

BIG CYPRESS BAYOU ENVIRONMENTAL FLOWS PROJECT: EFFECT OF RAINFALL AND
HIGH FLOW PULSE RELEASE ON SOIL MOISTURE

LONG TERM MONITORING
IN RESPONSE TO
IMPLEMENTATION OF ENVIRONMENTAL FLOW RECOMMENDATIONS
IN THE CADDO LAKE WATERSHED

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Introduction

This work was done by the Caddo Lake Institute (CLI) to help evaluate the results of a five year experiment by the U.S. Corps of Engineers and the Northeast Texas Municipal Water District, to provide the recommended environmental flows for Big Cypress Bayou, which is the major tributary to Caddo Lake. To support more formal operation changes for Lake O' The Pines dam following this period, the CLI has implemented this priority aspect of the overall monitoring plan. The major tasks are: 1) establish regular fish monitoring, including coordination with U.S. Fish and Wildlife Service (USFWS) on paddlefish monitoring and gravel bar utilization, to track changes versus pre-implementation baseline, and 2) use pulse flow experiments to refine high flow pulse recommendations.

The CLI has completed the first task of establishing an implementation period fish monitoring baseline. The Texas Parks and Wildlife Department led a major effort to establish and sample two sites for fish, mussel and invertebrate communities in Big Cypress Bayou and monitored fish at several sites on Little Cypress Bayou and Black Cypress Bayou (adjacent similar tributaries that serve as monitoring analysis controls). The resulting fish data is currently being analyzed relative to pre-implementation data and pre-dam data to establish fish community responses. In addition, CLI and the U.S. Fish and Wildlife Service completed the first phase of a paddlefish reintroduction experiment. A report on that work is included separately.

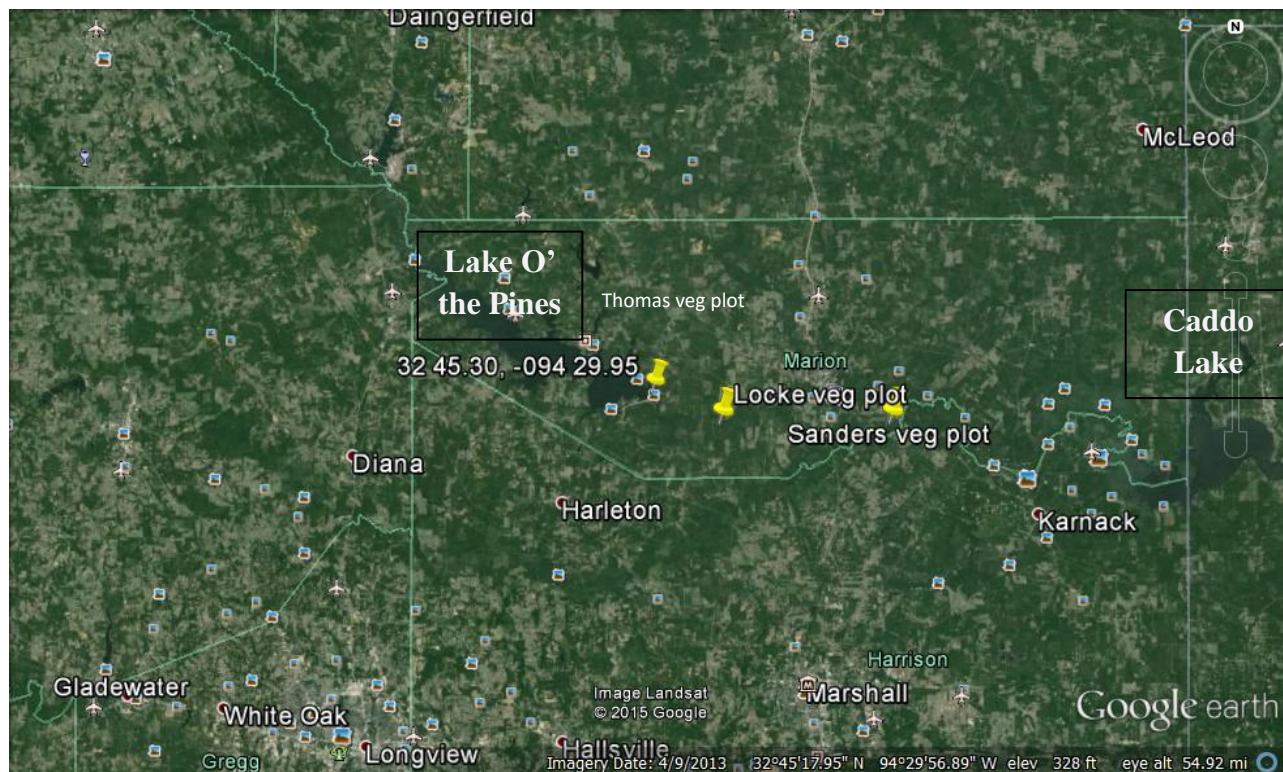
The second task of evaluating high flow pulses has been somewhat limited by hydrologic conditions. Flow pulse releases have been limited to one 3000 cfs pulse and two approximately 2000 cfs pulses. During this time period, floodplain soil moisture and ground water levels have been monitored using soil moisture sensors and water wells.

The specific goal of this part of the Big Cypress Bayou environmental flows project was to determine the current plant community structure in the floodplain along Big Cypress Bayou and to determine if high environmental flow releases would leave the Big Cypress Bayou channel and enter the adjacent floodplain. Soil moisture, either from rainfall or from overbank flooding, is a key factor controlling the type of plant community that lives in the floodplain. The purpose of this report is to examine the effect of rainfall on soil moisture and the effect that high pulse releases from the Lake O' the Pines have on soil moisture.

Study Sites and Plant Community Types

Three sites along Big Cypress Bayou between Jefferson and Lake O' the Pines were selected to conduct vegetation plot surveys: Thomas (upstream site, just below the Lake O' the Pines dam), Locke (middle site), and Sanders (lowermost site) (Figure 1).

Figure 1. Map of the Study Areas Located along Big Cypress Bayou between Lake O' the Pines and Jefferson, Texas



At each study site, four plant communities were identified and delineated:

- Lower swamp (LS) – dominated by bald cypress
- Upper swamp (US) – dominated by overcup oak
- Seasonally flooded forest (SFF) – dominated by willow oak
- Temporarily flooded forest (TFF) – dominated by water oak

During 2014 and 2015 three high pulse releases were made from the Lake O' the Pines dam. The first release occurred during January 2014, the second during April 2014, and the third during March – May 2015. This report will analyze the data from the first three high pulse releases.

Project Work Timeline

Date	Activity
5/16/12 – 5/17/12	Locate monitoring sites along Big Cypress Bayou
10/15/12 – 10/16/12	Survey monitoring sites for specific location of soil moisture and plant communities; Install monitoring well

2/3/13 – 2/7/13	Install soil moisture systems
2/16/13 - 2/28/13	Install soil moisture systems and monitoring wells
3/6/13 – 3/15/13	Install soil moisture systems and monitoring wells
4/28/13	Download soil moisture data and checked well levels
6/10/13	Download soil moisture data and checked well levels
7/25/13 – 7/30/13	Establish vegetation plots
12/17/13	Download soil moisture data and checked well levels
1/18/14 – 1/19/14	Pre-pulse release visit to all three sites and gravel bar at Sander’s site
1/23/14	Check gravel bar at Sander’s site
1/27/14	Check gravel bar at Sander’s site
3/11/14 – 3/12/14	Download soil moisture data and checked well levels
6/19/14	Download soil moisture data and checked well levels
9/20/14	Download soil moisture data and checked well levels
2/7/15	Download soil moisture data and checked well levels
2/20/15	Download soil moisture data and checked well levels
3/16/15	Download soil moisture data and checked well levels
6/17/15 – 6/18/15	Download soil moisture data and checked well levels
7/15/15 – 7/16/15	Check all three sites for level of flooding due to high pulse release
8/14/15	Download soil moisture data and checked well levels

Methods

Seven moisture sensors and a Watermark Model 900M monitor were installed at each study site. At the US, SFF, and TFF sites, moisture sensors were installed at both one foot and two feet below the soil surface. At the LS site, one moisture sensor was installed at one foot below the soil surface. The sensors determined soil moisture once per hour. Water monitoring wells were dug by hand in the water oak (TFF) and bald cypress (LS) plant community types at all three study sites. Water depths were checked manually.

Rainfall

Three USGS rain gages were used during the study:

- Black Cypress Bayou at US59 (USGS 07346045) – north of Jefferson
- Little Cypress Bayou at US59 (USGS 07346070) – south of Jefferson
- Lake O’ the Pines dam (USGS 07345900) – just west of Thomas study site

The average annual rainfall for Jefferson, Texas is about 49 inches (www.usclimatedata.com). As shown in Table 1, both 2013 and 2014 were much drier than normal. Rainfall totals at the Little Cypress Bayou site were higher than the other two sites. Rainfall for the first half of 2015 has been higher than normal.

Table 1. Rainfall (inches) at the three U.S. Geological Survey (USGS) precipitation monitoring stations near the study sites. Rainfall data for 2015 is through June 25, 2015.

Year	Black Cypress Bayou	Little Cypress Bayou	Lake O' the Pines
	USGS 07346045	USGS 07346070	USGS 07345900
2013	26.82	36.58	28.45
2014	26.77	34.19	28.66
2015	18.46	35.62	35.55
Mean for 2013- 2014	26.80	35.39	28.56

Rainfall occurred on about 27% of the days with the mean rainfall on days when it rained was about 0.5 inches. The maximum rainfall measured on one day was 4.44 inches.

Soil Moisture Correlation to Rainfall

Soil moisture at all three study sites was analyzed between January 1, 2013 and February 9, 2015 and was correlated to rainfall during the same time period. Analysis of the one foot and two foot soil moisture in the water oak, willow oak, and overcup oak plant communities showed that the soil moisture was not statistically different, therefore those data were combined for this analysis. There were weak but statistically significant correlations at the Sanders and Locke sites (Table 2). When correlations were run between the plant community types located at same study site, the correlations were much higher and statistically significant (data not shown). This indicates that the soil moisture of the four plant community types is responding in a similar way to rainfall.

Table 2. Correlations between Soil Moisture and Rainfall at the Four Different Plant Communities at all Three Study Sites Combined. Correlations shown in bold are statistically significant.

Plant Community Type	Sanders	Locke	Thomas
Lower swamp - Bald cypress	-0.127	-0.579	-0.126
Upper swamp - Overcup oak	-0.128	-0.506	-0.136
Seasonally flooded swamp - Willow oak	-0.152	-0.323	-0.144
Temporarily flooded swamp - Water oak	-0.153	-0.410	-0.139

Soil Moisture in the Four Plant Community Types

Soil moisture was monitored at the four plant community types from January 1, 2013 – February 9, 2015 (Table 3). According to the monitoring system manufacturer, a soil moisture reading of 0 – 10 centibars means that the soil is saturated. A soil moisture reading of 10 – 30 centibars means that the soil is moderately wet. A soil moisture reading of 30 – 100 centibars means that the soil is somewhat wet. A soil moisture reading of greater than 100 means the soil is becoming increasingly dry. As predicted, the highest soil moisture was found at the bald cypress plant community. The other three plant community types did not follow the expected soil moisture

predictions. The overcup oak plant community was drier than predicted, and the water oak plant community was wetter than predicted.

Table 3. Comparison of Soil Moisture (centibars) in the Four Plant Community Types at all Sites Combined, January 1, 2013 – February 9, 2015.

Plant Community Type	Mean	Standard Deviation	Minimum	Maximum
Lower swamp - Bald cypress	102.6	29.6	54.6	148.7
Upper swamp - Overcup oak	225.1	14.1	198.6	239.0
Seasonally flooded swamp - Willow oak	197.0	17.9	170.6	216.8
Temporarily flooded swamp - Water oak	174.2	26.4	143.8	221.9

Water Well Data

As expected the BC water wells had significantly more water than the WA wells (Table 4). Also, the amount of water in the BC wells was affected by season with the winter having the largest amount of water and the summer having the least amount of water. The water levels in the wells at the Sanders site were checked just prior and during the pulse release during January 2014. The data indicate that some water did reach the BC well during the release, however water did not reach the WA well. The USGS has now installed continuous monitoring systems in many of the wells. These data are not currently available.

Table 4. Water Depths in Monitoring Wells at the Three Study Sites, 2013-2015.

Date	Sanders		Locke		Thomas	
	WA	BC	WA	BC	WA	BC
	cm	cm	cm	cm	cm	cm
3/08/2013			0	67		
3/09/2013	0	75			0	61
3/15/2013	0	71	0	62	0	94
4/28/2013	0	88	0	93	0	132
6/10/2013	0	36	0	52	0	28
9/06/2013	0	0				
9/07/2013			0	0	0	0
12/17/2013	0	51	0	71	0	80
1/19/2014*	0	91	0	105	0	175
1/23/2014*	0	95				
3/11/2014	0	133				
3/12/2014			35	149	17	(underwater)
6/19/2014	0	NA	7	(underwater)	0	69.75

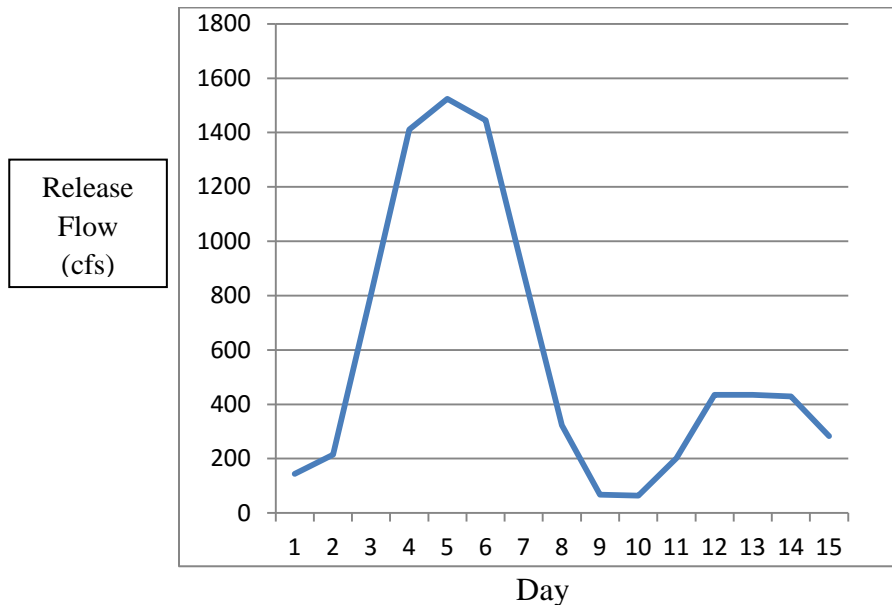
9/20/2014	0	NA	0	11	0	0
2/7/2015	0	NA	0	NA	0	NA
Mean	0.0	71.1	3.8	67.8	1.5	71.1

*= January 19, 2014 was day one of the high pulse release from Lake O' the Pines. January 23, 2014 was the day of the highest flow during the release period.

Effect of High Pulse Release #1 on Soil Moisture – January 2014

Beginning on January 19, 2014, the U.S. Corps of Engineers began to increase the rate of water released from the Lake O' the Pines dam (Figure 2). The release included a three day ramp up, held steady for about two days, and a ramp down that lasted three days. During the study period, the maximum flow in Big Cypress Bayou was 1,560 cfs on January 23, 2014 (day 6).

Figure 2. Release (cfs) of water from the Lake O' the Pines into Big Cypress Bayou, January 18, 2014 – February 1, 2014.



It is important to note that there was no rainfall during the study period except for a small amount of rain during the last day of the release period (Table 5).

Table 5. Rainfall (inches) at the three precipitation monitoring stations near the study sites, January 19, 2014 – February 1, 2014.

Date	Black Cypress US59 USGS 07346045	Little Cypress US59 USGS 07346070	Big Cypress Below LOP USGS 07345900
1/19/2014	0	0	0
1/20/2014	0	0	0
1/21/2014	0	0	0

1/22/2014	0	0	0
1/23/2014	0	0	0
1/24/2014	0	0	0
1/25/2014	0	0	0
1/26/2014	0	0	0
1/27/2014	0	0	0
1/28/2014	0	0	0
1/29/2014	0	0	0
1/30/2014	0	0	0
1/31/2014	0	0	0
2/1/2014	0.11	0.09	0.02

Data analysis showed that there were small but statistically significant differences between the soil moisture at the one foot and two feet depths. However, the soil moisture differences were not ecologically significant, therefore the soil moisture data for the two depths were combined into one mean.

At the Thomas site, the soil moisture levels were very wet at the beginning of the release. All four vegetation types became drier during and following the release, so it seems that the release did not affect this site (Table 6).

Table 6. Soil moisture at the Thomas site in the four vegetation site-types during pre-release, release, and post-release days. The soil moisture scale is from 0 (soil is completely saturated) to a minimum of 256 (complete dryness).

Site-type	Relative Elevation	Pre-release (Day 1)	Release (Day 2-8)	Post-release (Day 9-15)	Moisture Change
Water Oak	Highest	16.0	17.3	17.7	-1.7
Willow Oak	Mid-High	3.0	6.9	9.5	-6.5
Overcup Oak	Mid-Low	3.0	6.9	9.5	-6.5
Bald Cypress	Lowest	0.0	0.0	0.9	-0.9

At the Locke site, all four vegetation types became wetter during and following the release (Table 7). The bald cypress area had the largest change in soil moisture.

Table 7. Soil moisture at the Locke site in the four vegetation site-types during pre-release, release, and post-release days. The soil moisture scale is from 0 (soil is completely saturated) to a minimum of 256 (complete dryness).

Site-type	Relative Elevation	Pre-release (Day 1)	Release (Day 2-8)	Post-release (Day 9-15)	Moisture Change
Water Oak	Highest	16.5	14.8	14.2	2.3
Willow Oak	Mid-High	16.5	15.1	14.2	2.3

Overcup Oak	Mid-Low	13.0	8.7	7.4	5.6
Bald Cypress	Lowest	40	2.8	2.8	37.2

At the Sanders site, three of the vegetation site-types became wetter, while the bald cypress site stayed fully saturated (Table 8).

Table 8. Soil moisture at the Sanders site in the four vegetation site-types during pre-release, release, and post-release days. The soil moisture scale is from 0 (soil is completely saturated) to a minimum of 256 (complete dryness).

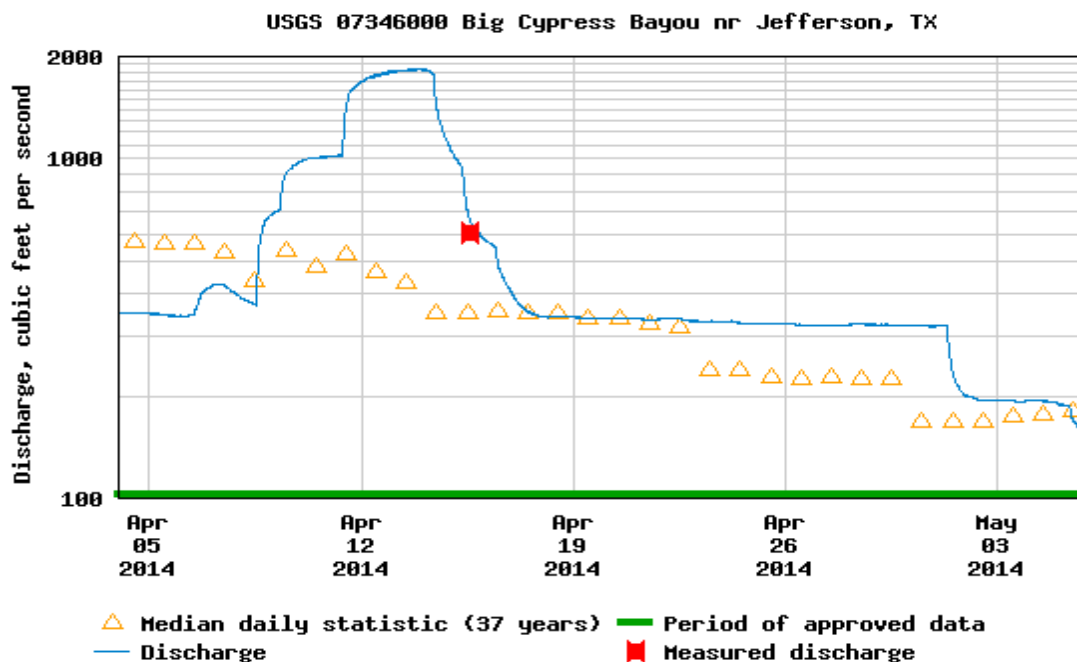
Site-type	Relative Elevation	Pre-release (Day 1)	Release (Day 2-8)	Post-release (Day 9-15)	Moisture Change
Water Oak	Highest	16.5	15.1	12.5	4.0
Willow Oak	Mid-High	12.5	11.6	9.4	3.1
Overcup Oak	Mid-Low	9.5	10.5	4.1	5.4
Bald Cypress	Lowest	0	0.07	0	0

As a summary, as expected the bald cypress site-type had the highest soil moisture and the water oak site had the lowest soil moisture. The willow oak site and the overcup oak site had relatively equal amounts of soil moisture. The release of water from Lake O' the Pines increased soil moisture at the Locke and Sanders sites, but not at the Thomas site. At this time there is no explanation for this difference.

Effect of High Pulse Release #2 on Soil Moisture – April 2014

A second high pulse release began on April 8, 2014 and ended on April 18, 2014 (Figure 3). The maximum flow during the time period was 1,800 cfs which was held for about two days.

Figure 3. Release (cfs) of water from the Lake O' the Pines into Big Cypress Bayou, April 2014



Rainfall occurred at the study sites on several days prior to the beginning of the high pulse release and occurred on the day that release flow peaked (Table 9).

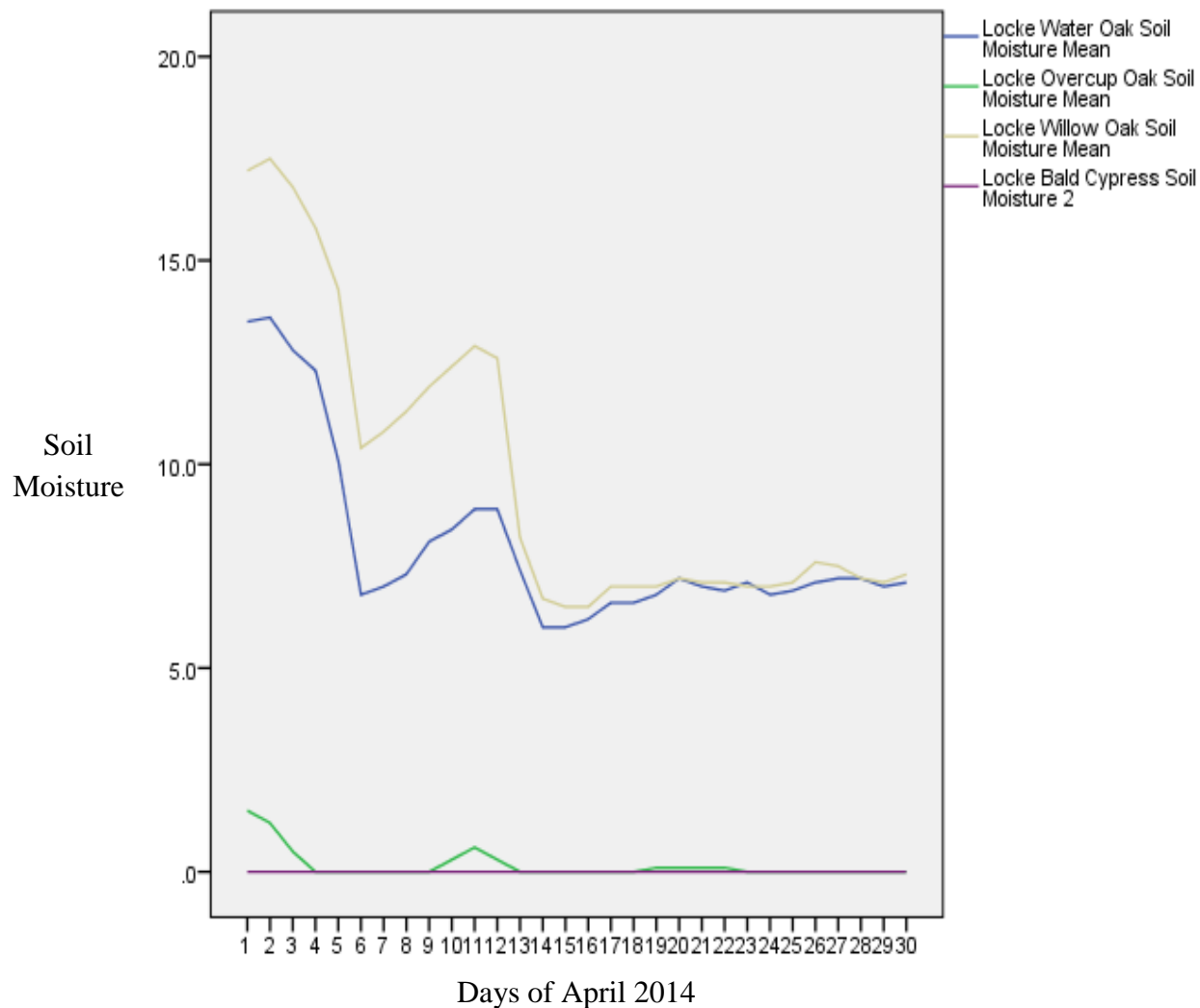
Table 9. Rainfall (inches) at the three USGS precipitation monitoring stations near the study sites, April 2014.

Date	Black Cypress US59 USGS 07346045	Little Cypress US59 USGS 07346070	Big Cypress LOP USGS 07345900	Mean
4/1/2014	0	0	0	0.000
4/2/2014	0	0	0	0.000
4/3/2014	0.33	0.42	0.5	0.417
4/4/2014	0	0	0	0.000
4/5/2014	0.05	0.02	0.05	0.040
4/6/2014	1.49	1.83	1.84	1.720
4/7/2014	0.01	0.01	0	0.007
4/8/2014	0.02	0.04	0.14	0.067
4/9/2014	0	0	0	0.000
4/10/2014	0	0	0	0.000
4/11/2014	0	0	0	0.000
4/12/2014	0	0	0	0.000
4/13/2014	0	0	0	0.000
4/14/2014	0.37	0.36	0.57	0.433
4/15/2014	0	0	0	0.000
4/16/2014	0	0	0	0.000

4/17/2014	0	0	0	0.000
4/18/2014	0	0	0	0.000
4/19/2014	0	0	0	0.000
4/20/2014	0	0	0	0.000
4/21/2014	0.02	0.33	0.57	0.307
4/22/2014	0.05	0	0	0.017
4/23/2014	0	0	0	0.000
4/24/2014	0	0	0	0.000
4/25/2014	0	0	0	0.000
4/26/2014	0	0	0	0.000
4/27/2014	0	0	0	0.000
4/28/2014	0.23	0.06	0.27	0.187
4/29/2014	0	0	0	0.000
4/30/2014	0	0	0	0.000
Total	2.57	3.07	3.94	3.19

Soil moisture data for the Locke site and the Sanders site were analyzed; there was no data for the Thomas site. In general, the Locke site was wetter than the Sanders site. The plant communities were wettest to driest in the following order: bald cypress, overcup oak, water oak, willow oak (Figure 4).

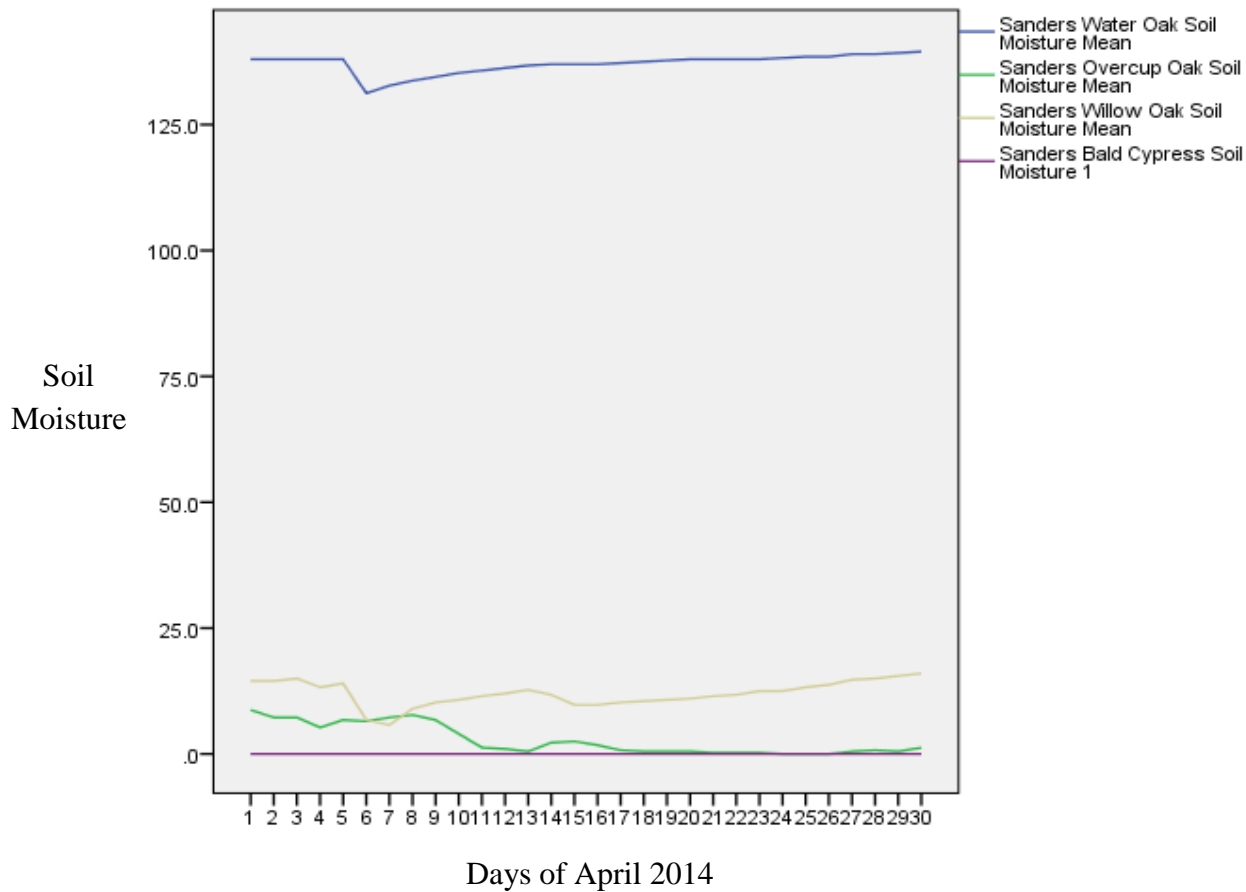
Figure 4. Soil moisture at the four plant communities types at the Locke site during the April 2014 high pulse flow release.



The bald cypress soil was completely saturated, so the pulse release had no effect on its moisture content. With the other three sites, the soil moisture increased beginning on April 11 and became maximum on April 14 which was the day of peak flow. Following April 14, these three soils became slowly drier.

At the Sanders site, the plant communities were wettest to driest in the following order: bald cypress, overcup oak, willow oak, water oak (Figure 5). The release did not have an effect on the bald cypress soil because it was completely saturated. Also, it did not have an effect on the water oak soil which slowly dried during the release period. The willow oak soil and the overcup oak soil did become slightly wetter during the release period, but the change was not significant. The water oak, willow oak, and overcup oak soils slowly dried following the release.

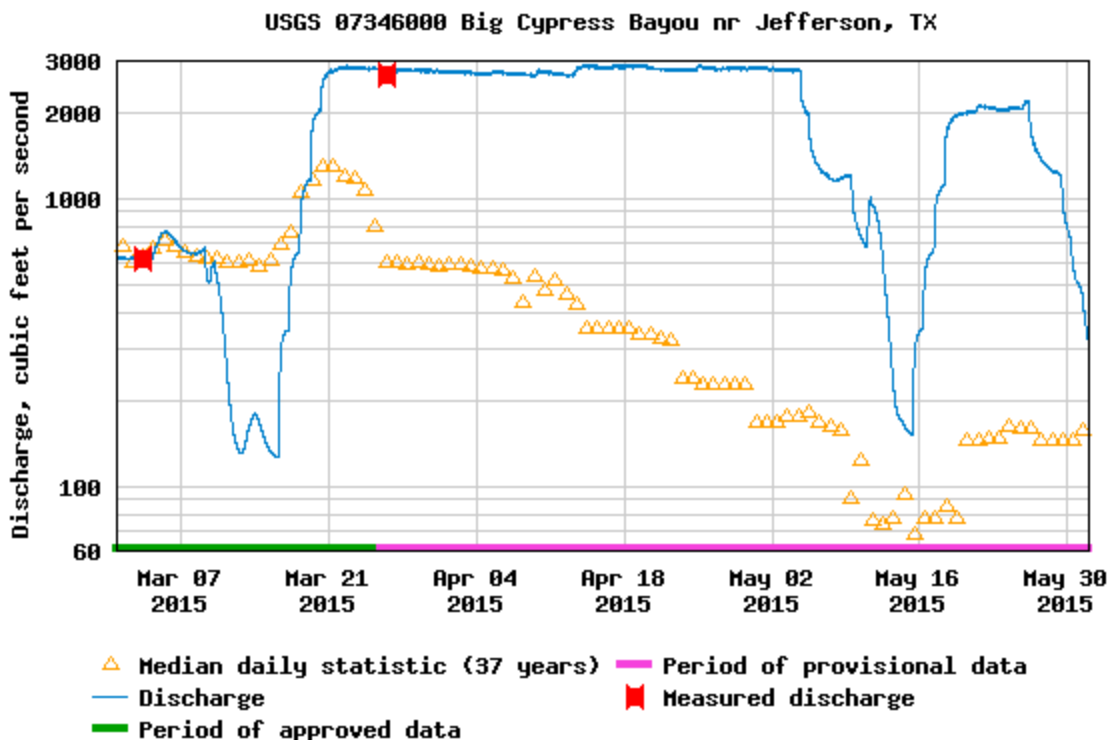
Figure 5. Soil moisture at the four plant communities types at the Sanders site during the April 2014 high pulse flow release.



Effect of High Pulse Release #3 on Soil Moisture – March - May 2015

Due to abnormally high rainfall during the late spring in the area, a high release of about 3,000 cfs occurred beginning on March 21 and continued until May 4, a total of 44 days (Figure 6).

Figure 6. Release (cfs) of water from the Lake O’ the Pines into Big Cypress Bayou, March – May 2015



On March 16, 2015 all three sites were inundated by recent rainfall at higher than normal levels. At some point when the releases exceeded 2,000 cfs, river water left the channel and entered the floodplains. All three sites were completely inundated and stayed that way through June 18, 2015. The water levels in the bald cypress sloughs were a minimum of two feet deep and were as much as seven feet deep. The data recording boxes at the Sanders and Locke sites were accessible by wading through water, however the recording box at the Thomas site was not accessible due to chest-high water in the slough. On July 16, 2015 the sites were visited and the water levels were still very high. On August 14, 2015, the sites were visited and the water levels had receded significantly. The months of June and July were very dry, so it can also be assumed that the continued flooding was due to river water and not rainwater. Thus, for a period of about three months following the end of the high pulse release, significant levels were found in the bald cypress sloughs. When the recording boxes were downloaded in August, it was found that much of the soil moisture data was corrupted, and thus cannot be used in the analysis. During the flooding period, it can be assumed that all soil moisture sensors read zero.

Summary and Conclusions

The weather conditions during the past couple of years have limited the ability to follow the environmental flow recommendations, but the results obtained so far allow for some conclusions to be drawn. During the next several years, soil moisture data and water well data will continue to be collected and analyzed.

1. The data show that a pulse release of 2,000 cfs does not result in water leaving the river channel and inundating the Big Cypress Bayou floodplain below Lake O' the Pines. However, this release level causes a small, but measureable increase in soil moisture in the floodplain.

2. The data show that a pulse release of 3,000 cfs results in river water leaving the channel and completely inundating the Big Cypress Bayou floodplain below Lake O' the Pines. The soil moisture in all four plant community types are fully saturated.
3. The data suggest that the soils dry out more slowly in the winter and spring months and more quickly in the summer months.
4. Additional soil moisture data and water well data will be collected during the fall 2015 months so that the drying of the soils in all four plant communities types can be measured.