evident in the reference area of the Mermentau River as the once codominant species *Cynodon dactylon* (Bermuda grass) has been replaced with Zizaniopsis miliacea (giant cutgrass), again showing more flood adapted species selection (Figure 20). The final two reference locations, Calcasieu Lake and Catfish locks south, are outside the project area's freshwater impoundment and are significantly different due to salinity, water levels, and to a lesser extent tidal fluctuations. The Catfish locks south

area is dominated by *Spartina patens* (saltmeadow cordgrass) as it is an intermediate marsh with lower water levels present for much of the year through management practices, proximity to the Gulf of Mexico, and lack of exterior fresh water input (Figure 21). The marshes of the Calcasieu Lake area are brackish with a mix of high salinity tolerant plants that typically also thrive with tidal movement and intermittent low water levels such as *Spartina alterniflora* (smooth cordgrass), *Juncus roemerianus* (needlegrass rush), and *Spartina patens* (saltmeadow cordgrass) (Figure 22). These species assemblages are indicative of current and recent historic hydrologic conditions in the project and reference areas, displaying the near complete elimination of saline waters entering the Mermentau Lakes sub-basin and the elevated water levels within the sub-basin due to boundary conditions and management practices.

This is represented in the Vegetation Volume Index data (VVI) (Wood et al. 2015) (Figure 23). Both the project CRMS sites and the reference CRMS sites have similar vegetation volume index scores, which is simply a measurement of the amount of vegetation present, regardless of species. The VVI uses the volume of vegetation present and scales it by marsh type from 0-100. In the reference locations and other CWPPRA project areas, the VVI remain fairly static post 2010, after hurricane recovery. However, in the CS-29 project area, the VVI jumped substantially during the years post drought (2012 and 2019), leading to the conclusion that extensive colonization and increased covers were a byproduct of lower water levels and soil oxidation. So if the project area continues to experience intermittent droughts, especially before or early in the growing season, the vegetation volume should continue to increase accordingly.

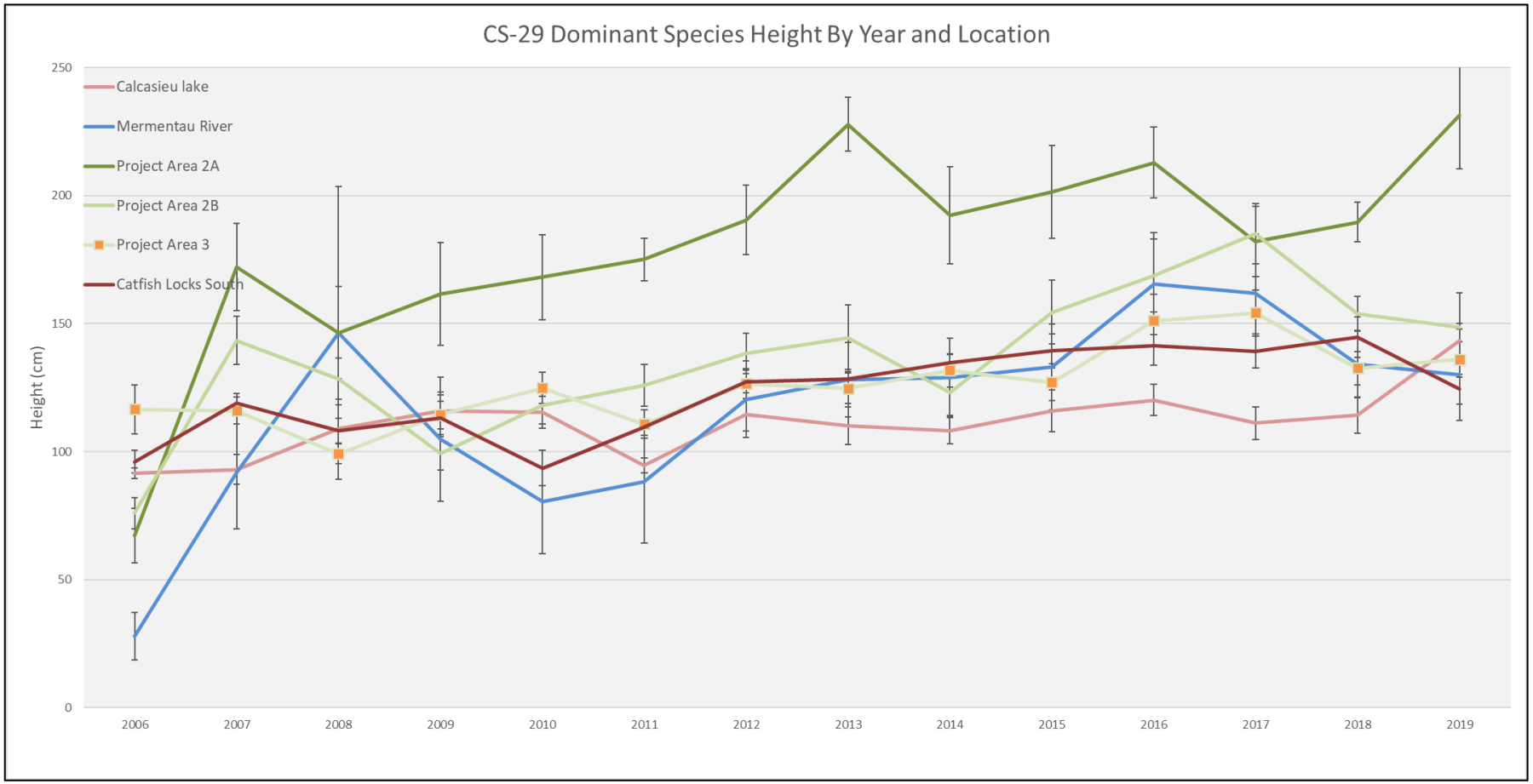


Figure 14. The height of the dominant species in the project sub areas and reference areas from 2006-2019. There is a strong recovery from the 2005 hurricane season with a generally positive trend overall. The vegetation in project Area 2A reached nearly 2.3 meters on average in 2013 and 2019, the highest year or location value in the data set.

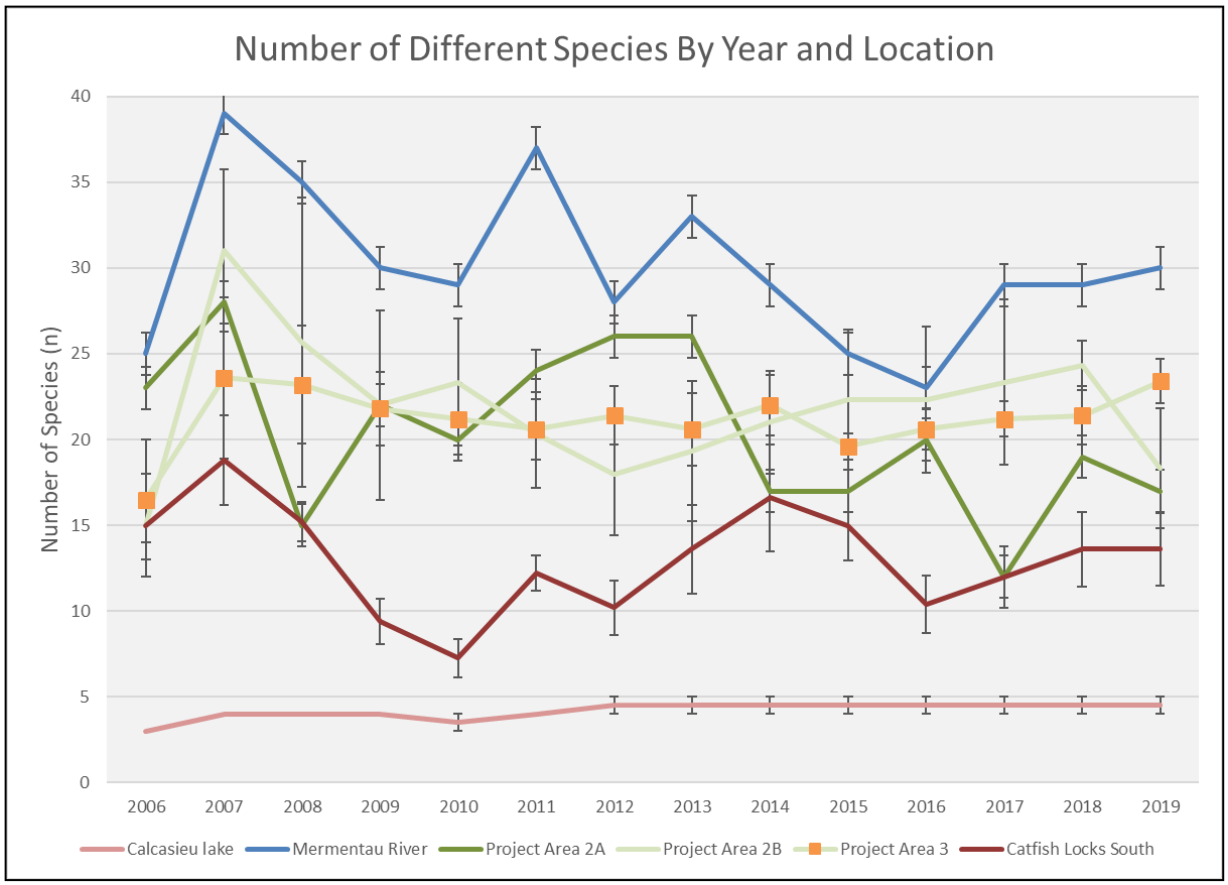


Figure 15. The number of the distinct species in the project sub areas and reference areas from 2006-2019. There is a general reduction of species through time as the major disturbances of 2005 and 2011 have become further removed. The reference area of the Mermentau River annually contains the most species and the trends generally follow the areas' salinity stratifications, with an increase in salinity leading to a decrease in species.

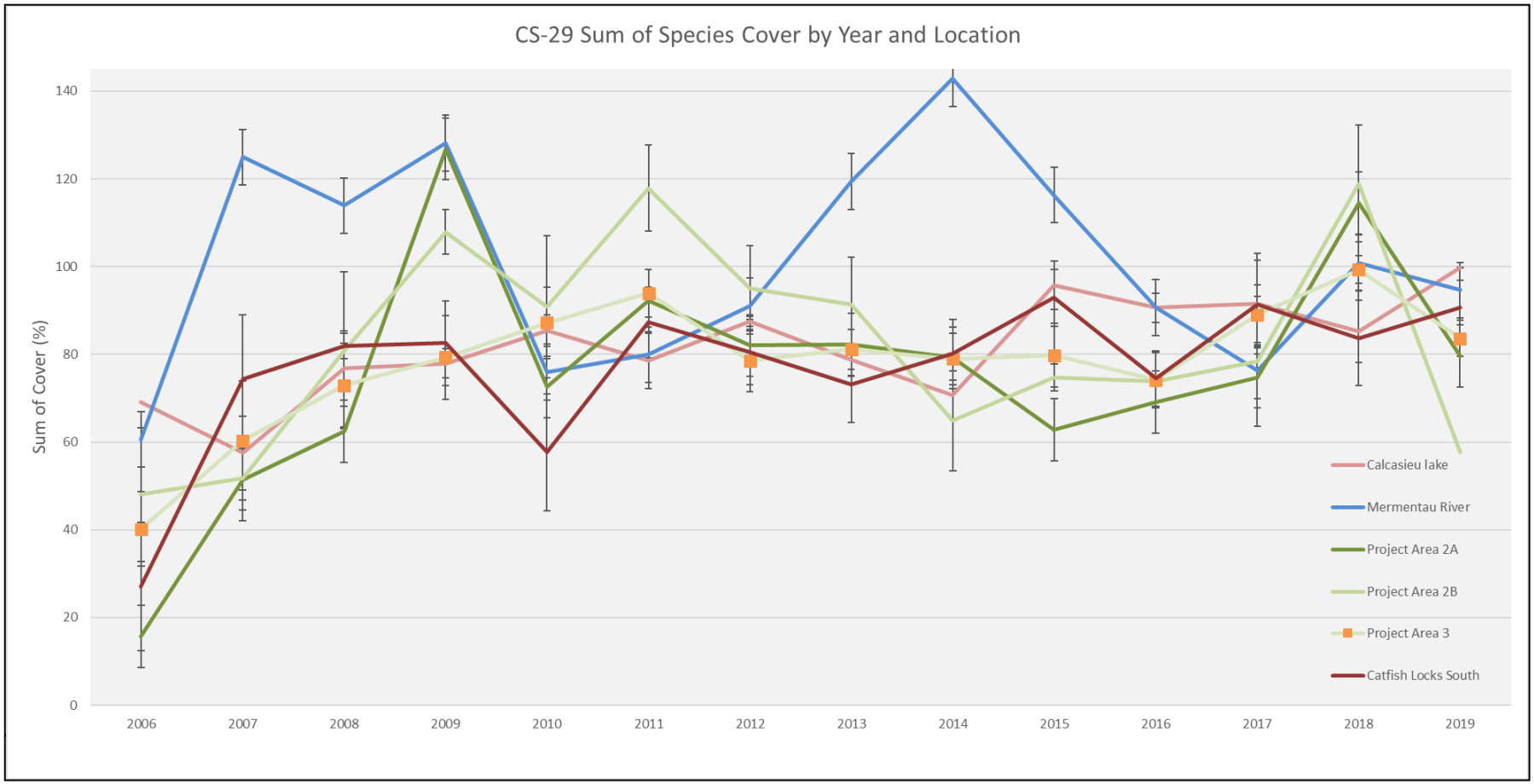


Figure 16. The sum of the individual species percent cover in the project sub areas and reference areas from 2006-2019. There is a recovery from the 2005 hurricane season, and then a disorganized pattern within the project sub areas and reference conditions with occasional peaks accentuating early growing season droughts. Note: Sums are > 100 when plants occupy the same space in layers.

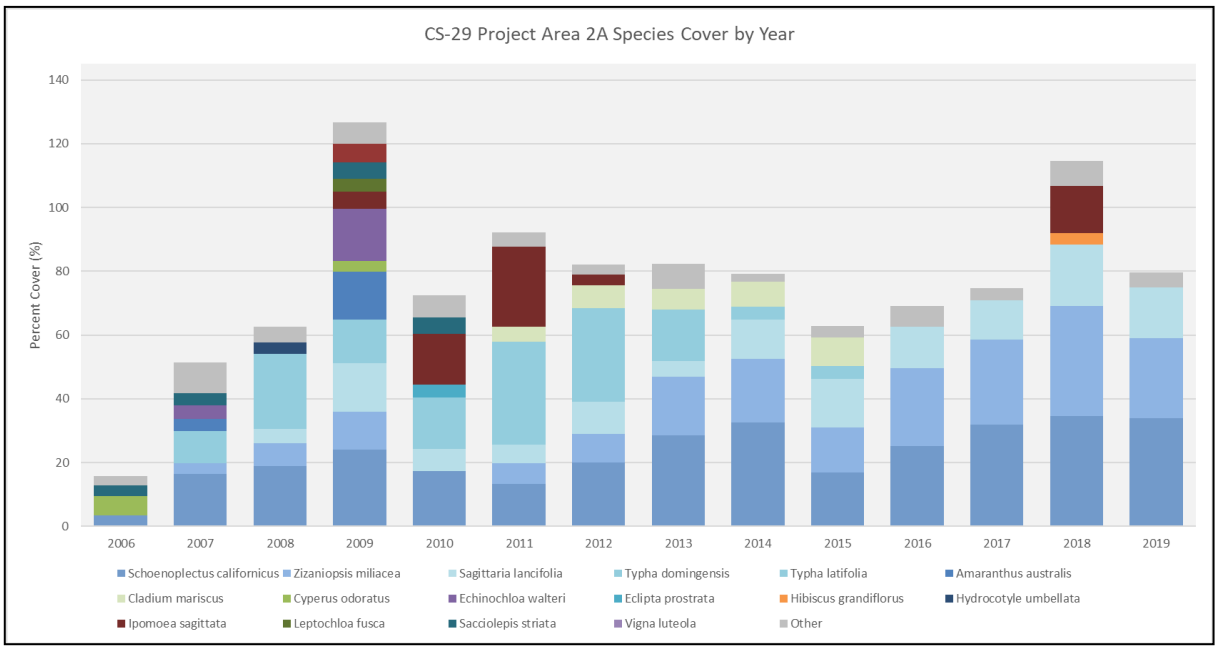


Figure 17. The percent cover of major species in the project Area 2A from 2006-2019, displaying mostly flood tolerant fresh species.

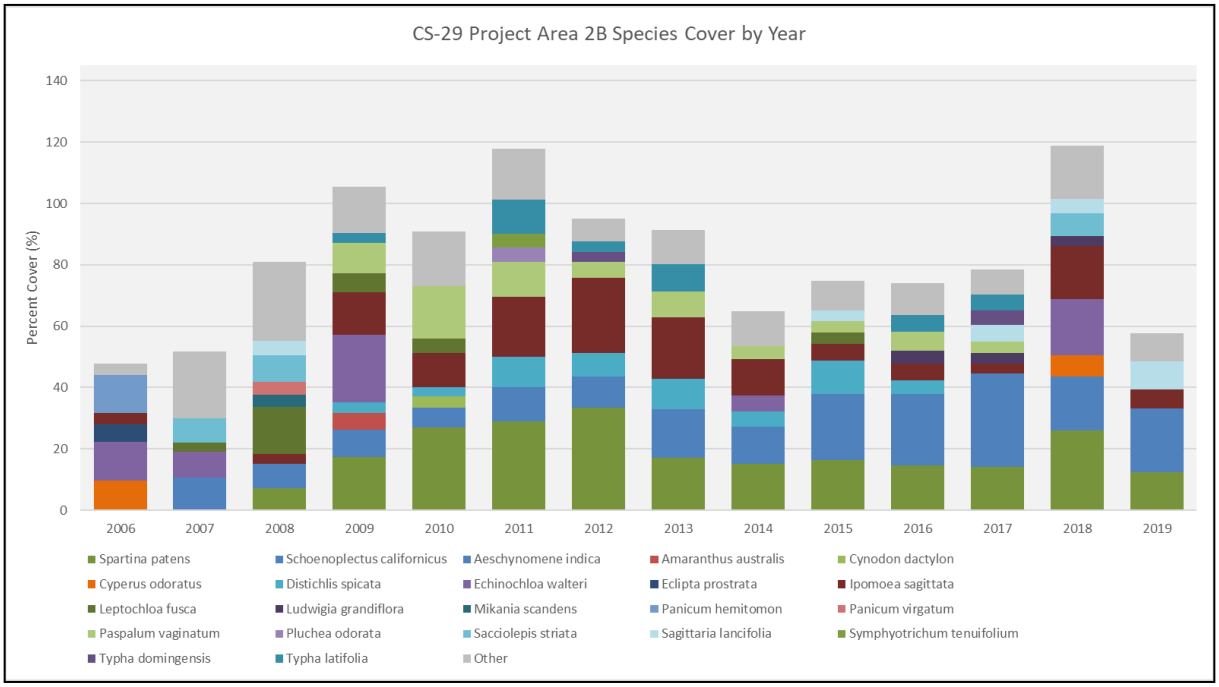


Figure 18. The percent cover of major species in the project Area 2B from 2006-2019, displaying mostly intermediate and flood tolerant species.

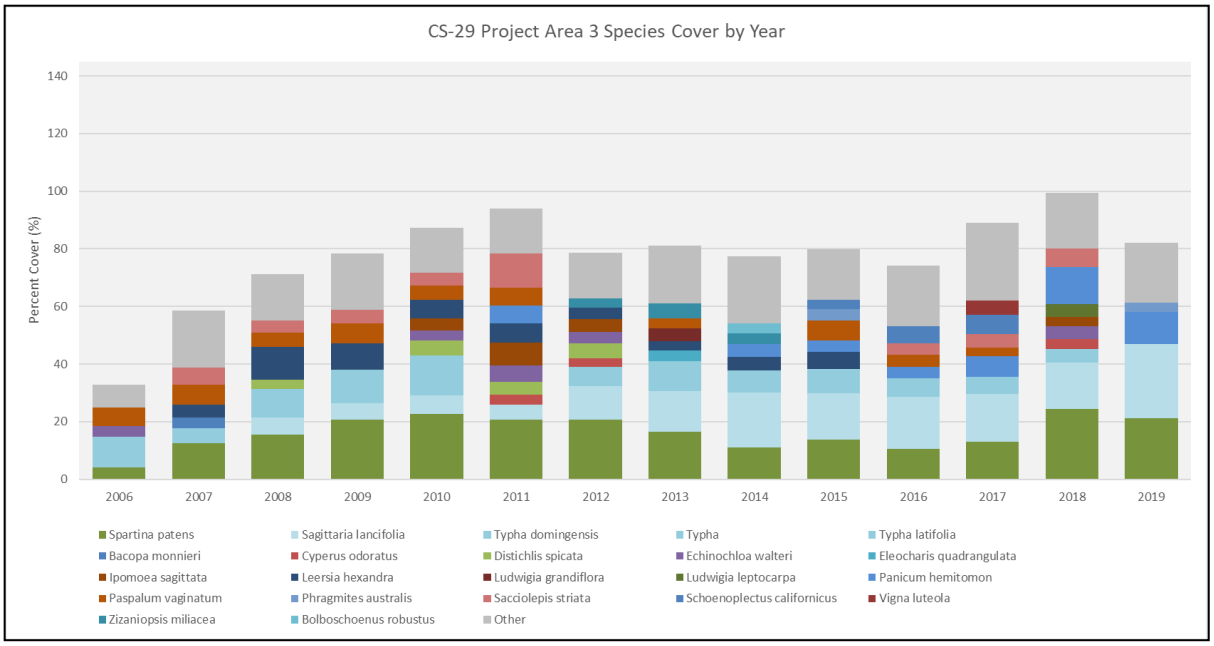


Figure 19. The percent cover of major species in the project Area 3 from 2006-2019, displaying mostly intermediate and flood tolerant species.

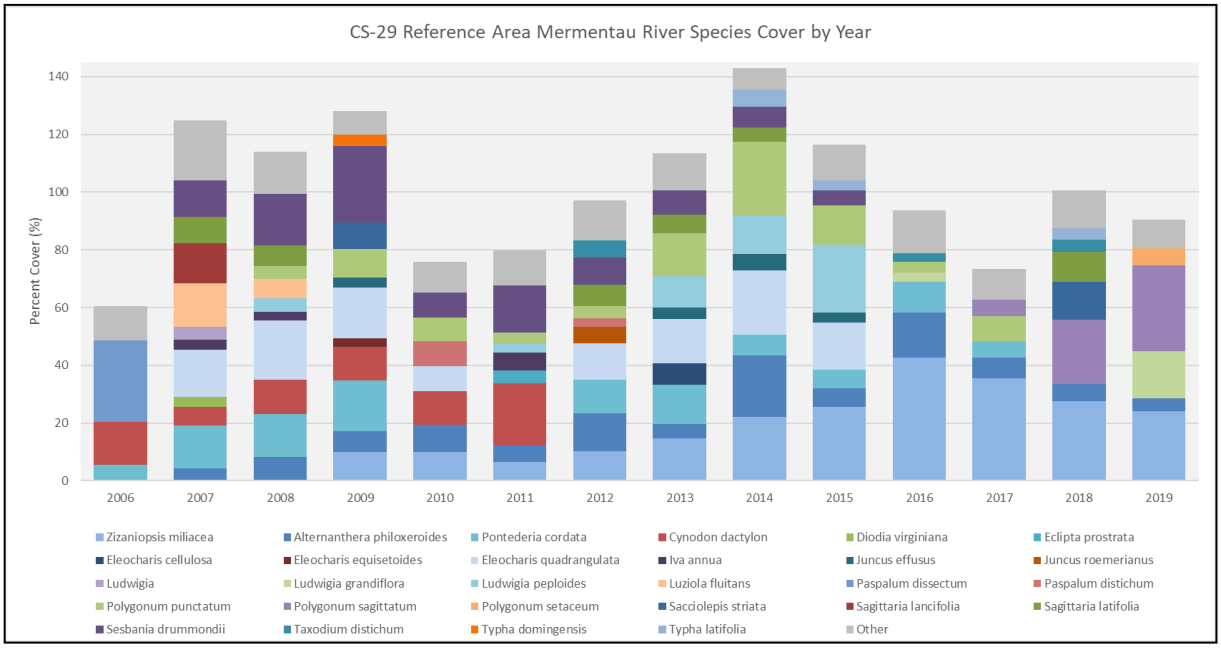


Figure 20. The percent cover of major species in the reference area Mermentau River from 2006-2019, displaying mostly flood tolerant fresh species.

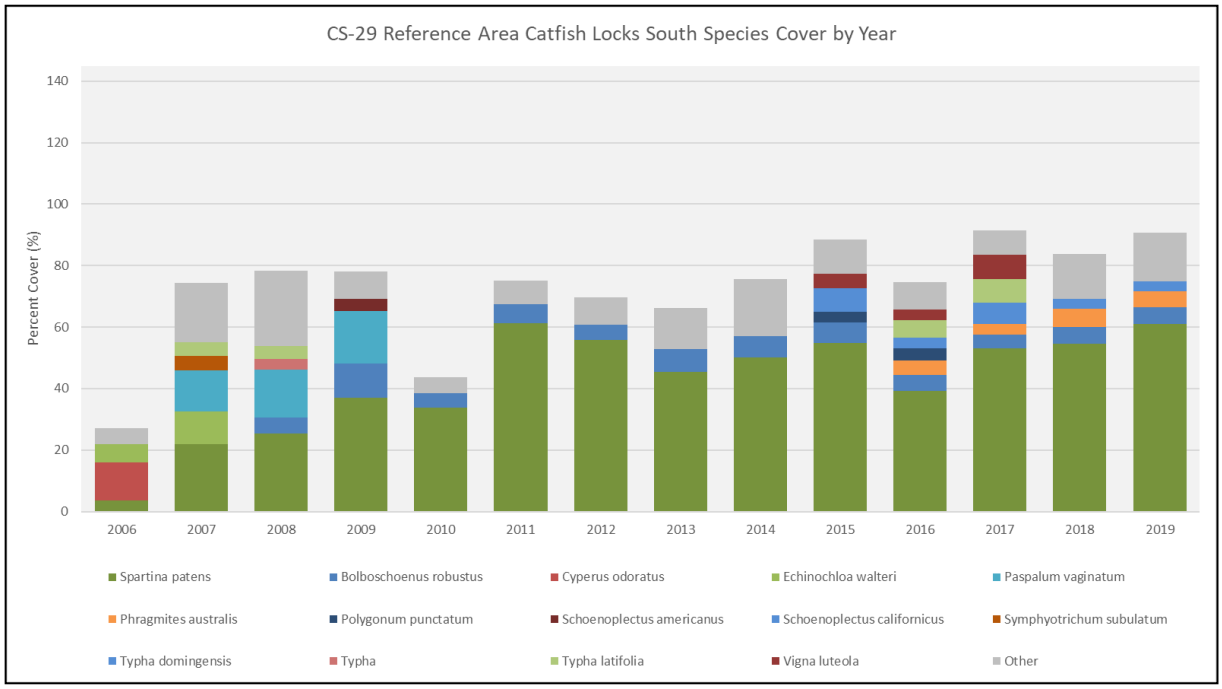


Figure 21. The percent cover of major species in the reference area Catfish locks south from 2006-2019, displaying mostly intermediate species.

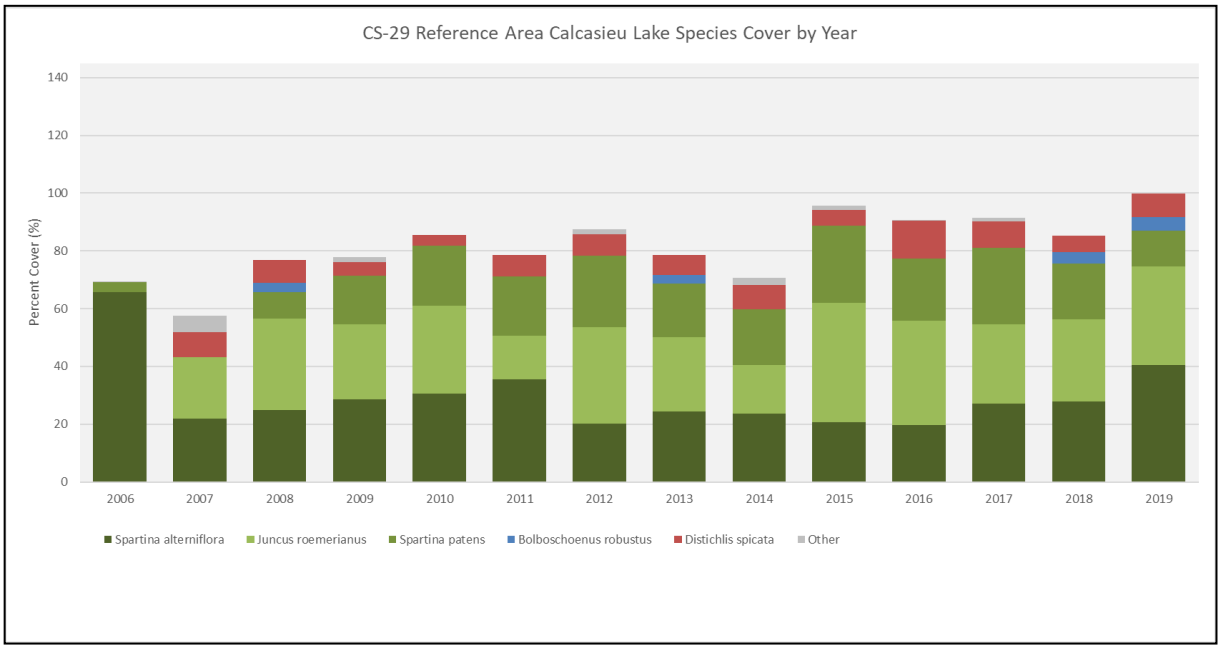


Figure 22. The percent cover of major species in the reference area Calcasieu Lake from 2006-2019, displaying mostly brackish to saline species.

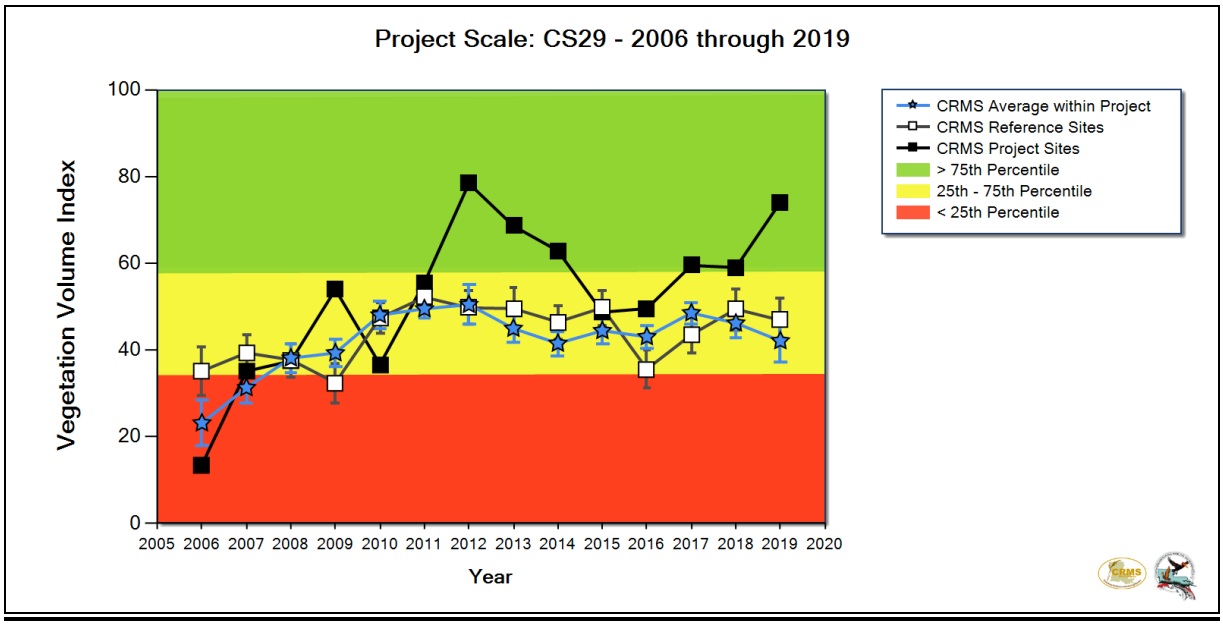


Figure 23. Vegetation volume scores for CRMS sites in the CS-29 project areas shown over time relative to all other CRMS sites (CWPPRA project and reference) within similar marsh types. The CS-29 project area performs significantly better under low water conditions, such as those present around the 2011 and 2018 droughts.

Hydrologic Index

High Hydrologic Index (HI) scores indicate that flooding and salinity conditions are ideal for vegetation growth in a given marsh type. In fresher marsh cohorts this can include a significant amount of flooding in the absence of salinity. In 2018, the HI scores were higher at CRMS sites within the CS-29 project than at CRMS sites outside CS-29 or in other CWPPRA project areas, in the same basin and marsh type, during any other year (Figure 24). This was due to the separation between the Mermentau Lakes sub-basin and the Calcasieu basin via the Calcasieu locks and the CS-29 project structure during a growing season drought that allowed the fresh waters of the project area to drain below local marsh elevation for a substantial portion of the growing season. This predictive index was validated as the project area's sum of species percent cover increased during this year by nearly 40%. In most years, the HI scores in the project area were higher than the other sites in the region. The project was not fully operational until mid-2016. Therefore, previous large differences during the extreme drought of 2011 were not related to project features, but to the hydrologic management of the Mermentau Lakes sub-basin as a whole.

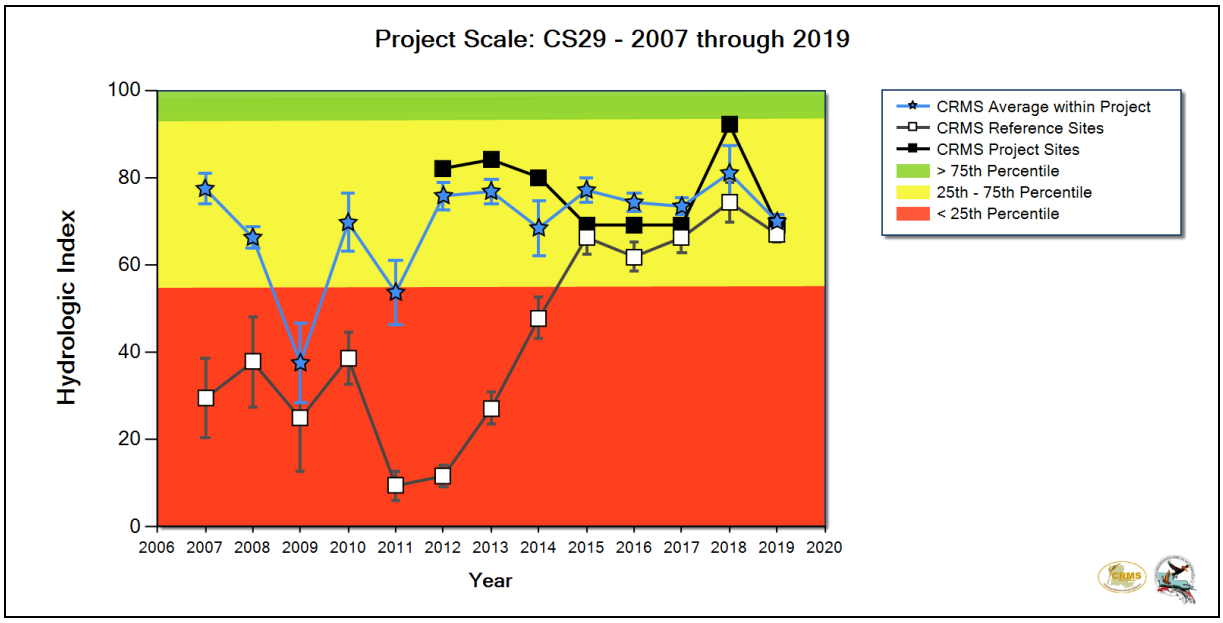


Figure 24. Hydrologic Index scores for CRMS sites in the CS-29 project areas shown over time relative to all other CRMS sites (CWPPRA project and reference) within similar marsh types. These sites are either fresh or intermediate and are indexed by marsh type before a project average HI is calculated.

Soils

Physical soil properties were analyzed from three 24 cm deep soil cores collected from each site in the three sub-areas inside the project area and three reference locations outside of the project area. The soils from these distinctly managed or unmanaged locations differed substantially, however the project Areas 2A, 2B, and 3 were all very similar in regards to bulk density (0.1 – 0.15 g/cm^3) (Figure 25); soils from the reference locations were notably much more dense. Soil core samples outside the project area began to diverge almost immediately, with the exception of the 0-4 cm sample in the Mermentau River, which was very similar to the project area. However, when deeper samples were analyzed, the bulk density increased rapidly, likely due to substantial sedimentation along the river of heavy clays or sands. The project's effect on bulk density shows that isolation from tidal forces and riverine inputs have caused a majority of soil formation from in situ organic material. The organic content of the project areas, relative to the other sites, was also very different. The project areas were between 45-65 percent organic matter, while the reference conditions were mostly below 35 percent organic matter (Figure 26). The soils of the Catfish Locks South area marshes were the most similar to that of the project area, at least along the upper samples of the soil profile, and then, with depth, transitioned to be more similar to that of the other reference locations, consisting of far more mineral and less organic material. Within the project area, location 2A had the most organic matter, but was not substantially different from other project locations.

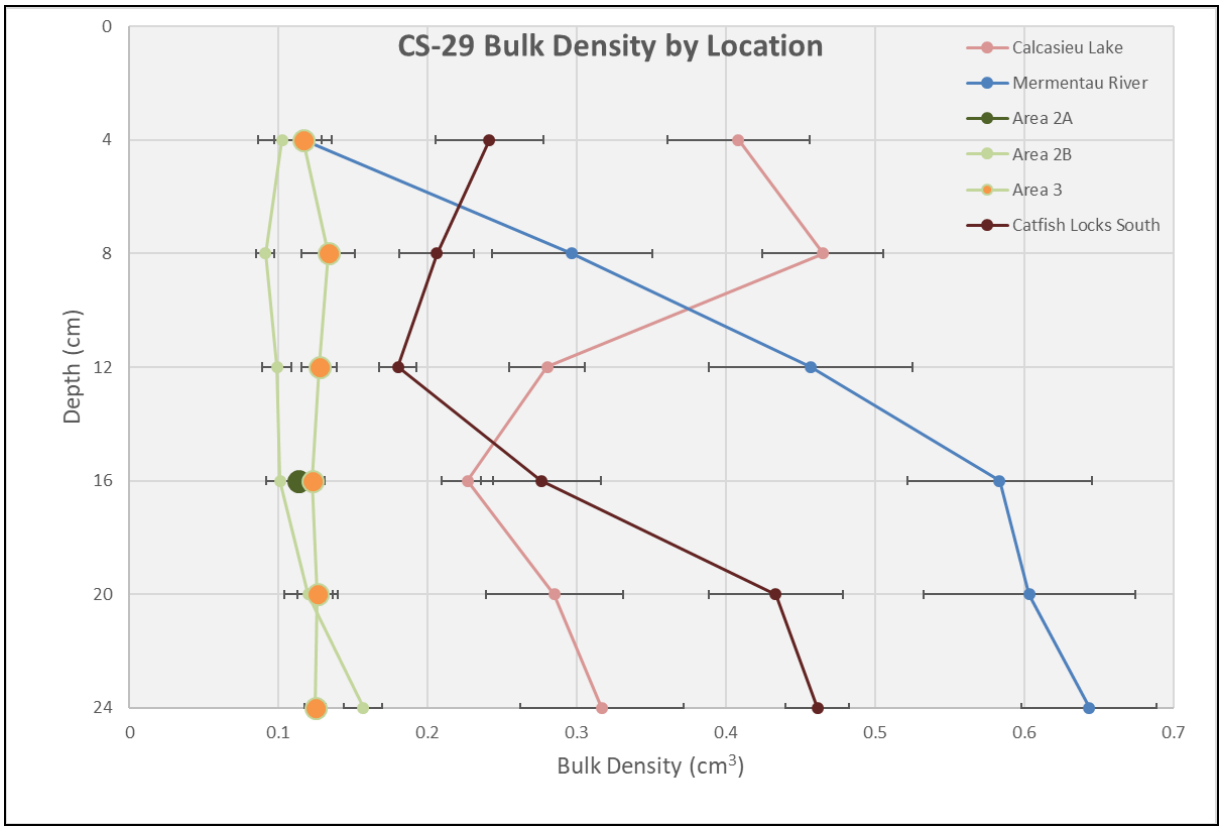


Figure 25. Soil bulk density collected at CRMS sites in the project and reference areas. Note project Area 2A only has data for the 12-16 cm depth profile, which is an average for the entire depth profile.

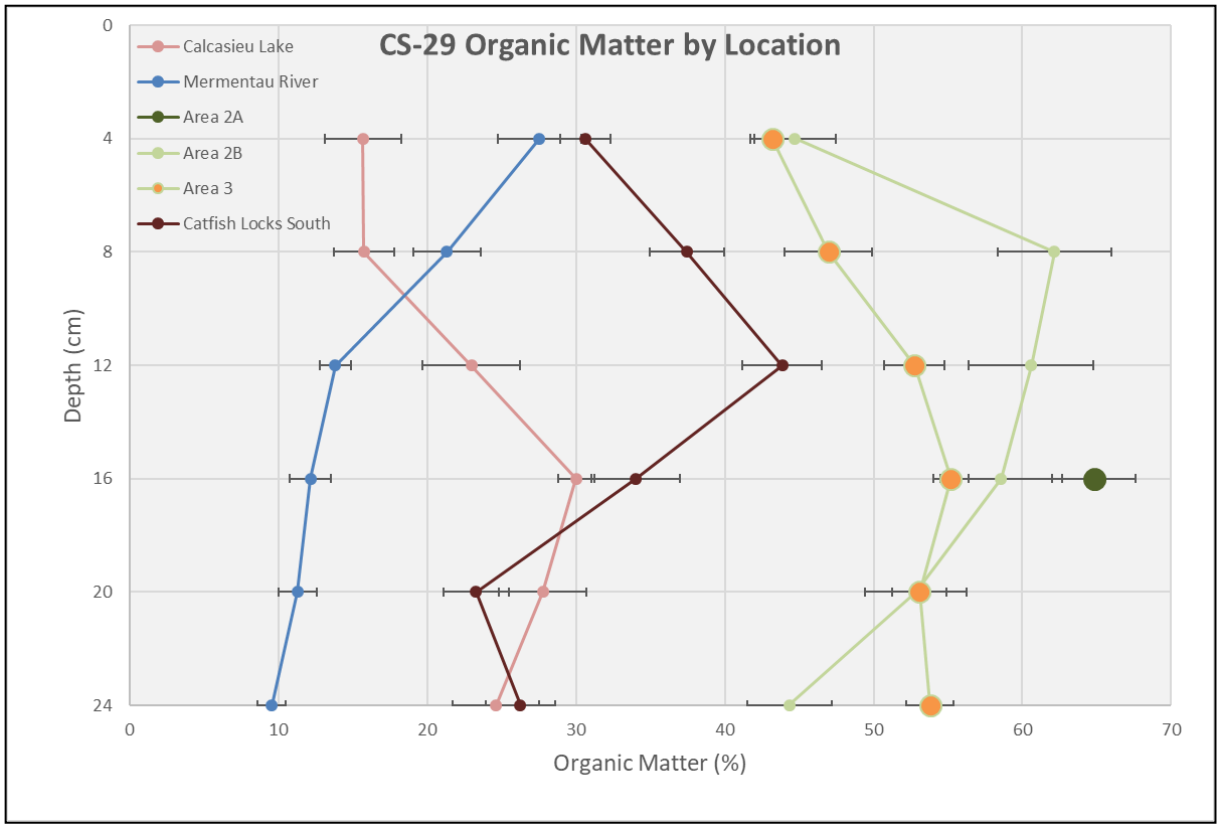


Figure 26. Soil percent organic matter collected at CRMS sites in the project and reference areas. Note project Area 2A only has data for the 12-16 cm depth profile, which is an average for the entire depth profile.

Elevation Change

Elevation change data, collected in the CS-29 project and reference CRMS sites, show there is significant variability within locations, both inside and outside of the project area, making it difficult to interpret a local average representing a large geographic area (+0.87 to -0.48 cm/yr). This suggests that the variability is occurring from smaller scale environmental features than at the project scale (Figure 27). All of the project sites are likely experiencing slight to moderate increases in inundation, when compared to the Galveston NOAA tide gauge sea level rise estimate of 0.655 centimeters per year, except CRMS0590 which is in Area 3 of the project and is very organic and likely undergoing some expansion following average water level increase (Zervas 2009 and 2013). The relatively stable elevation change among project area 3 sites is likely a result of the organic soil materials and their expansion capabilities as previously mentioned (Figure 28). The reference area along Calcasieu Lake also has a positive trend in elevation change across sites with minimal variability, but the soil formation processes are likely completely different as tidal forces bring mineral sediments to these locations, while removing organic detritus and the occasional deposition of storm driven accretion. Project Area 2B site CRMS0553 is losing elevation at an alarming rate of -0.48 cm/yr. This is reflected in the 2019 vegetation data that showed the possible beginnings of marsh collapse and appears to be on the trajectory for land loss. However, as the area is maintained in the project area, and in a fresh marsh environment, there are multiple species that could expand and revegetate a more flooded marsh platform or as a floating mat.

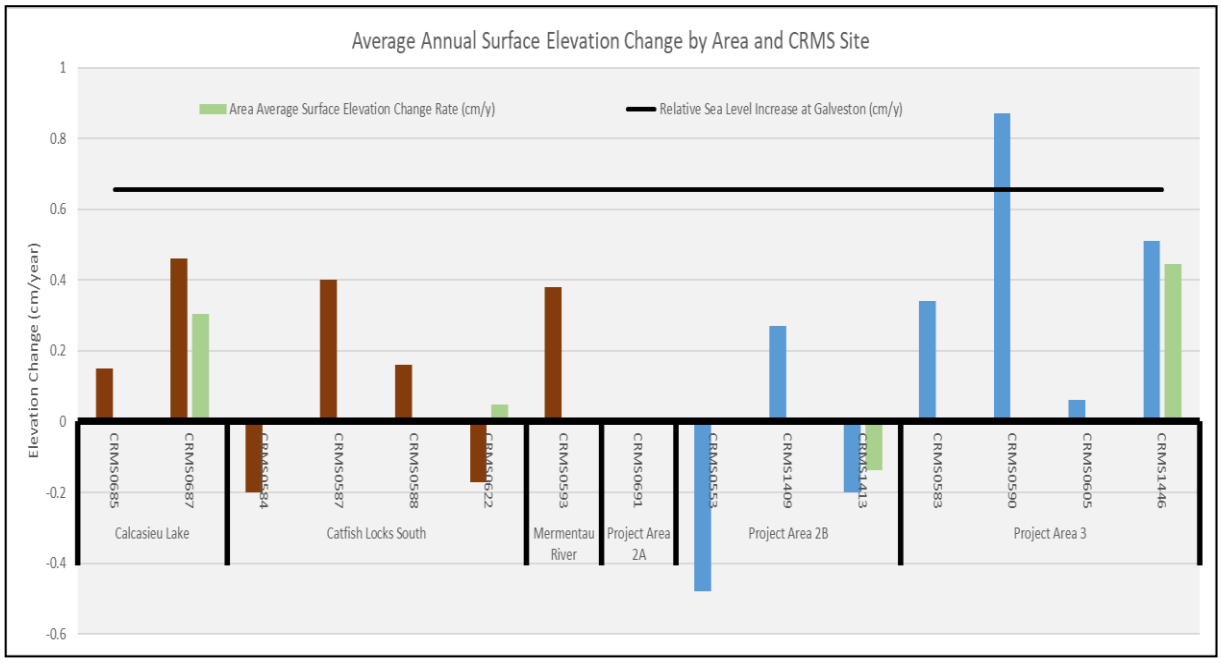


Figure 27. Elevation change per year experienced in the project CRMS sites and reference condition CRMS sites, along with sea level rise rates from Galveston, TX. Project area 2A (CRMS0691) is almost directly on the axis at -0.01 cm per year long term average.

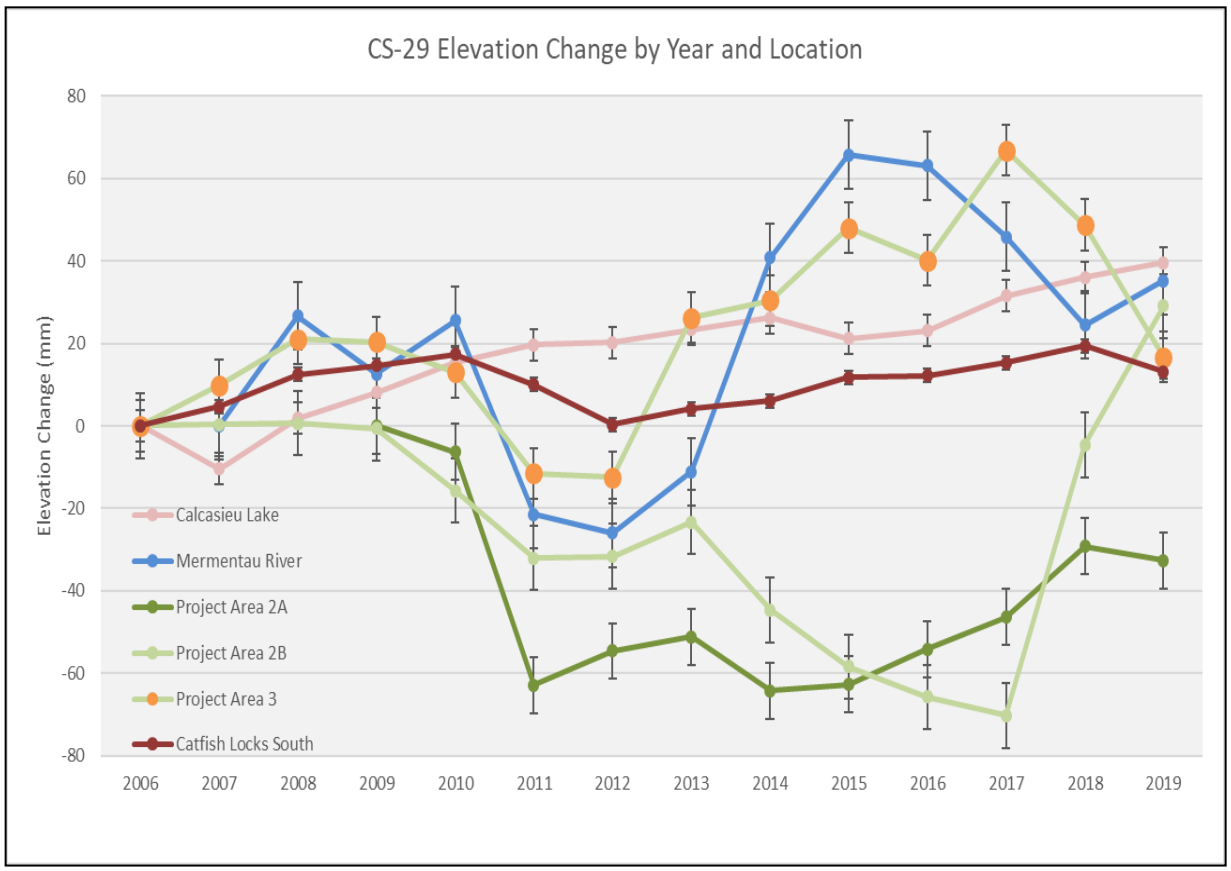


Figure 28. Elevation change from 2006-2019, experienced at project area CRMS sites in CS-29 project area and in reference locations, showing a loss and recovery in elevation through time at most locations tied to water level fluctuations; namely an increasing water level and the soil keeping pace post drought.

V. Discussion

a. General Discussion

The CS-29 project area hydrology is controlled by larger outside environmental forces but some of these boundary conditions are significantly dampened by the Black Bayou culverts and the Calcasieu locks, especially salinity and tidal amplitude. Water levels are somewhat elevated in the project area by continuously limited drainage opportunities and generally high waters in the receiving basins upon which the project depends for gravity drainage, though water level is reduced with proximity to the structures. The land mass of the project area remains quite stable when compared to the Mermentau basin or coastal Louisiana as the fresh relatively placid waters of the project area allow for a mix of attached, deeply inundated, and floating marshes which typically can recover from interior damage and some marsh loss due to storm surge. Most of the recovery from damaging environmental conditions happens when localized or regional droughts cause reduced water levels in the project area and vegetation spreads out into previously un-vegetated open water ponds and shorelines and is maintained as water levels increase. The marsh vegetation in the project area is typically large robust species which dominate fresh marshes of coastal Louisiana, such as *Schoenoplectus californicus* (California bulrush), Zizaniopsis miliacea (giant cutgrass), and *Sagittaria lancifolia* (bulltongue arrowhead), along with more generalist species found almost everywhere along the coast such as *Spartina patens* (saltmeadow cordgrass) and *Typha L.* (cattail). The CS-29 vegetation is fairly diverse with 20-25 species per project sub-area being common, even as there is little elevation variability across large expanses of marsh.

The soils of the project area are very organic and have low bulk densities common to peaty fresh marshes in which vegetative production both above and below ground are responsible for long term soil formation with little outside mineral deposition. This can lead to weak soils but also to extremely flexible soils which can adjust to varying water levels assuming salinity and eutrophication are not significant local factors. This is rather evident in the project area's elevation change data showing over 80 mm of change from starting elevation over an approximately 15 year span. This was due to a serious drought shrinking and dewatering of organic soils and high waters conditions forcing an upward response from the project's pliable soils, either stretching or detaching from the underling substrate. Overall the project structure in concert with the Calcasieu locks helps maintain the fresh marsh habitat of the upper Mermentau basin while increasing the opportunistic drainage capacity within the project area at times when the receiving basins will allow.

VI. Conclusions

a. Project Effectiveness

Overall, the project successfully increases the drainage potential of the Mermentau Lakes sub-basin, while excluding saltwater introduction. The Black Bayou culverts are most effective when either the receiving basin of Calcasieu Lake is low, allowing for east to west drainage, or when localized or regional droughts reduce the input from the Mermentau River, preventing saltwater backflow as evapotranspiration and agricultural demands increase. However, when the project structure was undermined soon after construction, it failed an important mandate of design to exclude saline waters from entering the Mermentau Lakes sub-basin. As of the completed repairs in early 2016, the project structure removes excess fresh water when conditions in Calcasieu Lake permit and continues the exclude saline waters from entering the project area under normal environmental conditions. This causes the project impoundment to continue to be successful at increasing freshwater vegetative growth and species diversity.

From 1985 to 2016, the project area's emergent marsh has remained very stable through multiple negative episodic events. This trend is likely to continue with the project's addition of increased cross sectional drainage potential, mitigating some of the effects of increased receiving basin water levels due to sea level rise from multiple sources.

The Mermentau River introduces fresh water, some mineral sediments, and nutrients from non-point source runoff of mostly agricultural origin. The project structure, along with the Calcasieu locks, allows for the retention of much of this material in the upper Mermentau, enhancing the area's robust and diverse vegetation. The combination of these inputs, and the complete control over salinity, gives the project area the unique ability to continuously adapt to water level fluctuations and often continuous inundation for much of the year.

As water levels in the Gulf of Mexico and Calcasieu Lake continue to increase, the opportunity for gravity drainage through both the CS-29 project structure and the Calcasieu locks become increasingly limited, and accentuates the necessity of maintaining these key pieces of infrastructure, along with either additional gravity drainage or mechanical removal of water from not only the project area but the entire Mermentau Lakes sub-basin.

b. Recommended Improvements

The CS-29 project area is relatively large and is bounded by the immense impoundment of the Mermentau Lakes sub-basin. As such, the project area may drain excess water from local marshes through the project structure, but there is generally a vast fresh water reservoir available to replenish the dewatered wetlands. For this reason, coordination with the USACE and its management plan and objectives are a key concern for the success of this project and has been the management practice of the LRO of CPRA.

The usage of project specific flow and or stage monitoring sondes in real time inside and outside the structure would benefit operational decisions and the assessment of monitoring goals, along with future hydrodynamic modeling in the area and in the design of additional drainage structures which will be a necessity if future water level predictions are reasonably accurate.

It is critical to maintain the newly repaired CS-29 structure in good working order, both to allow the project goals to be met, but also as an emergency relief valve in the event of damage at the Calcasieu locks. The project structure would be the main westerly drainage feature of the Mermentau Lakes sub-basin until the locks were again operational. This maintenance should extend to the channels that feed the structure from the GIWW, making sure they are of adequate depth and width to maximize the function of a structure of this size.

The location of the structure makes it susceptible to vandalism. Various materials have been used to prop open the flapgates to allow water movement, thus damaging the gate hinges and locking rings. Alternative measures may be needed if this continues to be an issue.

c. Lessons Learned

Impoundments are designed to hold more water than surrounding areas and are difficult to maintain because of additional hydrodynamic forces on the boundary levees and structures. As such, breaches are difficult to stop and repair within a reasonable timeframe as to not cause disruptions to the project area. A more robust structure was necessary to prevent such a breach from undermining the Black Bayou structure which needed sheetpile cutoff walls on each side of the structure to eliminate potential undermining through subsurface sand lenses.

After initial construction and shortly after the structure was put into operation, it was found that the aluminum flapgates were being damaged from extreme forces caused by the gates slamming closed during high tides. The gates required additional structural reinforcement in order to withstand the impacts of the repetitive forces.

A few years into structure operations, it was found that the repetitive movement of the gates was causing the nuts on the flapgate hinges to back off the threaded rods holding the gates in position. These nuts were changed to a locking nut with a teflon insert.

The duration of flooding in the project area is dependent on current marsh elevation and local water level along with drainage potential. The CS-29 project has increased the overall drainage potential of the project area though marsh elevation remains low while and receiving basin water levels remain high. The project structure effectively removes water when conditions are favorable, while not allowing saline waters to flow into the project area, which would directly damage project area marshes.

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APPENDIX A
(Inspection Photographs)

Photo No. 1, West Side of Box Culvert Structure (Looking North) -November 2019

Photo No. 2, West Side (Looking North) – Rip Rap on North Bank of the Channel- January 2020

Photo No.3, West Side of Box Culvert Structure, Steel Bulkhead - October 2019

Photo No.4, West Side of Box Culvert Structure, Warning Sign- October 2019

Photo No. 5, West Side of Box Culvert Structure, Flapgates & Headwall- February 2020

Photo No. 6, West Side of Box Culvert Structure,
Flap Gate No. 4 – Broken Locking Rings & Steel Drill Pipe - January 2020

Photo No. 7, East Side of Box Culvert Structure (looking North), Trash Screens, Vegetation & Debris (October 2019 & February 2020)

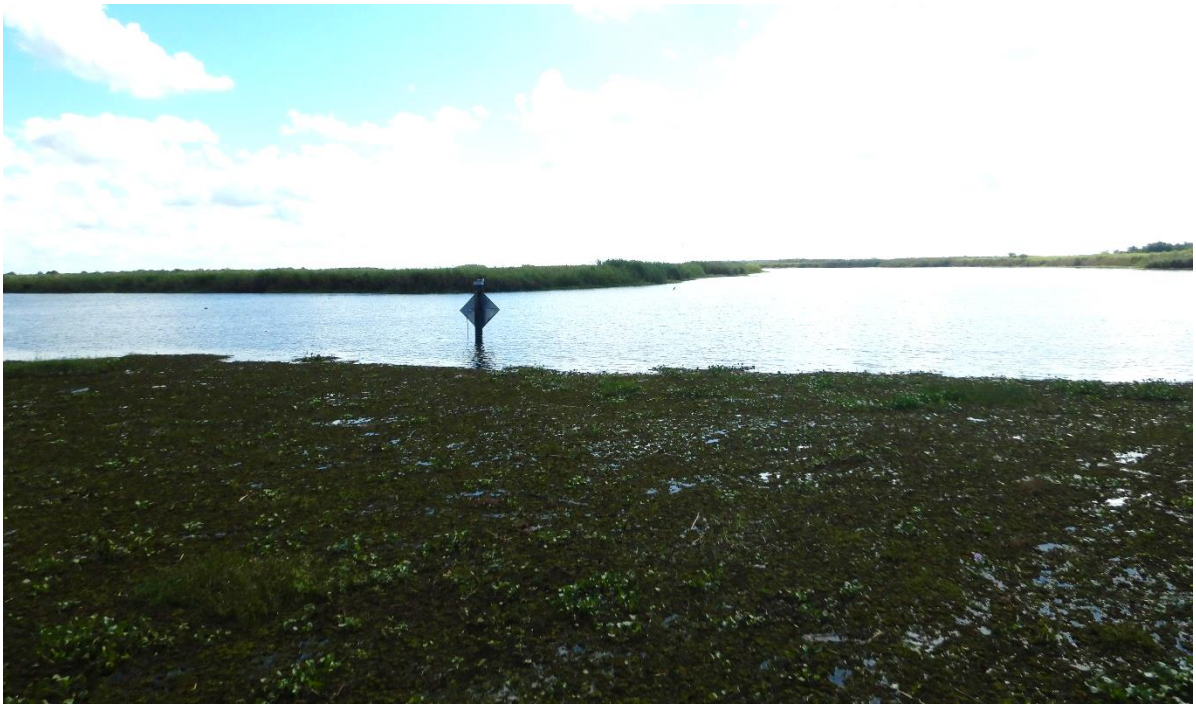


Photo No.8, East Side of Box Culvert Structure, Warning Sign - October 2019

APPENDIX B
(Three Year Budget Projection)

BLACK BAYOU CULVERTS H R/ CS-29 / PPL 9

Three-Year Operations & Maintenance Budgets 07/01/2020 - 06/30/2023

Project Manager	O & M Manager	Federal Sponsor	Prepared By
Jody White	*Jody White*	*NRCS*	*Jody White*

	2020/2021	2021/2022	2022/2023
Maintenance Inspection	$ 8,181.00	$ 8,426.00	$ 8,679.00
Structure Operation	$ 27,950.00	$ 30,000.00	$ 30,000.00
State Administration	$8,000.00	$ 8,000.00	$ 8,000.00
Federal Administration		$ -	$ -
Maintenance/Rehabilitation			

2020/2021 Description:

E&D	
Construction	$ 25,000.00
Construction Oversight	
Sub Total - Maint. And Rehab.	$ 25,000.00

2021/2022 Description: Traffic control for inspection

E&D		$ -
Construction		$ 1,300.00
Construction Oversight		$ -
	Sub Total - Maint. And Rehab.	$ 1,300.00

2022/2023 Description: Repair locking rings, debris removal

E&D		$ -
Construction		$ 30,000.00
Construction Oversight		$ -
	Sub Total - Maint. And Rehab.	$ 30,000.00

	2020/2021	2021/2022	2022/2023
Total O&M Budgets	**$ 69,131.00**	**$ 47,726.00**	**$ 76,679.00**

O &M Budget (3 yr Total)	**$ 193,536.00**
Existing O & M Budget	**$ 1,151,868.00**
Remaining O & M Budget (Projected)	**$ 958,332.00**

OPERATION AND MAINTENANCE BUDGET WORKSHEET

BLACK BAYOU CULVERTS H R/CS-29/PPL 9/2020-2021

DESCRIPTION	UNIT	EST. QTY.	UNIT PRICE	ESTIMATED TOTAL
O&M Inspection and Report	EACH	1	$8,181.00	**$8,181.00**
General Structure Maintenance	LUMP	1	$25,000.00	**$25,000.00**
Engineering and Design	LUMP	0	$0.00	**$0.00**
Operations Contract	LUMP	1	$27,950.00	**$27,950.00**
Construction Oversight	LUMP	0	$0.00	**$0.00**

ADMINISTRATION

STATE Admin.	LUMP	1	$8,000.00	$8,000.00
FEDERAL SPONSER Admin.	LUMP	0	$0.00	$0.00
SURVEY Admin.	LUMP	0	$0.00	$0.00
OTHER				$0.00
			TOTAL ADMINISTRATION COSTS:	**$8,000.00**

MAINTENANCE / CONSTRUCTION

SURVEY

SURVEY DESCRIPTION:					
Secondary Monument	EACH	0	$0.00	$0.00
Staff Gauge / Recorders	EACH	0	$0.00	$0.00
Marsh Elevation / Topography	LUMP	0	$0.00	$0.00
TBM Installation	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL SURVEY COSTS:	**$0.00**

GEOTECHNICAL

GEOTECH DESCRIPTION:				
Borings	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL GEOTECHNICAL COSTS:	**$0.00**

CONSTRUCTION

CONSTRUCTION DESCRIPTION:					
Rip Rap	LIN FT	TON / FT	TONS	UNIT PRICE	
	0	0.0	0	$0.00	
	0	0.0	0	$0.00	$0.00
	0	0.0	0	$0.00	$0.00
Filter Cloth / Geogrid Fabric		SQ YD	0	$0.00	$0.00
Navagation Aid		EACH	0	$0.00	$0.00
Signage		EACH	0	$0.00	$0.00
General Excavation / Fill		LUMP	0	$0.00	$0.00
Dredging		CU YD	0	$0.00	$0.00
Sheet Piles (Lin Ft or Sq Yds)			0	$0.00	$0.00
Corrugated Alum. Pipe (30")		LF	0	$0.00	$0.00
Repair Rings on Aluminum Flap Gate		LUMP	0	$0.00	$0.00
Fabricate & Install 2 SS Flap Gates		LUMP	0	$0.00	$0.00
Materials		LUMP	0	$0.00	$0.00
Mob / Demob		LUMP	0	$0.00	$0.00
Contingency		LUMP	0	$0.00	$0.00
General Structure Maintenance		LUMP	0	$0.00	$0.00
BOARDED FOUNDATION PAD			0	$0.00	$0.00
OTHER			0	$0.00	$0.00
OTHER			0	$0.00	$0.00
					$0.00

TOTAL OPERATIONS AND MAINTENANCE BUDGET: **$69,131.00**

OPERATION AND MAINTENANCE BUDGET WORKSHEET

BLACK BAYOU CULVERTS H R/ CS-29/ PPL 9/ 2021-2022

DESCRIPTION	UNIT	EST. QTY.	UNIT PRICE	ESTIMATED TOTAL
O&M Inspection and Report	EACH	1	$8,426.00	**$8,426.00**
General Structure Maintenance	LUMP	1	$1,300.00	**$1,300.00**
Engineering and Design	LUMP	0	$0.00	**$0.00**
Operations Contract	LUMP	1	$30,000.00	**$30,000.00**
Construction Oversight	LUMP	0	$0.00	**$0.00**

ADMINISTRATION

STATE Admin.	LUMP	1	$8,000.00	$8,000.00
FEDERAL SPONSER Admin.	LUMP	0	$0.00	$0.00
SURVEY Admin.	LUMP	0	$0.00	$0.00
OTHER				$0.00
			TOTAL ADMINISTRATION COSTS:	**$8,000.00**

MAINTENANCE / CONSTRUCTION

SURVEY

SURVEY DESCRIPTION:					
Secondary Monument	EACH	0	$0.00	$0.00
Staff Gauge / Recorders	EACH	0	$0.00	$0.00
Marsh Elevation / Topography	LUMP	0	$0.00	$0.00
TBM Installation	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL SURVEY COSTS:	**$0.00**

GEOTECHNICAL

GEOTECH DESCRIPTION:					
Borings	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL GEOTECHNICAL COSTS:	**$0.00**

CONSTRUCTION

CONSTRUCTION DESCRIPTION:					
Rip Rap	LIN FT	TON / FT	TONS	UNIT PRICE	
	0	0.0	0	$0.00	
	0	0.0	0	$0.00	$0.00
	0	0.0	0	$0.00	$0.00
Filter Cloth / Geogrid Fabric		SQ YD	0	$0.00	$0.00
Navagation Aid		EACH	0	$0.00	$0.00
Signage		EACH	0	$0.00	$0.00
General Excavation / Fill		LUMP	0	$0.00	$0.00
Dredging		CU YD	0	$0.00	$0.00
Sheet Piles (Lin Ft or Sq Yds)			0	$0.00	$0.00
Corrugated Alum. Pipe (30")		LF	0	$0.00	$0.00
Repair Rings on Aluminum Flap Gate		LUMP	0	$0.00	$0.00
Fabricate & Install 2 SS Flap Gates		LUMP	0	$0.00	$0.00
Materials		LUMP	0	$0.00	$0.00
Mob / Demob		LUMP	0	$0.00	$0.00
Contingency		LUMP	0	$0.00	$0.00
General Structure Maintenance		LUMP	0	$0.00	$0.00
BOARDED FOUNDATION PAD			0	$0.00	$0.00
OTHER			0	$0.00	$0.00
OTHER			0	$0.00	$0.00
					$0.00

TOTAL OPERATIONS AND MAINTENANCE BUDGET: **$47,726.00**

OPERATION AND MAINTENANCE BUDGET WORKSHEET

BLACK BAYOU CULVERTS H R/ CS-29/ PPL 9/ 2022-2023

DESCRIPTION	UNIT	EST. QTY.	UNIT PRICE	ESTIMATED TOTAL
O&M Inspection and Report	EACH	1	$8,679.00	**$8,679.00**
General Structure Maintenance	LUMP	1	$30,000.00	**$30,000.00**
Engineering and Design	LUMP	0	$0.00	**$0.00**
Operations Contract	LUMP	1	$30,000.00	**$30,000.00**
Construction Oversight	LUMP	0	$0.00	**$0.00**

ADMINISTRATION

STATE Admin.	LUMP	1	$8,000.00	$8,000.00
FEDERAL SPONSER Admin.	LUMP	0	$0.00	$0.00
SURVEY Admin.	LUMP	0	$0.00	$0.00
OTHER				$0.00
			TOTAL ADMINISTRATION COSTS:	**$8,000.00**

MAINTENANCE / CONSTRUCTION

SURVEY

SURVEY DESCRIPTION:					
Secondary Monument	EACH	0	$0.00	$0.00
Staff Gauge / Recorders	EACH	0	$0.00	$0.00
Marsh Elevation / Topography	LUMP	0	$0.00	$0.00
TBM Installation	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL SURVEY COSTS:	**$0.00**

GEOTECHNICAL

GEOTECH DESCRIPTION:					
Borings	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL GEOTECHNICAL COSTS:	**$0.00**

CONSTRUCTION

CONSTRUCTION DESCRIPTION:					
Rip Rap	LIN FT	TON / FT	TONS	UNIT PRICE	
	0	0.0	0	$0.00	
	0	0.0	0	$0.00	$0.00
	0	0.0	0	$0.00	$0.00
Filter Cloth / Geogrid Fabric		SQ YD	0	$0.00	$0.00
Navagation Aid		EACH	0	$0.00	$0.00
Signage		EACH	0	$0.00	$0.00
General Excavation / Fill		LUMP	0	$0.00	$0.00
Dredging		CU YD	0	$0.00	$0.00
Sheet Piles (Lin Ft or Sq Yds)			0	$0.00	$0.00
Corrugated Alum. Pipe (30")		LF	0	$0.00	$0.00
Repair Rings on Aluminum Flap Gate		LUMP	0	$0.00	$0.00
Fabricate & Install 2 SS Flap Gates		LUMP	0	$0.00	$0.00
Materials		LUMP	0	$0.00	$0.00
Mob / Demob		LUMP	0	$0.00	$0.00
Contingency		LUMP	0	$0.00	$0.00
General Structure Maintenance		LUMP	0	$0.00	$0.00
BOARDED FOUNDATION PAD			0	$0.00	$0.00
OTHER			0	$0.00	$0.00
OTHER			0	$0.00	$0.00
					$0.00

TOTAL OPERATIONS AND MAINTENANCE BUDGET: **$76,679.00**

APPENDIX C
(Field Inspection Notes)

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name:CS-29 Black Bayou Culverts Hydrologic Restoration

Date of Inspection: October 9, 2019 & January 16, 2020 Time: 10:00am

Structure No. ___ N/A

Inspector(s): Jody White & Stan Aucoin, CPRA, Richard Evely, Carol Clement & Cody Lefleur, NRCS, Chris Simon , Simon and Delany & 4 support labor

Structure Description: Conc. Box Culverts with Flapgates, Sheet Pile Wall

Water Level Inside:_____ Outside: _____

Type of Inspection: Annual

Weather Conditions: cool and partly cloudy

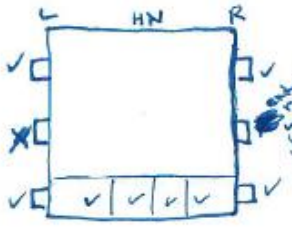
Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Steel Bulkhead	good			3	
Flap Gates	good			1, 5, & 6	free flapping since September 2018. Locking rings broken on six gates. Stop plate welds broken on three gates. See attached diagram.
Conc. Box Culverts	good				Operational
Hardware	good			5	Backing nuts loosening off of gate hinge.
Trash Guard	good			7 & 8	Debris against trash screens moves back into GIWW with fluctuation of hydraulics
Signage	good			4 & 8	

What are the conditions of the existing levees?
Are there any noticeable breaches?
Settlement of rock plugs and rock weirs?
Position of stoplogs at the time of the inspection?
Are there any signs of vandalism? yes, steel drill pipe was found in the headwall locking rings of Gate No. 4

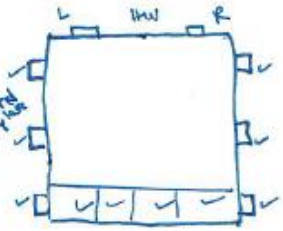
CS-29 Black Bayou Culverts 1-16-20 Gate Inspection

Note: Gates are numbered North to South
Black Bayou Pontoon Bridge closed at time of inspection Traffic Control wasn't necessary.

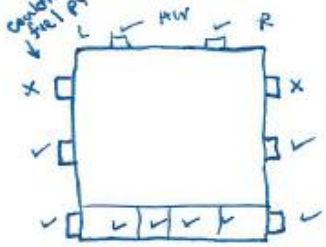
GATE 1



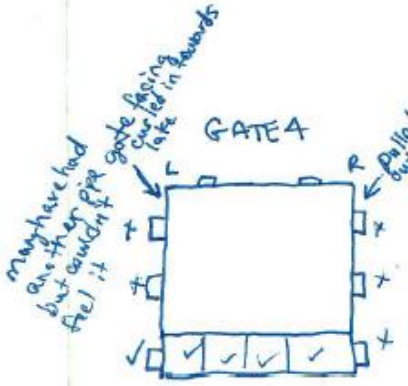
GATE 2



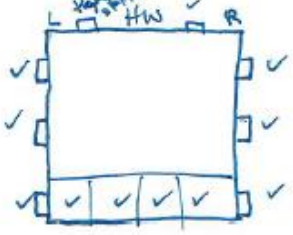
GATE 3



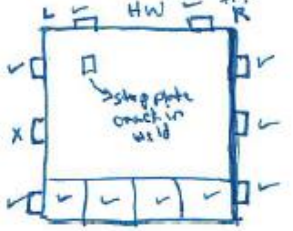
GATE 4



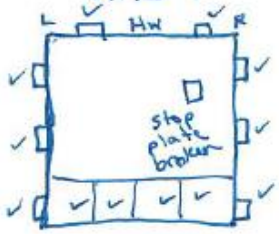
GATE 5



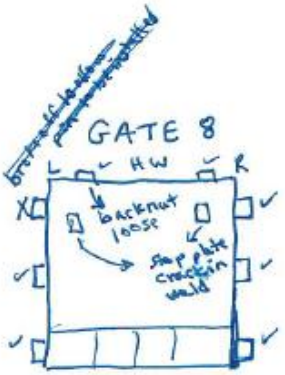
GATE 6



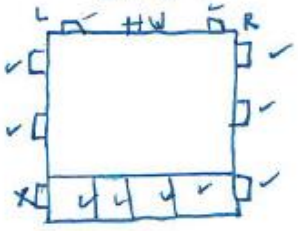
GATE 7



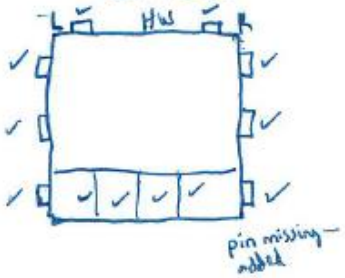
GATE 8



GATE 9



GATE 10



- Sedimenting gates
- we broke off remaining ring to be able to insert pins

Rings look ¼" thick - Sch 40
- Verify if ring is Schedule 80

Need pins - bigger than pins used for sandbags

Gate No. 1:

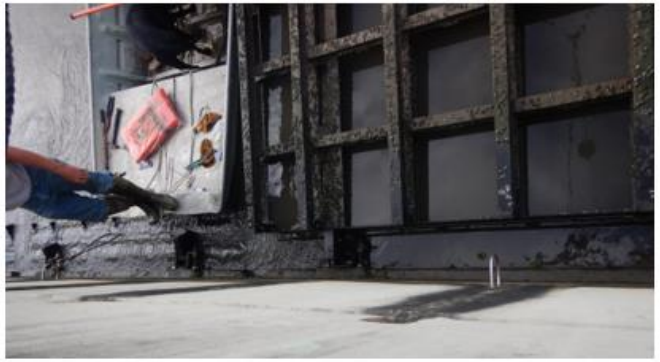
-Broken North Center Locking Ring
-Reshaped South Center Locking Ring

Gate No. 2:

No damage noted

Gate No. 3:

-Broken North and South Top Locking Ring



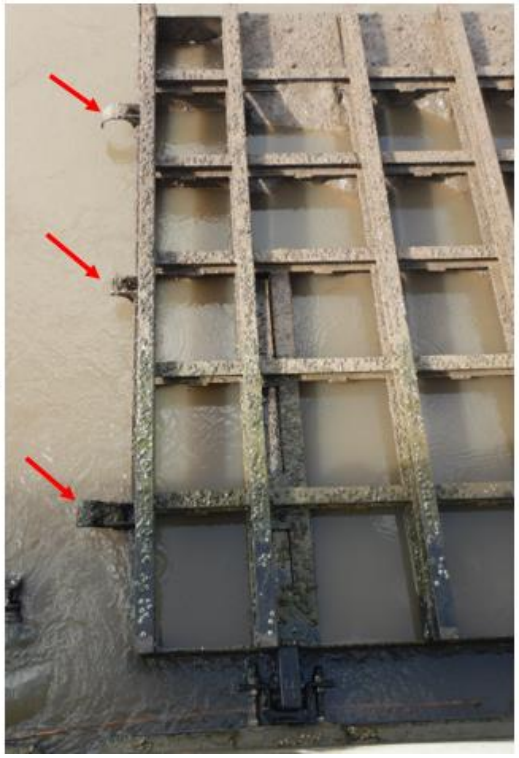
Gate No. 4:

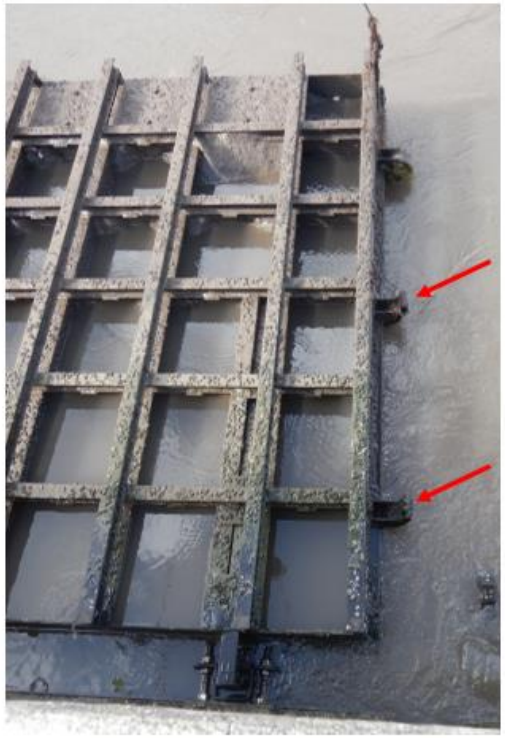
-Broken North and South Top Locking Ring

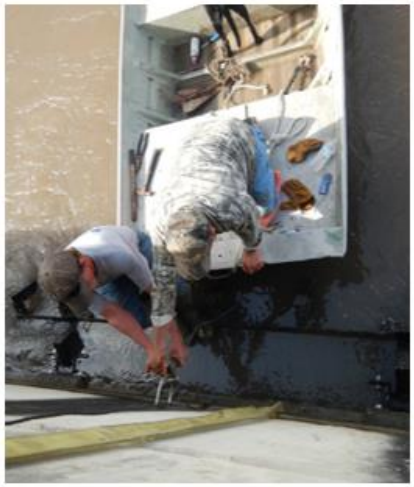
-Broken North and South Center Locking Ring

-Broken South Bottom Locking Ring

-Pulled steel drill pipe from the headwall locking rings on South side

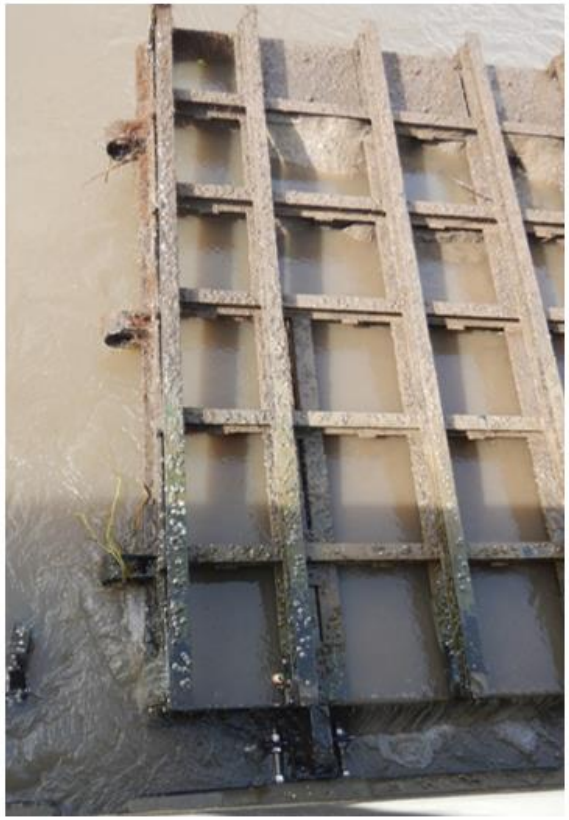






Gate No. 5:

-All rings are intact. Tightened backing nuts on the hinge bolts.



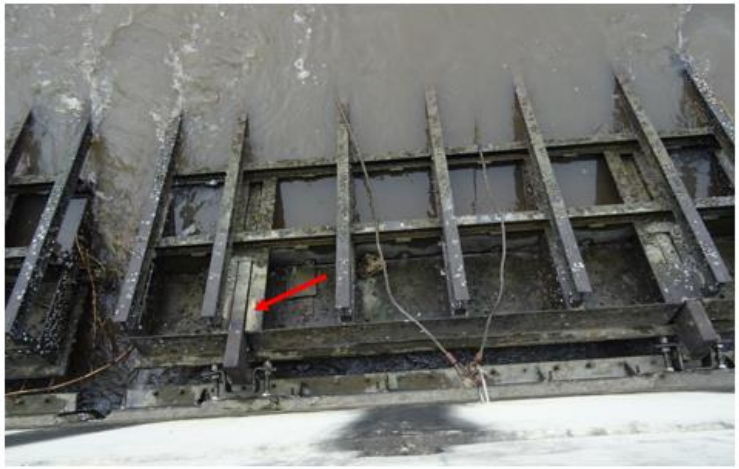
Gate No. 6:

-Broken North Center Locking Ring

-Tightened backing nut on hinge bolts

Gate No. 7:

-All locking rings intact. Stop plate broken off, still on gate.

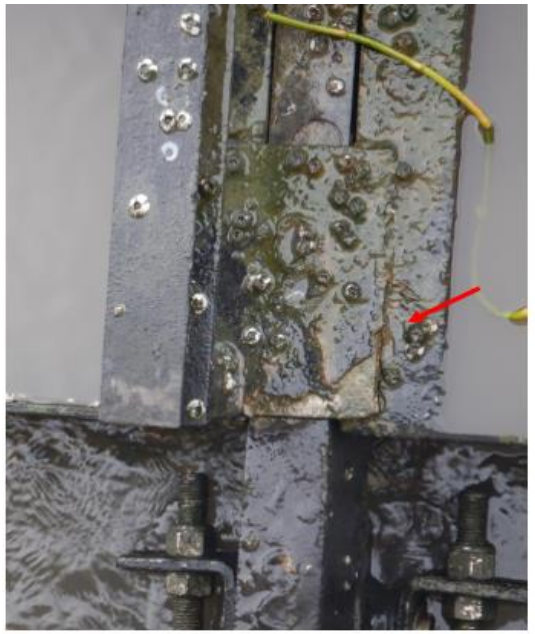


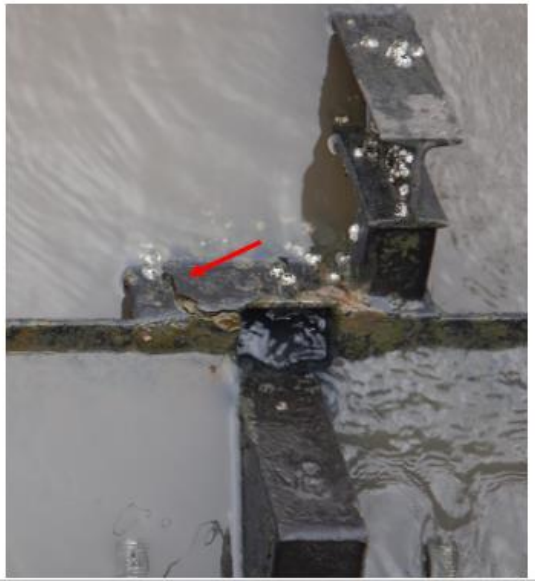
Gate No. 8:

-Broken North Top Locking ring

-Crack in North & South top Stop plate welds

-Tightened backing nut on hinge bolts





Gate No. 9:

-Broken North Bottom Locking ring

Gate No. 10:

-Replaced Missing pin on South Lifting Eye/Cable

-All locking rings are intact.