EXPERT REPORT

of

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ON BEHALF OF ATCHAFALAYA BASINKEEPER ET AL

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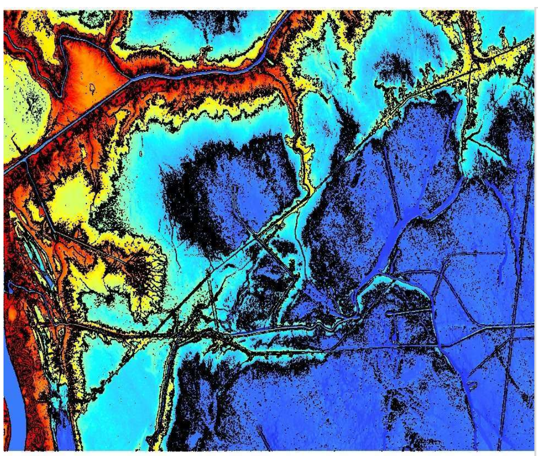
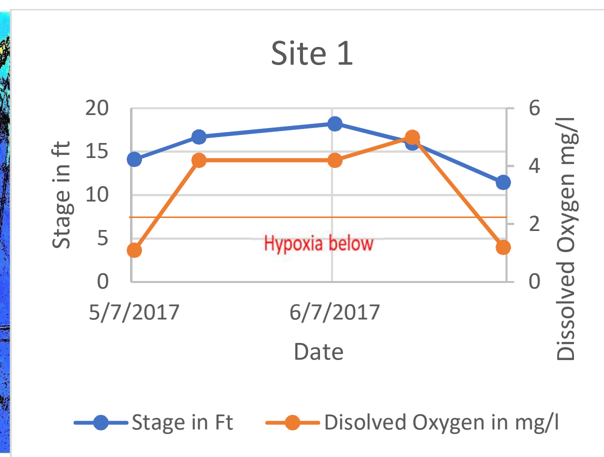
REVIEW OF THE COMMENTS OF OTHERS AS RELATES TO THE EGL PROJECT PROPOSED

BY THE LOUISIANA DEPARTENT OF NATURAL RESOURCES





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INTRODUCTION

This review is aimed at expanding some of the science as the comments of SIGMA and others are addressed. While it may at time have a negative tone, it is not meant to be disrespectful. What to me is most important is that a proposal is presented in an Appendix for a project that will have great value for the Basin, reintroduce natural flow pathways that will supply low suspended sediment and nutrient loads, and will be a win-win as it will reduce flooding in the adjacent built environment.

THE ATCHAFALAYA BASIN IS NOT A 'NATURAL" FEATURE IN TERMS OF THE DYNAMICS THAT DOMINATE THE SYSTEM

The Atchafalaya Basin, South Central Louisiana, is truly one of the ecological wonders of the Earth. Humans are trying to manage the Basin as a Mississippi River major flood "overflow" or pressure release valve (cutting its original area in half by flood control levees) and as a natural swamp. Unfortunately, and therefore, the Basin is undergoing dramatic physical changes due to sediment input and infilling with attendant environmental and ecological stress. Cypress swamp is being converted to bottomland hardwoods. Once this process is started the latter much faster growing bottomland trees including invasive species eventually shade out the cypress trees, and the original very productive and unique swamp is lost. Given this serious stress on the natural system because of the Corps management plan (van Heerden 2019a) it is incumbent on them to ensure that all projects they permit do not stress the system beyond that associated with the Corps present flood control management plan. Oil and gas pipelines significantly add to this stress as does any project that enhances suspended sediment deposition in the Basin.

Thus, since about 1930 the system has undergone significant human-induced physical changes that have severely impacted the natural dynamics such that this swamp basin now does not function as the natural river basin that existed prior to 1930.

1. ABOUT HALF ITS ORIGINAL AREA

The Atchafalaya Basin, preconstruction of the Atchafalaya flood control levees (the so-called M R & T guide levees), was almost twice its present size. As depicted in Figure 1, the guide levees crossed open water and swamp. Basically, it would appear that two lines were drawn on a map, each being a guide levee, without any consideration of the environmental and ecological impacts. Thus, construction of the control structure at Old River and the flood control 'role' given the Basin has meant that the sediment load of the Atchafalaya River has now only half the area it used to have to be ‘spread out,’ thus significantly enhancing the average annual sediment deposition rate in the Basin. Half the area with the same load as before means twice the potential sedimentation rate across the Basin. Additionally, the guide levees cut off the Basin Floodway from beneficial low sediment freshwater inputs, from surrounding areas, resulting from precipitation events, by closing channels, slews and such, with the solid levee system. Thus, disruption of the natural hydrology dramatically reduced the benefits of these low sediment and nutrient inputs, while undoubtedly contributing to the prevention of hypoxia events.

The Corps very effectively altered the physics, setting up a change in the physical environment with its attendant biological responses. It is also resulting in enhanced sediment infilling of the Flood Way Basin, reducing its capacity, decreasing the efficiency and potential for the floodway to hold flood waters – a real public safety issue.

2. CLIMATE CHANGE AND ACCELERATED SEA LEVEL RISE

Climate change is real and manifests itself in both more robust precipitation events, followed by dry spells (USGCRP, 2018 amongst many others).The recent major events in the Mississippi Basin, as well as tropical episodes in addition to stalled storm systems (the 2016 Baton Rouge flood), will become far more common and are strong evidence of global warming and its climate change consequences. Readers wanting to know more can just goggle “Climate Change.”

3. MANIPULATION OF THE NATURAL HYDROLOGY

Van Heerden 2018 and 2019 discussed the above issues resulting from the COE management of discharges through the system; and the impacts of pipelines and other channel/canal excavations. As van Heerden(2019) pointed out the LiDAR “says it all.”

4. NUTRIENT LOADING AND THE CHANGING NUTRIENT LANDSCAPE

Van Heerden (2019) discussed this issue in detail but it is worth repeating the salient points.

The Mississippi River forms the largest watershed on the North American continent. It discharges on average 580 km^3 of fresh water per year to the northern Gulf of Mexico through two main distributaries: the birdfoot delta southeast of the city of New Orleans, Louisiana, and the Atchafalaya River delta 200 km to the west that carries about one-third of the flow (Meade 1996). The Mississippi River system discharges sediment yields of $210 * 10^6$ Mg/yr., $1.6 * 10^6$ Mg/yr. nitrogen, of which $0.95 * 10^6$ Mg is nitrate and $0.58 * 10^6$ Mg is organic nitrogen, $0.1 * 10^6$ Mg/yr. phosphorus, and $2.1 * 10^6$ Mg/yr. silica (Milliman and Meade 1983, Meade 1996, Goolsby et al. 1999). The Louisiana coastal ecosystem is productive (~300 g Cm^2yr^1; Turner and Allen 1982, Lohrenz et al. 1990) and the location of the second largest zone of coastal hypoxia (defined here as dissolved oxygen <2 mg/L) in the world’s oceans (Rabalais et al. 2002).

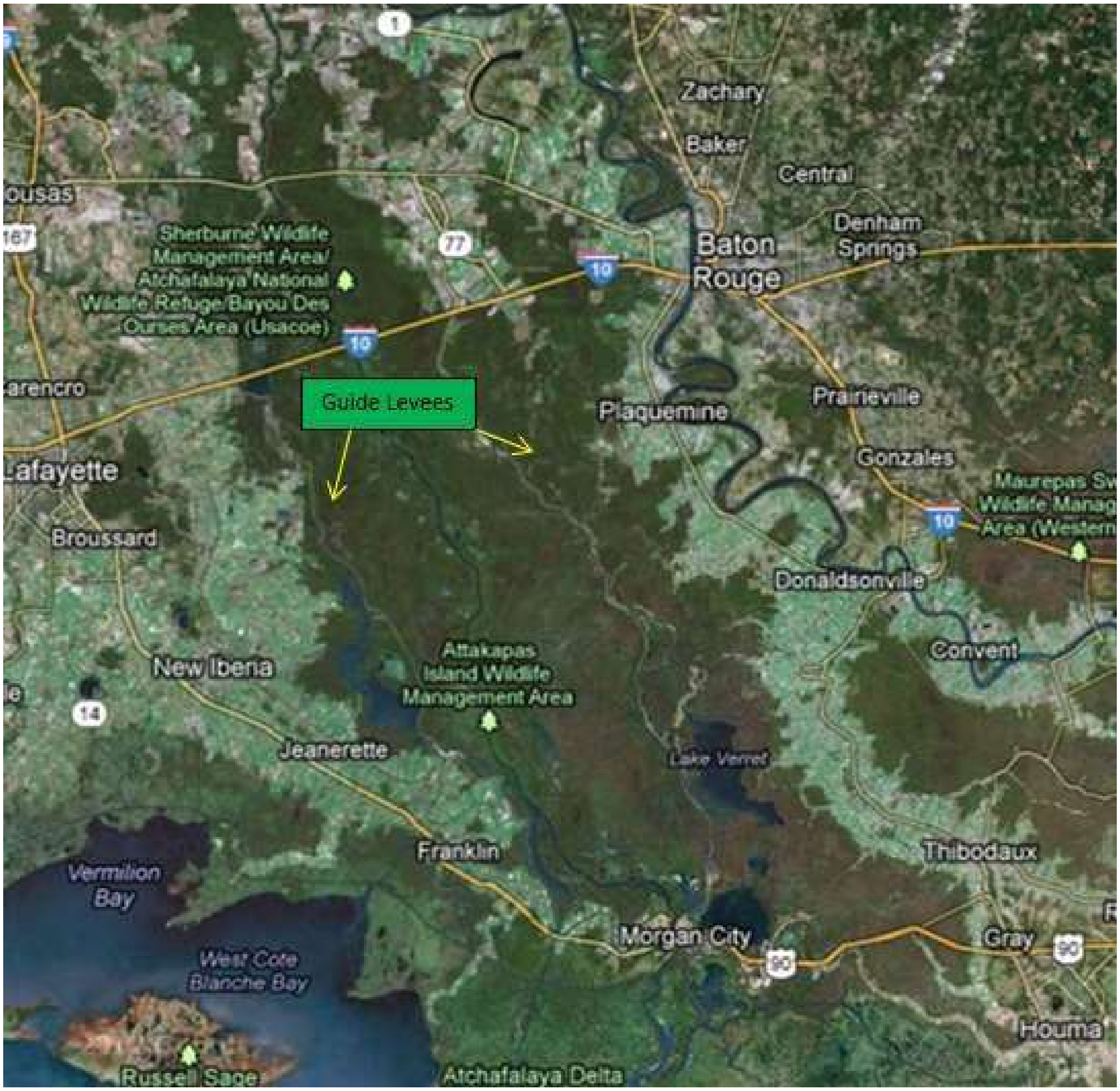

Figure 1. Atchafalaya Basin, south central Louisiana. Note the large area of swampland outside the M R & T guide levees.

Figure 2 aptly reveals the uncoupled relationship, before 1975, between the mean annual concentration of nitrate and silicate in the Mississippi River at New Orleans and the coherent changes after 1980 (Rabalais 2007). In other words, mean annual concentration of nitrate and silicate in the Mississippi River at New Orleans were not linked in the pre-heavy use of industrial fertilizer in the Mississippi River's catchment. Once commercial fertilizer use became widespread the concentrations of these variables became linked, the suspended sediment of the Mississippi River (represented by the silica concentration), and nutrient loading became coupled. Thus, measurements of turbidity then become a good measure of the ever-changing suspended sediment and coupled nutrient loads. Present day nutrient loads are twice what they were prior to about 1973 (Figure 2), See also van Heerden 2019a.

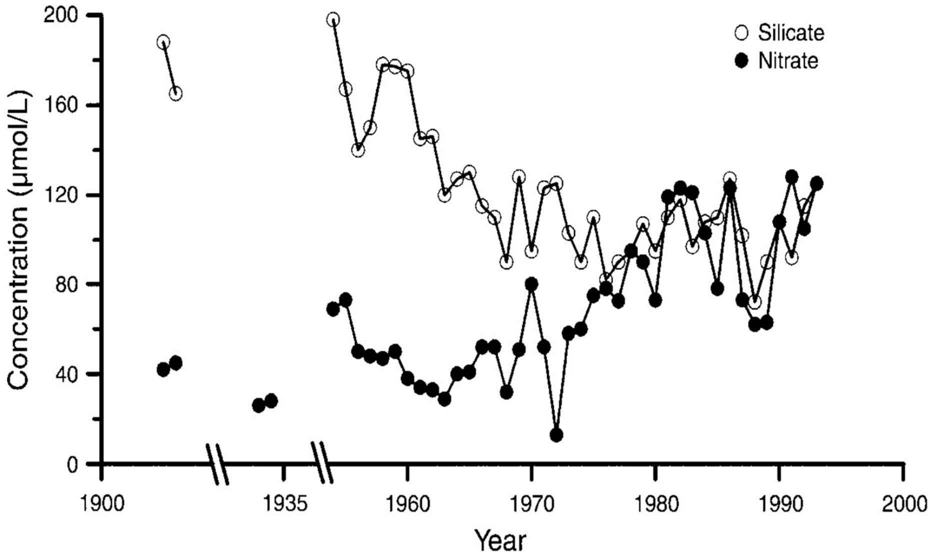

Figure. 2. The mean annual concentration of nitrate and silicate in the Mississippi River at New Orleans. Note the uncoupled relationship between the two variables before 1975 and the coherent changes after 1980 (Rabalais. 2007).

In 2017 L. Kong's thesis titled "*Population characteristics of red swamp crayfish Procambarus clarkii from hydrologically impaired locations in the Atchafalaya River Basin*" was published by Nichols State University. This thesis presented data vital to assessing the impacts of Atchafalaya floodwaters entering backswamp environments. Ms. Kong's thesis has, I am told, being used to justify this EGL project; but unfortunately, she totally misses the science that her data reveals (van Heerden 2019a). She makes unsupported assumptions and her conclusions are therefore skewed. Kong's (2017) data shows conclusively that flood waters entering a swamp lead to eutrophication and resulting hypoxia because of the nutrient loading – as clear as day (van Heerden 2019a). Although missing some of the specific data that Kong (2017) collected (i.e., GPS Coordinates; individual sites did not list all data collected on each date, rather seasonal or location means were presented) the data still allow an assessment of the 2016 and 2017 flood peaks and the resultant water quality.

The 2016 Missisppi catchment flood originated on the Missouri (largest tributary) and Missisppi Rivers and as such the Atcahafalaya River would have had significant suspended sediment loads, as compared if the major flood had been from the Ohio River. Thus, floodwaters that would have overflowed river levees and utilized man-made channels and pipeline conduits and would have carried suspended sediment into Kong's study sites. By contrast the 2017 flood peak sampled by Kong was due to a 1:1000-year induced rainfall event in the mid portion of the Missisppi River, not a catchment flood. As such the sampled 2017 flood peak had a very low suspended sediment load and hence turbidity and hence nutrients (van Heerden 2019a). We will again reference this difference further on in this report.

The sample sites chosen for van Heerden's (2019a) evaluation were done to compare her data with that being collected by TNC (2017, 2018). At all her sites she assumes that when low oxygen or anoxic conditions are present, it meant that hydrologic connections to the flooding River and Bayou Sorrel were disconnected; in other words, there was no 'fresh' flow entering her sites. This is a major flaw in this study. At all times that these sites had at least 3.0 feet of flow over ground van Heerden 2019a). The low oxygen concentrations in 2016 towards the end of the flood as presented by Kong (2017) are not a hydrologic connection issue. During the rain induced 2017 flood peak that was sampled by Kong, oxygen concentrations peaked as the flood peaked, totally opposite of the catchment flood of 2016! Additionally, low DO is not a lack of hydrologic connection as Kong surmised.

In comparing Kong's 2016 flood data with her 2017 data it is readily apparent that the impacts of suspended sediment and nutrient loading associated with the Atchafalaya floodwaters explains the lowering of oxygen levels in 2016. Fortunately, she does supply some turbidity data that support the conclusion that dropping dissolved oxygen concentrations and resultant hypoxia are a consequence of nutrient load associated with suspended sediment inputs in 2016 – very different to the less turbid 2017 flood.
AS CONCERNS THE MANAGEMENT OF THE BASIN, THIS 1:1000 YEAR RAIN INDUCED 2017 FLOOD DATA AS WELL AS THE 2016 CATCHMENT FLOOD DATA AS PRESENTED IN KONG'S 2017 THESIS DOES NOT SUPPORT OPENING OR CUTTING CUTS IN CHANNEL BANKS AND TRYING TO FLUSH SWAMPS WITH SUSPENDED SEDIMENT LADEN FLOOD WATERS TO IMPROVE WATER QUALITY AND REDUCE HYPOXIC EVENTS. RATHER THESE ACTIONS LEAD TO HYPOXIA

5. SPECIFIC COMMENTS ON REVIEW DOCUMENTS

a. SIGMA 06/24/2019

SIGMA states, "Main focus of project was to 1) introduce water from Bayou Sorel and Gulf Intracoastal Waterway at the northern and eastern portion of the EGL Upper Region into the swamps and 2) remove impediments to flow to interior swamp habitat further south." So seemingly no questions were asked about sediment loads or nutrient loading. In other words, let's just get suspended sediment laden water into the swamps! They clearly state that the impact to wetlands are mainly confined to areas been disturbed by dredging activities by removing spoil piles. In other words, allowing suspended sediment laden waters to enter the system through a series of man-made cuts in the bank, with no consideration of the suspended sediment carried by these waters year-round. They do admit that 16 acres of wetlands will be impacted by spoil but most importantly over 5000 acres of wetlands will additionally be affected. Is this a 'natural' response or solution?

They quote Piazza (2014) as their supportive document. Piazza however is very clear in his document about sediment accretion issues. He states "The science is clear that central to these solutions is a new water management model that restores natural flooding and drying cycles within the ARB floodway – both by addressing large scale inputs at the Old river Control structure and local barriers to flow. ….need to find new ways to manage flooding and sediment accretion to maximize the ecological value of the accretionary processes, which are now unique to the eroding Mississippi River delta plain". To me and others who have reviewed his document he is acknowledging what the Louisiana Department of Natural Resources (LaDNR) have stated over the years; namely, "Ongoing rapid and detrimental sedimentation in the Atchafalaya Basin fills swamps and waterways, impairs water quality, and degrades habitats. Conversely, areas of the Louisiana Coast outside the Atchafalaya Basin protection levees area experiencing erosion and subsidence and need sediment sources for restoration projects." This is the sad truth, by infilling the Basin we are compounding a major public safety issue, by our incorrect and short-sighted management of the Atchafalaya Basin including this EGL project.

b. SIGMA 08/28/2019

SIGMA states "Dr. van Heerden uses the term sediment as an all-encompassing term and does not define the term into its component fractions. It is not until the second part of the report, in the section on geological principles, that he differentiates sediment into its component fractions – sands, silts, and clays. Using this all-encompassing "sediment" term without definition in the project evaluation leads to the incorrect assumption that all the component sediment fractions behave the same both in the water column, and when they enter a floodplain wetland. Sands are typically found in, and transported through, the lower portions of the water column, while silts and clays are typically transported throughout the water column - a point that the author makes himself in section two of the report. Likewise, the depositional pattern, fate, and ecological role in terms of building and sustaining wetlands are far different for sands than silt and clay fractions. This distinction is critical to make, because the project elements that will receive waters are designed so that they do not interact with the water column depths that contain the highest sand fractions."

Definitions of Sediment (Oxford Dictionary):

Sediment is any particulate matter that can be transported by fluid flow and which eventually is deposited as a layer of solid particles on the bed or bottom of a body of water or other liquid. **Sedimentation** is the deposition by settling of a suspended material.

In Geology: Sediment particulate matter that is carried by water or wind and deposited on the surface of the land or the bottom of a body of water, and may in time become consolidated into rock.

Van Heerden was very specific in his 2019 report SIGMA quoted, from page 1 referencing that we are dealing with suspended sediment that in the Atchafalaya consists of clays, silts and fine sands. Many scientific studies have shown that here is no bedload in the Atchafalaya, what little may be in the Mississippi River upstream of the Old River sill, does not make it past the sill. This has been once again concluded by the Corps themselves (Nguyen etal 2011). Below I will dispel the notion that the sand is concentrated in the bottom of the flow. As DuMars (2002) showed the Atchafalaya is a well-mixed system with no apparent correlation to suspended sediment concentration, sample locations, depth or channel stream velocity.

The author references a number of papers including Piazza (2014) but none that are referenced discuss the sediment regime or suspended sediment dynamics or such. In fact, it appears that in total sediments and their deposition are not or never were thoroughly considered in developing the EGL project. But more importantly this SIGMA comment as well as all others that talk about the benefits of the project use the phrase that it will operate in 'moderate' floods implying that these excavated channels to high suspended load flows will not operate at above higher that moderate flows seemingly that once the spoil pile banks and levees are over topped the channel does no longer function as a main delivery source. This is a fallacy, if the Mississippi river is in flood where does most of the sediment get transported? In the channel of course. No matter the flood stage the channel because of its width and depth and lack of flow impediments, and in the case of these channels that have very steep gradients (to be discussed shortly), are very efficient transporters of sediments and nutrients to down channel locations.

SIGMA also take affront with van Heerden's 2019 "first cut" at calculating the sediment load and distribution if these EGL Channels were ever excavated. They question the width of the channels, the depth of flow during floods, the water velocity, suggest the maximum sediment flux is in the lower part of the flow and the nature of the sediment load he chose amongst others, so let's explore each

The Realities of excavating channels. I have been involved in dredging/excavating channels and levees since 1969 and have worked on such across the US, South Africa and advised on such on Brazil. I have worked closely with Dutch engineers and hence was called by Governor Blanco in 2006 to head up the state of Louisiana s forensic investigation into the Katrina levee failures (van Heerden and Bryan 2006). My experience includes the exaction of gravels from the sea floor in the mining of diamonds. I was the CEO if a marine diamond mining company off the west coast of South Africa and in many ways help pioneer this now multibillion-dollar industry.

In my experience contractors always go deeper that the contract calls for. Many contracts state that payment will be held up if bathymetric surveys post excavation reveal depths shallower than the contact calls for. Additionally, because of the potential of sloughing of channel banks into the channel so there is a tendency to go over the contract width. Once opened these EGL channel will scour at their entrances. So, being conservative and ignoring realities I used the design parameters as presented in the SIGMA Design Memoranda.

Sediment characteristics. SIGMA imply that because the water (with suspended sediments and nutrients) will only come "from the upper part of the water column of the connecting channel" that the sediment loads would be therefore lower. Maybe they imply that flood loads would be inconsequential. However, this is not the case at all.

DuMars (2002) in a very thorough MSc thesis undertaken at the Department of Geology and Geophysics at LSU through direct measurement investigated the suspended sediment loads, and concentrations through the water column, amongst other sediment transport factors in the natural delta forming at the mouth of Wax Lake. He found that homogenous suspended sediment concentrations of coarse silt to fine sand (mean grain size) were found throughout the system, indicating well mixed turbulent flow. Van Heerden etal (1983) amongst other journal publications) and van Heerden (2019) pointed this out as well, based on his studies in the lower

Atchafalaya Basin and Atcahafalaya Delta. In fact, this characteristic of the Mississippi and Atchafalaya flows has been documented for years by a slew of researchers.

Suspended sediment concentrations and flux. Van Heerden (2019) used a very conservative estimation of 138 mg/l, and pointed out that this was a low concentration. DuMars (2002 for example) in his work showed that suspended sediment concentrations during the flood of 2001 (not a very big flood) varied from 580 to 1140 mg/l – from 4.2 to 8.3 times the conservative estimate of van Heerden (2019), who could have used higher numbers but wanted to be conservative!

SIGMA also states "The bottom elevation of the proposed elements is set high enough that they will not be flowing year-round. Instead, they will provide water (from the upper part of the water column of the connecting channel) into the swamp where the river stages are high enough to reach 6.0 ft NAVD88 at each proposed elements location. This is roughly equivalent to a stage of 12.5 ft at the Butte la Rose gage…" Well why use the Butte la Rose gauge?

DuMars (2002) found that downstream sediment fluxes vary directly with velocity. The thalweg transports the highest volume of sediment per unit time (sediment flux) even though the sediment concentrations per unit volume are homogeneous. Thus, the upper portions of the flow have the highest sediment flux in both flood and non-flood conditions (Figures 3 and 4). Van Heerden etal (1983) found the same to be true in the Atchafalaya Delta, both being reflections of the sedimentary processes operating within the whole Atchafalaya Basin complex.

Thus, it is extremely important to note that in the Basin, dominated as it is by well mixed suspended sediment loads, the maximum flux of sediment (volume to unit time) occurs in the upper portions of the flow, not the lower portions as SIGMA are implying in their comments. These real data are is contrary to SIGMA's assertions.

Channel widths. As concerns the width of the EGL channels: van Heerden (2019) used two methods to determine the widths he used. As shown above most of the sediment flux is in the upper part of the channel and thus one needs to assume the actual width of the channel rather than just the proposed bottom width of 25 ft. Plate 1 of the SIGMA Design document of February 2018 revels that the typical dredge section of elements 1, 2, 3, 4, 12 and 13 varies from 25 to 53 feet – the average being 39. Similarly, for elements 5, 6, 7, 8, 9, 10 and 11 the width varies from 100 to 116 feet, average 108 feet. The second method involves the direct measurement of the cuts as depicted in the abovementioned design documents, so one can determine an average of 44.5 feet for elements 1, 2, 3, 4, 12 and 13. So my 39 feet was chosen as a conservative estimate!! Similarly, direct measurement of the proposed wider EGL cuts gave an average of 117 feet, again using 108 was a conservative estimate. Trying to give SIGMA and La DNR the benefit! Nothing incorrect here.

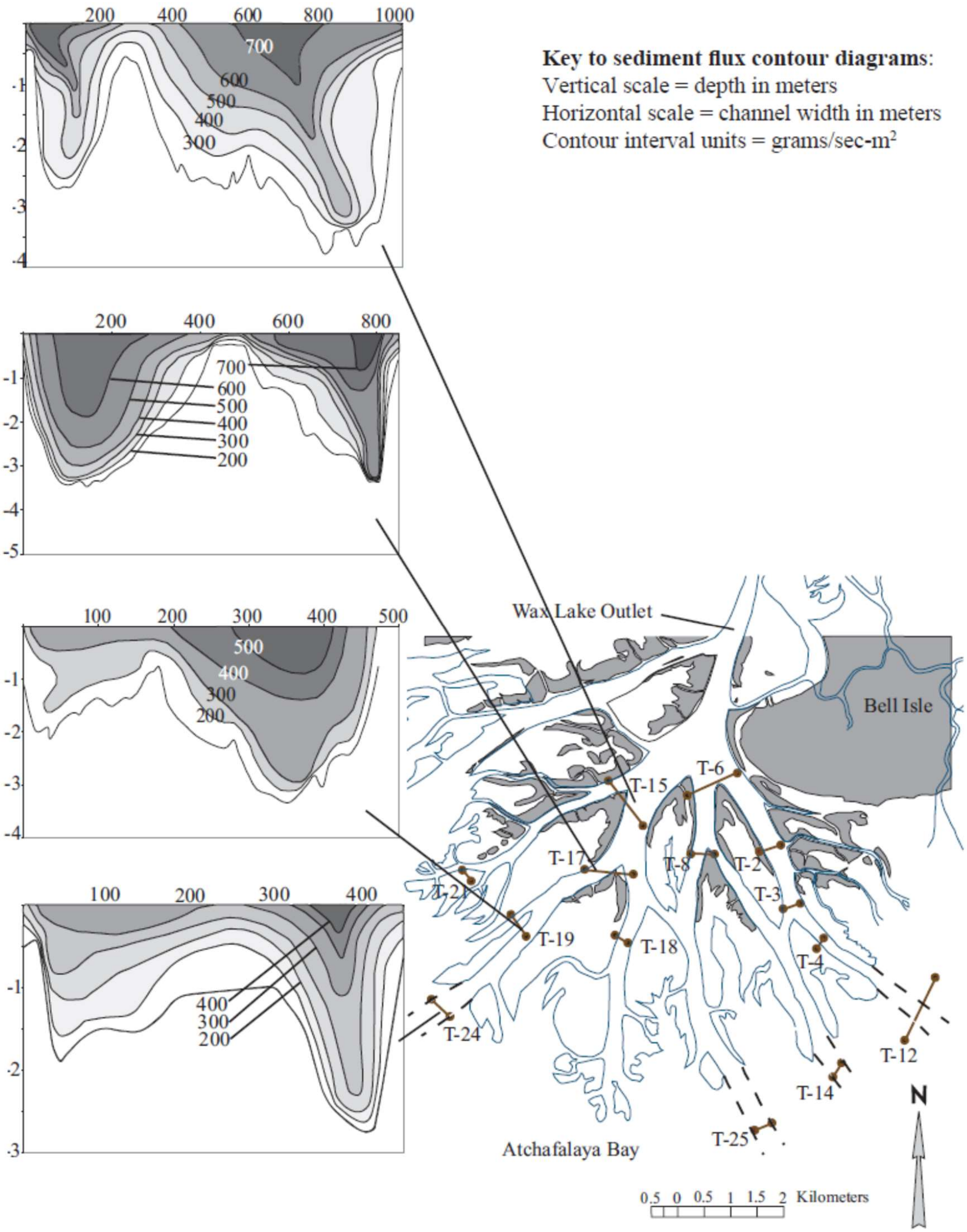

Figure 3. Flood condition sediment flux distribution. Shaded delta areas show approximate location of subaerial lobes. Outlined delta areas indicate location of subaqueous lobes. Modified from normal and color infrared USGS aerial photography, 1998. From DuMars, 2002.

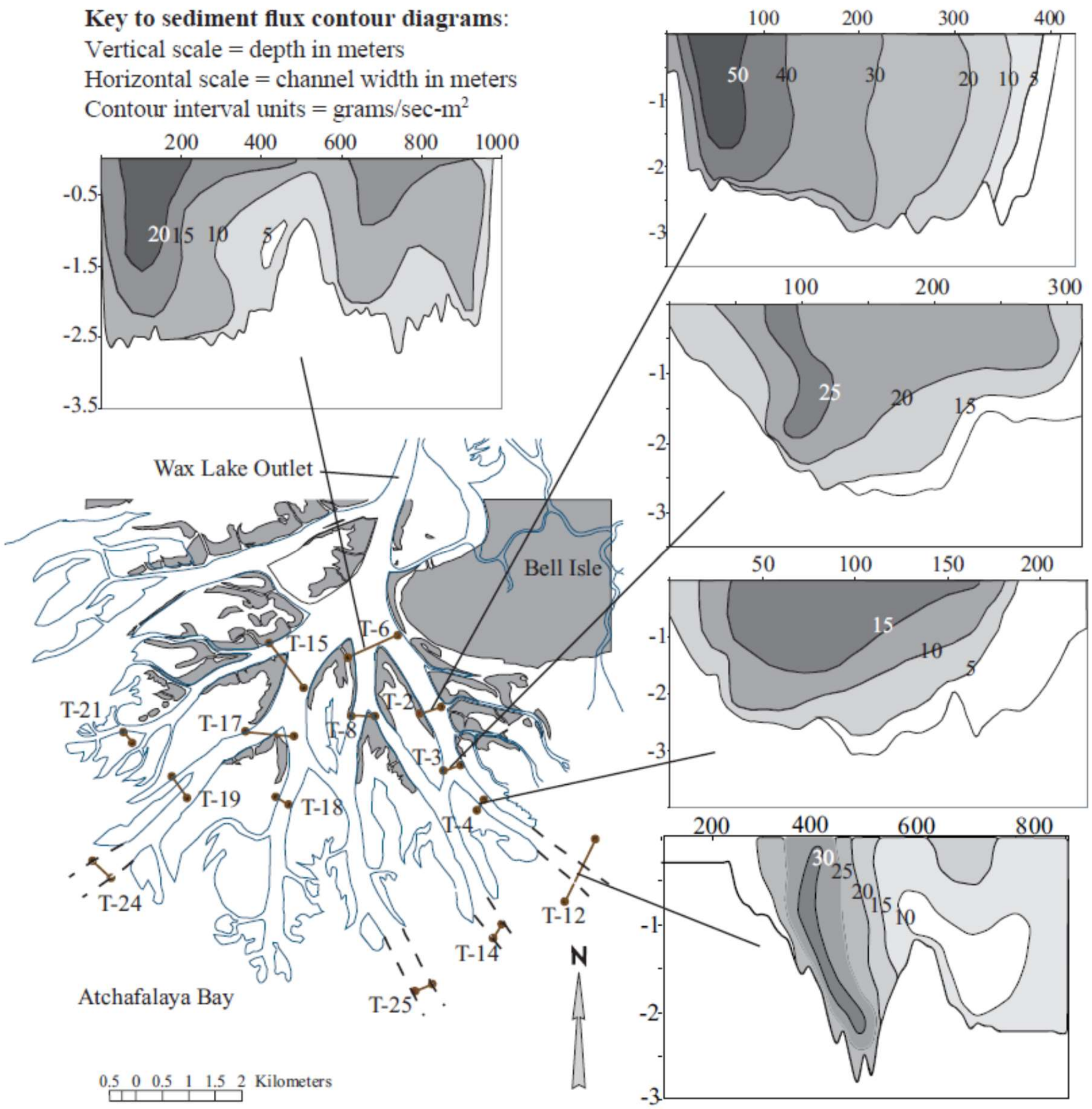

Figure 4. Non- flood condition sediment flux distribution. Shaded delta areas show approximate location of subaerial lobes. Outlined delta areas indicate location of subaqueous lobes. Modified from normal and color infrared USGS aerial photography, 1998. From DuMars, 2002.

<u>Sediment Deposition Processes in swamp stilling basins</u>. As explained in the van Heerden 2018 and 2019 reports as the flow goes from the confined to the unconfined and enters a stilling basin the suspended sediment will be progressively deposited. Additionally, because of the high number of filter feeder microorganisms such as Forams to small fish and crawfish, a portion of the very fine sediments are ingested and by the process of biological pelletization (creating faces) the ‘pellets” settle to the bottom leading to the clear waters we experience in inner swamp

locations after the flood peak. All the suspended load entering the inner basins is deposited. See also van Heerden (1983). Unlike in a coastal delta situation, there are no tidal currents to move the fine material onwards. Pure science here!

Water depths and flow velocities during high water events.

SIGMA then take issue with van Heerden (2019) using 3.3 ft/sec as a velocity for the upper layers in these channels, with steep slopes of between 0.2 % and 0.9% (except 12 and 13 with very low slopes (it appears about 0.08% but they did not supply the base elevation of the receiving basin), and quote data from the USGS (Table 1) taken who knows at what depth or what day or where along the channel width or length, in large low slope channels. Also, no reference. This is not a valid criticism of van Heerden (2019) as we will show shortly. At Butte La Rose a stage of 15.7 is not a flood stage. If one searched further you would have found data from DuMars (2002) amongst others that shows in similar situations, but with slopes as flat as 0.01%, channel flows are commonly in the 90 to 110 cm/s (Figure 5), similar to my own measurements elsewhere and in line with the 3.3 feet/sec that van Heerden used. Nothing incorrect here.

Very importantly, DuMars (2002) states "The inertial forces created by channel flow velocities greater than 20 cm/sec are capable of entrainment and transport of the available sediments." Thus, once the suspended sediment is in the water column a flow as low as 20 cm/sec will keep them entrained or suspended in the water column. Van Heerden (2018 and 2019) reported this nature of Atchafalaya River suspended sediment transport on numerous occasions.

SIGMA takes issue with the water depths van Heerden (2019) uses in his calculations of the amount of sediment that can be carried by the cut EGL channels into back swamp locations. The USGS point out that there is "no datum" for the Bayou Sorrel lock so its reliability is suspect. I used other gauging stations including that at Bayou Sorrel (Figure 6). One could argue that the water levels at all EGL elements would be more reflective of the Bayou Sorrel gauge.

If we view the 2019 Bayou Sorrel hydrograph for 2019 (Figure 7) we see that van Heerden's 2019 assumption of 4 months of 6.6 feet of water depth in all EGL channels would have held true. From discussions above we have discussed that his width determinations are true, that his velocity assumption is valid, and additionally the suspended sediment flux is at its maximum in the thalweg or upper part of the flow and that as long as the velocity is above 20 cms/sec, the suspended load passes merrily on its way down the cut channel until it reaches the still water swamp where it will be deposited. Additionally, van Heerden assumed a suspended sediment concentration taken from Welch et al (2014) which are actually lower than the long-term mean. Considering the higher 2019 flood stages at sites along Bayou Sorrel and those connected to it, van Heerden's 2019 determination that during the 2019 flood at least 1188 acres would have been covered by about 4 inches of sediment would have held. This much sediment in just one year would have been devastating.

During low flow months all that is needed is flow down these EGL channels at 20 cm/s or higher and they will move the suspended sediment (again there is no bedload) all the way down the confined channels until it reaches the unconfined swamp stilling basin and be deposited.

<u>Discharge numbers.</u> Figure 8 given van Heerden by the corps in 2000 (van Heerden 2001) reveals that prior to the excavation of the new cut for East Grand River and the closure of Little Tensas Bayou (as discussed by van Heerden 2019), 3% of the total Simmesport flow

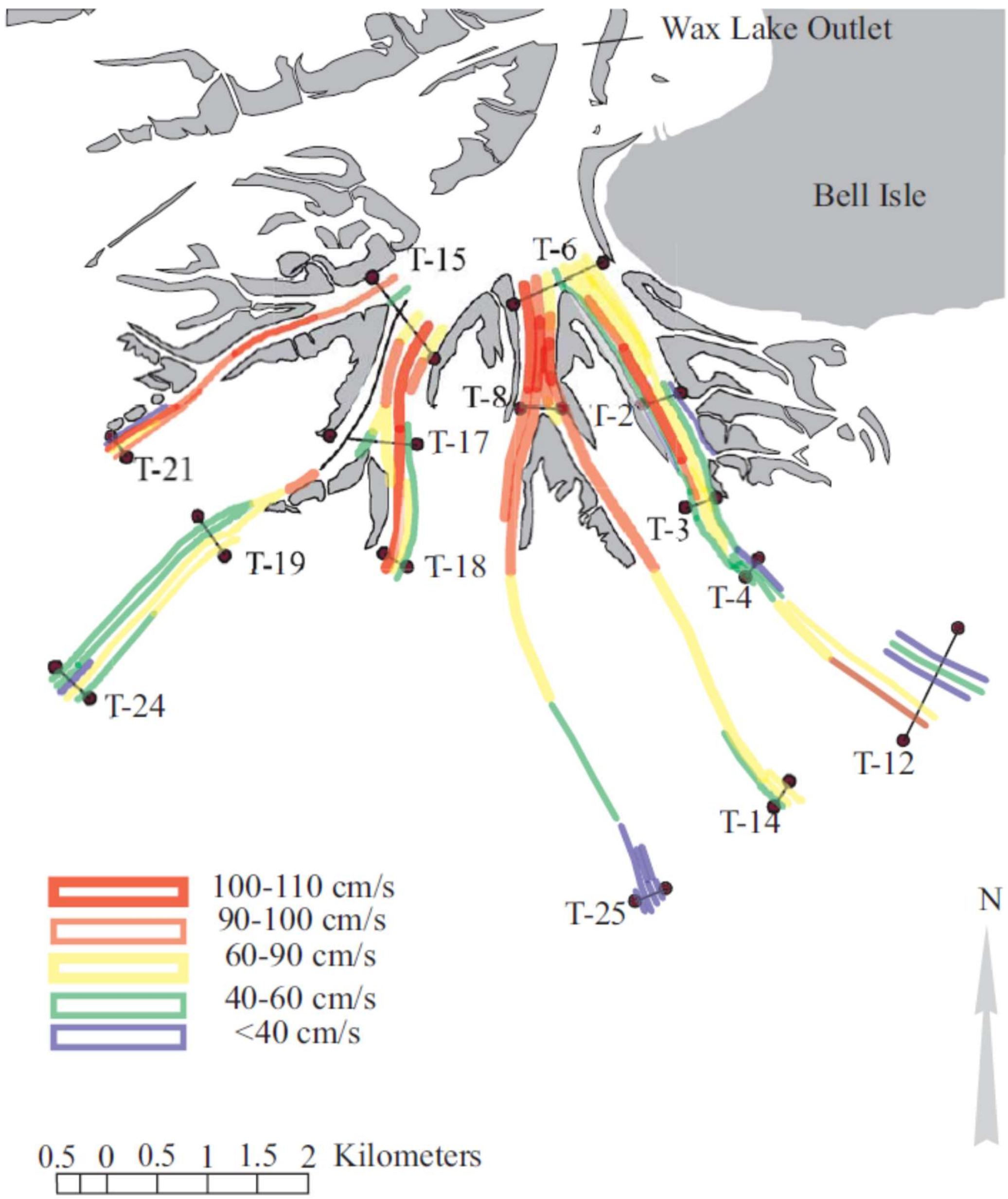

Figure 5. Wax Lake Delta channel velocity distribution. T=transect. Modified from USGS aerial photographs, 1998. From DuMars, 2002.

Figure 6. Location of Bayou Sorrel gauging station.

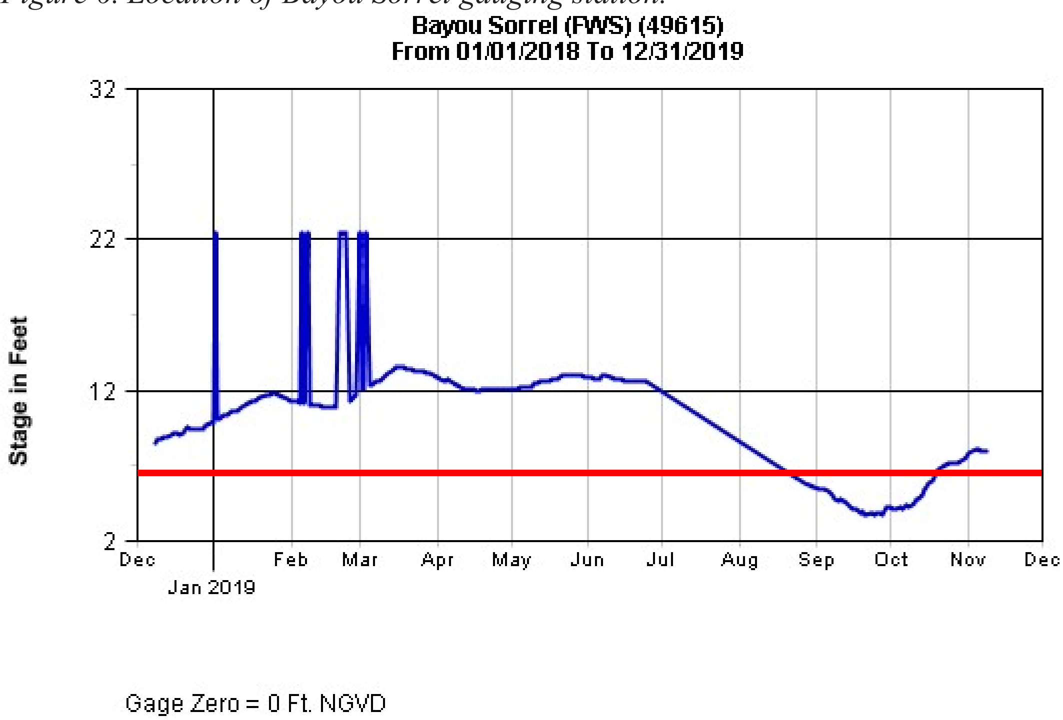

Figure 7. Bayou Sorrel gauge for 2018 and 2019. Plus 6.0 feet in red. As far as I could ascertain there is no correction to NAVD 88 for this location in Basin. The Corps river data available on web says that at Butte la Rose the two are equal.

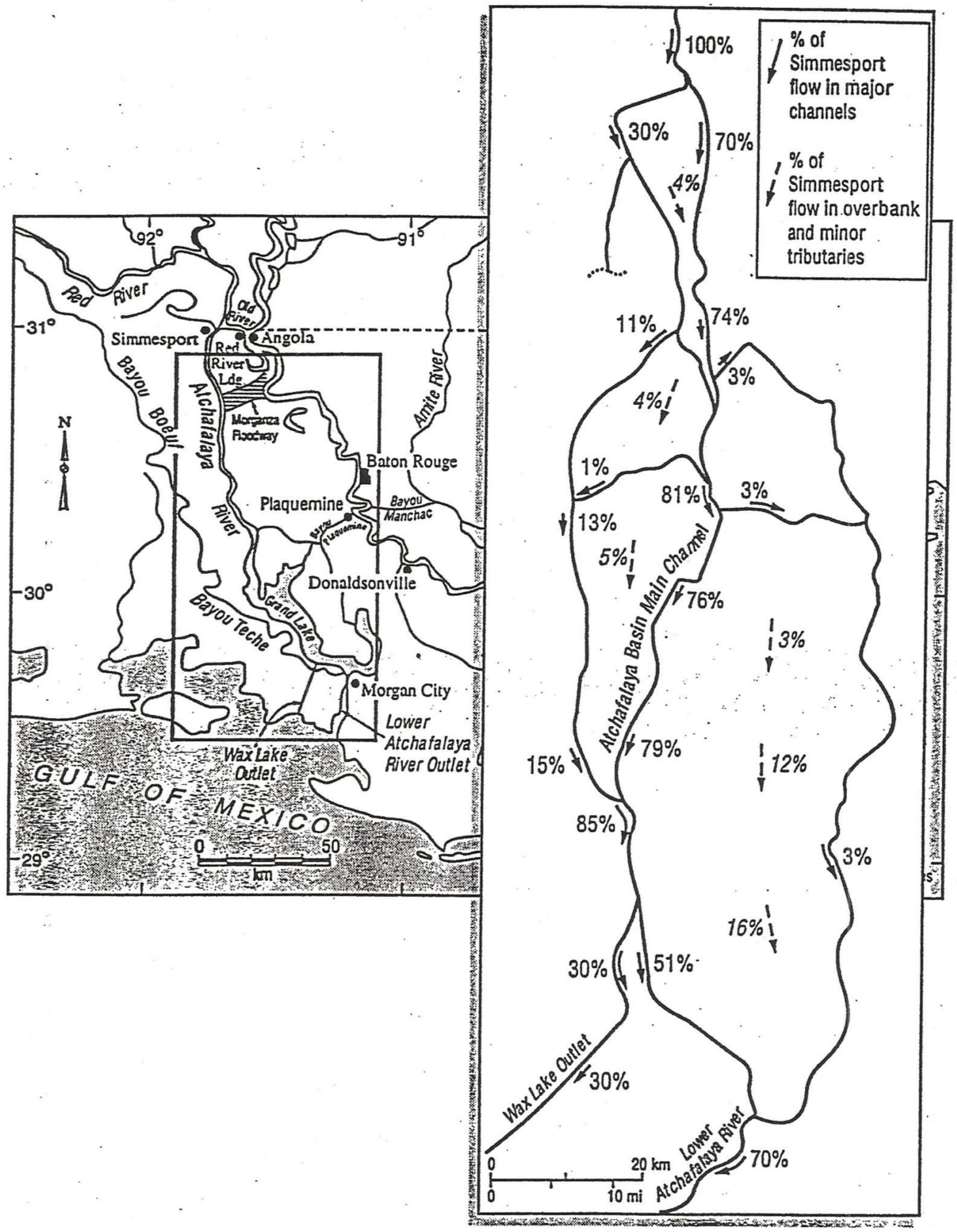

Figure 8. Distribution of flow across the Atchafalaya Basin prior to opening up Grand River and Bayou Sorrel, based on data from US Army COE (van Heerden 2001)

moved east along Grand River to the GIWW. And similarly, 3% eastwards down Bayou Sorrel. So, if we look at a peak flow of 500,000 cfs at Simmesport, then each of these channels (pre widening and deepening) has the potential to carry 15,000 cfs of flood water for a total of 30,000 cfs at the location of the Bayou Sorrel lock. Given the location of the EGL cuts both along Bayou Sorrel and the GIWW then it is easy to see that there is more than enough discharge to verify the discharge numbers that van Heerden (2019) used especially if one recognizes that the COE % flow distribution presented in Figure 8, represent high flood discharges in these two west to east feeder channels BEFORE they were excavated and really opened up!!

Now SIGMA present a table (Table 1) for discharges at three locations with the Butte La Rose gauge as a reference at 15.7 feet. They themselves seem to suggest that the stage at the EGL project area is at (12.5 – 6) = 6.5 below that of Butte La Rose. Figure 9 is the Butte La Rose hydrograph for 2019 as obtained from the COE.

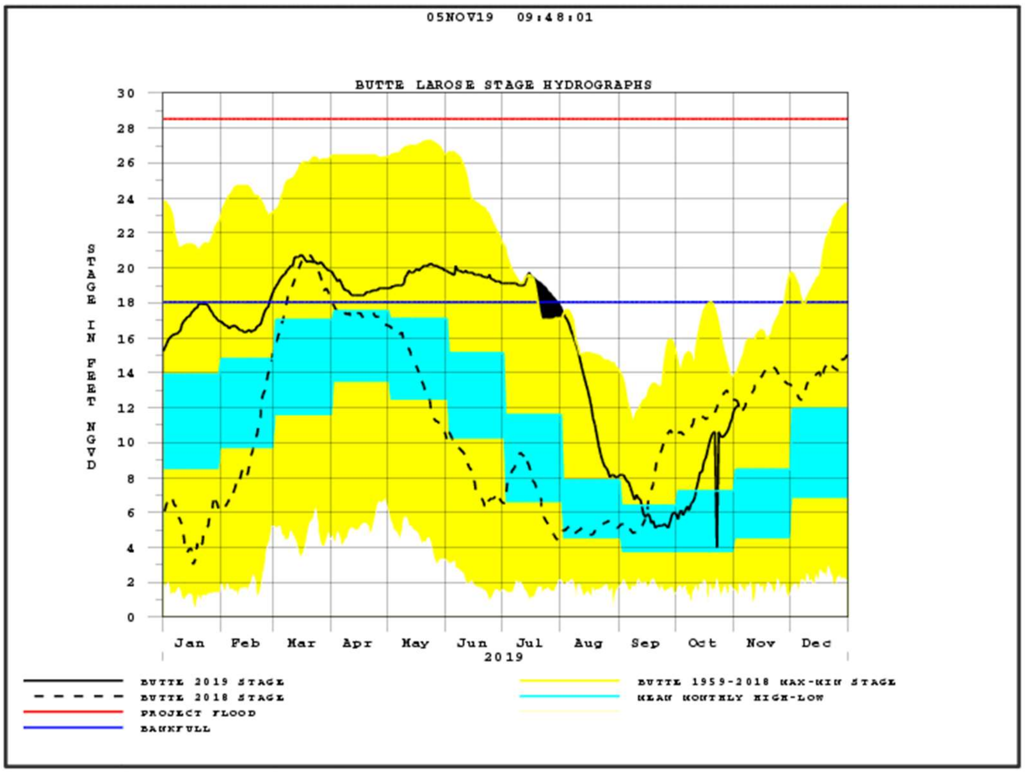

Figure 9. Butte La Rose hydrograph for 2019 Superimposed on hyrogrpah statistics for 1959 to 2018. Note that in terms of stage, an elevation of 15.7 feet is not a flood in the NWS sense.

Site	Butte La Rose Stage (ft)	Water Velocity (ft/sec)	Discharge (cfs)
GIWW@ Bayou Sorrel	15.7	2.27	17,100
Cannon Bayou	15.7	2.16	1,800
Bayou Sorrel @ Atchafalaya River	15.7	2.56	13,000

Table 1. As produced by SIGMA 2018. Source unknown.

At Butte La Rose, according to the National Weather Service, the flood stage is 20 feet, so the data in the table presented by SIGMA of a stage at 15.7 feet is not even a flood. If SIGMA's minus 6 feet correction from Butte La Rose to Bayou Sorrel is real, then Bayou Sorrel would have been at 9.2 feet. However, if we compare Figures 7 and 9 and specifically the flood stages from January to July then it is apparent that the difference in elevation between the two gauges is about 20 minus 12 which equals an 8 feet difference, not 6 feet. Referencing SIGMA's Table 1 a stage at Butte La Rose of 15.7 ft (high water non flood) would imply a water level of +7.7 ft at Bayou Sorrel, and the discharge measured by the USGS down this Bayou was 13,000 cfs, not to dissimilar to the max flood discharge before widening and opening of 15,000 cfs – a large increase in discharge for lower stages, a direct result of widening and deepening of Bayou Sorrel as part of the COE Management plan.

The 15,000 cfs discharge at Bayou Sorrel with a stage of 7.7 ft suggests two important aspects of discharges namely,

a.) When Bayou Sorrel was at + 12 feet for 5.5 months in 2019, discharges based on Table 1 would have been 13000 plus 200 ft(width Bayou Sorrel) x (12 – 7.7) = 4.3 ft x 2.56 ft/sec for a total discharge of 15,200 cfs. And this I at best a moderate flood, and
b.) Van Heerden's "first cut" calculations were very conservative.

Suffice to say, van Heerden's 2019 conclusion hold well under the science.

Subsidence. SIGMA claim that subsidence will basically take care of sediments entering the swamp stilling basins. Well there are two considerations, firstly they are acknowledging that sedimentation from the EGL channels will occur, but secondly it is weak argument because just one large flood could easily overwhelm the 6mm/yr that seemingly characterizes the EGL project area. As presented in Appendix A there are many measurement of the annual sedimentation rate that far exceed the subsidence rate. TNC own data reveals this (Table A12), and most of their samples were taken on levee locations where sedimentation rate is the lowest.

c. East Grande Lake Ecological Enhancement Project , anon

While a small thing, according to this anonymous commenter moderate flows would enter the EGL channels when Butte La Rose is at +10 ft while SIGMA claim about 12.6 feet. They reference the Bayou Sorrel Lock gauge which as discussed earlier has a datum issue. Perhaps no one was aware of the Bayou Sorrel gauge? The reader' attention is drawn to Appendix A and B below in discussing the data collected by the Nature Conservancy for the La DNR that they present for 2017. As discussed in these appendices there are some issues such as 'flat lining' that suggest instrument errors. Note they only present Data for 2017. By the own pers. comm. admission, they did not have useable data for 2016. As van Heerden (2109) pointed out the rising of oxygen levels in the 2017 flood in sympathy with rising water levels reflected a very special kind of flood peak, one associated with a 1:1000-year rainfall event that resulted in much lower nutrient levels and suspended sediment loads. Notice that the commentator does not look at or try to explain away the opposite results in 2016, when a normal Mississippi River upper basin flood dominated the picture with high suspended sediment loads and high nutrients levels, so their explanation does not hold scientific water. See also the appendices.

CONCLUSIONS

The EGL channel project proposed by the La DNR will lead to increased hypoxic in interior swamps as they fill with suspended sediments until they are replaced by bottom land hardwoods. It is my understanding that this infilling is what landowners are seeking.

The 2019 flood showed very dramatically the problem associated with the very high nutrient loads of the Missisppi River. The famous Gulf of Mexico dead zone grew, Lake Pontchartrain and locations as far as Florida had no drinking, or no bathing, or no fishing or all three bans for the protection of human health. To me that says it all. The bigger picture is that before too long the US Congress is going to have to deal with this issue, especially as climate change forces greater and more severe flooding.

THE CUTS AS PROPOSED BY THE LaDNR FOR THIS EGL PROJECT WILL DELIVER LARGE VOLUMES OF SUSPENDED SEDIMENT EVEN WHEN AT LOW DISCHARGES. ONCE THE SEDIMENT IS IN THE BASIN THERE IS NO GETTING IT OUT!

FLOODWATERS FROM THE MISSISPPI RIVER ARE A MAJOR SOURCE OF NUTRIENTS THROUGHOUT THE GULF COASTAL ZONE LEADING TO HUMANA HEALTH ADVISORIES AND HYPOXIA IN A WIDE RANGE OF AQUATIC ENVIRONMENTS. IT IS DETRIMENTAL TO BENTHIC ORGANISMS, THROUGH OYSTERS TO BIRDS AND OTHER AQUATIC HABITAT DEPENDENT SPECIES TO COMMERCIAL FISHING AND TOURISM. WHAT IS HAPPENING IN THE ATCHAFALAYA BASIN ID SYMPTOMATIC OF A MUCH LARGER PROBLEM THAT ALONG WITH GLOBAL WARMING WILL NEEDS TO BE ADDRESSED IMMEDIATELY.

A PROPOSAL

My experience includes running a coastal restoration program, advising agencies and doing the conceptual design of 10's of projects the solution to the problem the LaDNR claims is simple. East of the guide levees (Land Side or LS) water levels are quite often higher than inside the guide levees (Flood Water Side or FWS). This reflects the impact of sealing east to west channels and flows that were terminated by the East guide levees. On the LS flooding is a problem and flood waters have to be pumped out to locations south of the Basin. What if using pipelines, these relatively nutrient free and low suspended sediment water was piped under the GIWW, and then released into the swamps. This would dramatically reduce the hypoxia problem without filling the basin in with sediment. Now that CPRA have taken control of the management of the Basin, this might be a good time to start proposing such a project.

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APPENDIX A. DISCUSSION OF THE NATURE CONSERVANCY DATA COLLECTED FOR LaDNR/SEDIMENT SCIENTIFIC LITERATURE

Introduction

The Nature Conservancy (TNC) have since 2017 collected water quality data for the LaDNR in the same region of the Basin as Kong (2017) (See Section 3) although not at the same locations. Figure A1 is a Google Image depicting the sample sites where Kong (2017) collected her intensive data for the 2016 and 2017 Atchafalaya River floods. As stated previously Kong does not supply any explanations as to why her sites were chosen other than ease of access, and the environment or elevation. There is no GPS position data so as to make a determination where the sites were located, was it on a levee or was it in an open pond or in a forested swamp? There is no weather data either. Strong winds, rain, other boat traffic etc. before or during a sample event can markedly change the readings. The assumption as she was collecting crawfish implied that there was enough water depth to move by boat. Figure A2 depicts the location of TNC data collection sites but they do not supply any description of the sites as well, no GPS data or record of any severe weather events. Figure A3 is an attempt to superimpose the Kong (2017) data collection locations (Figure A2) on the TNC map.

The use of continuous reading Sonde instruments.

There are a number of issues in the use of YSI Exo2 sondes, namely:

1. Figure A4 reveals very low DO levels of 0.05 to 0.06 from 5/16/17 to 5/23/17 at Site AU6. A 'flat' line while the Butte La Rose stage is rising from 4.2 to 5.6 m as the flood peak advances; both the turbidity and water depth at Site AU 6 are also climbing in sympathy with the rising river. So why the DO flat line? Over the same time period Kong's (2017) Site 1 shows the DO climbing from about 1.0 to 4.6; Site 6 climbing from 0.5 to 4.0; Site 7 shows the DO declining from 0.4 to 0.3 before it shots up after 5/20/17; and, Site 8 indicates a fall from 3.0 to 1.4 before it also rises rapidly. This flat lining suggests to me that there is an instrument malfunction or a cable connectivity issue. Because the data was received a few days ago I have not had enough time to assess other flat lining, some also in the 2018 data such as site T3 where the DO seems to be flat lining from 2/20/18 to 3/12/18 while the water level is rising some 1.7 m or about 6 feet! From 03/13/18 the DO jumps up. Again, one needs more information to truly assess the data and to interpret what is happening at each site.
2. There is a very real need to calibrate sonde equipment regularly https://www.ysi.com/File%20Library/Documents/Tips/YSI-Calibration-Maintenance-Troubleshooting-Tips-6-Series-Sondes-2-8-10.pdf and https://www.ysi.com/ysi-blog/water-blogged-blog/2015/04/5-tips-to-prevent-costly-mistakes-with-your-sondes-tip-1-of-5 for example. No calibration information is presented in this report.
3. The USGS showed that turbidity measurements could be 25% off. Did TNC take this into account?https://www.ysi.com/ysi-blog/water-blogged-blog/2015/04/5-tips-to-prevent-costly-mistakes-with-your-sondes-tip-1-of-5.

4. The USGS also stated that some of the test results did not meet manufacturing specifications and suggest that the manufacturing specifications for accuracy and detection range may be exaggerated.
5. Another major issue with the Sonde is the propensity for its sensors and its casing to collect sediment during highly turbid peak flows. Debris or sediment that gets stuck in or around the sensor casing have an impact on the accuracy of the water quality readings. Without proper maintenance procedures in place, the Sonde will not provide accurate data. Because of this, many researchers conduct maintenance visits on a weekly basis and after high-flow events to check the Sonde for any debris accumulation or sediment clogging within the sensors.
6. Detailed records of calibration and maintenance must be kept. The calibration should be conducted using standards in the range of values expected to be encountered in the field. This is particularly important when calibrating electrical conductivity for use in fresh, tidal or marine waters. The calibration must be performed and recorded before the start of a field trip and should be checked at the conclusion of each field trip; it is advisable in very turbid locations to re-check calibration daily during an extended period of field use. These in-field checks should be recorded in a notebook and later transcribed into the calibration logbook for the instrument
7. If manufacturer's procedures do not refer to temperature calibration, manual temperature readings taken using a thermometer should be compared to the instrument temperature readings.

TNC do not supply any calibration information. Such is useful if included in an Appendix. Information of who, when, which laboratory did the calibrations.

<u>The TNC Data for 2017</u>

This is only a very limited initial preview of the TNC data for reasons stated previously.

The TNC data was collected from 04/22/2017 till 07/19/2017 – a 3-month period that included the time Kong (2017) was sampling around the same flood peak (Figure A4). A comparison is thus possible between the two data sets.

Site AU6 compared to Kong's Sites 6, 7, and 8. (Figures A6 to A11).

The turbidity at AU6 is lower than that in the Atchafalaya River around 5/2/17 but rises up to the same level as the River at its peak of 34 and then falls rapidly after mid-June. Notably the DO rises faster at Kong 6 as compared to AU6. Above I discussed my concerns about the flat lining although Kong 6 is closer to the intersection of two canals and therefore closer to the source of flood waters (Figure A3). However, both sites see a rapid decline in the DO after the 1:1000-year rain flood peaks. Kong 7 and 8 more resemble AU 6 as they appear to be in the same general water body.

Unfortunately, a lack of location data, as discussed previously, and not enough time limit my full review of the TNC 2017 data, but similarities can be drawn to the Kong 2017 data (Section 3) and the same conclusions!

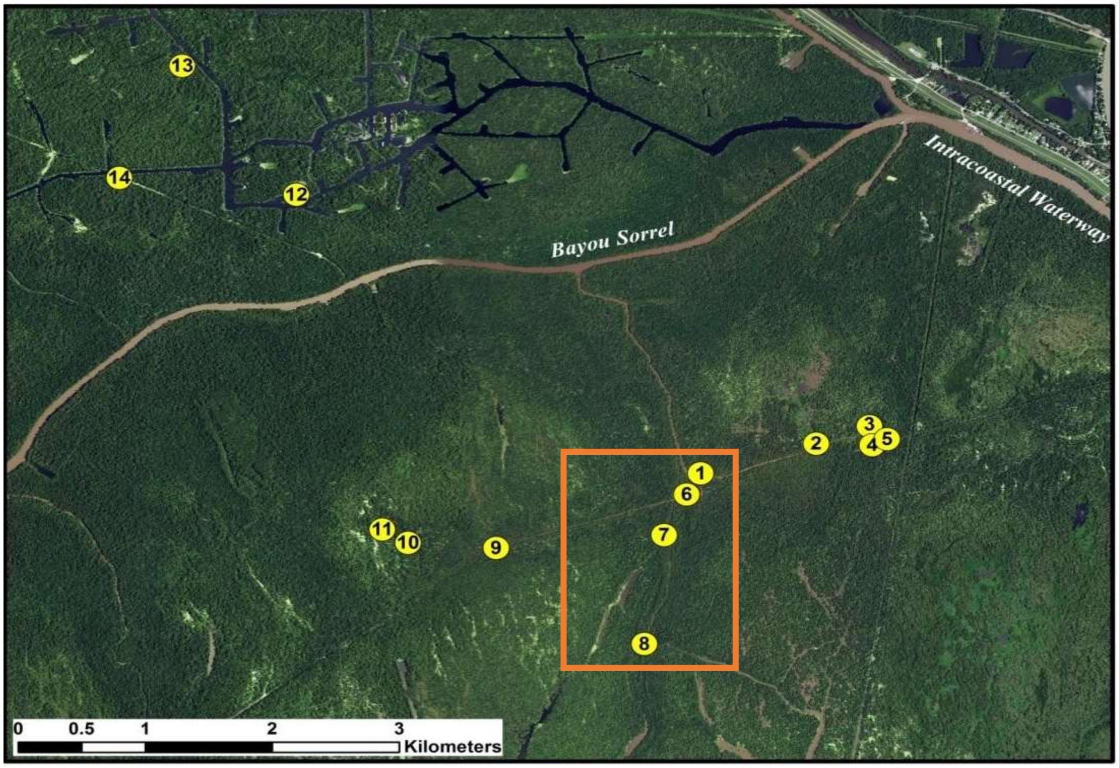

Figure A1. Location of Kong (2017) intensive sample sites. Review sites in orange box.

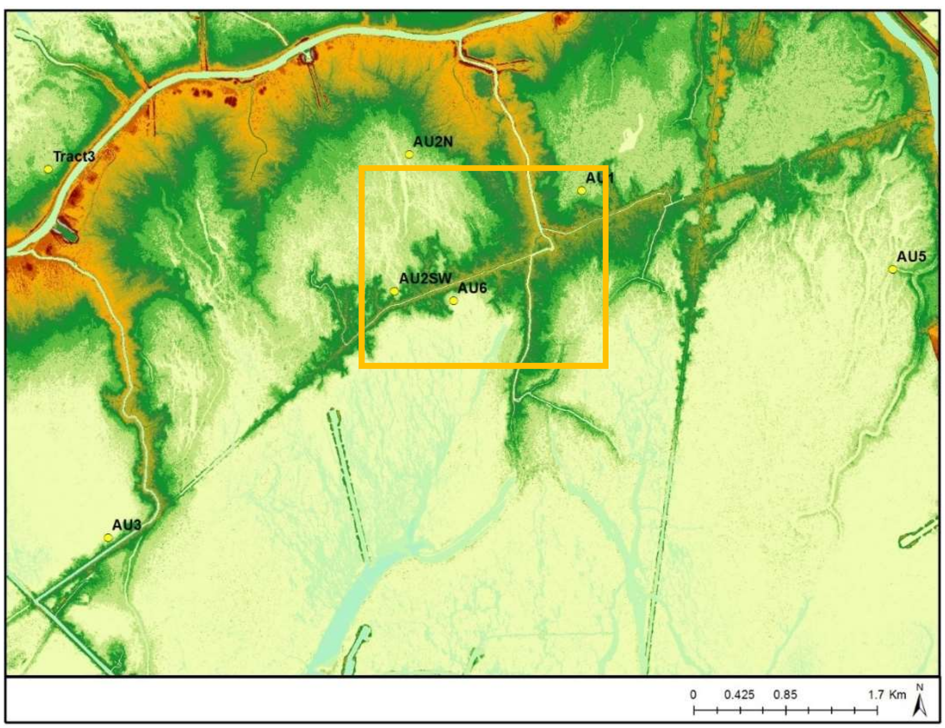

Figure A2. Location of TNC data sites (TNC Personal Comm.) Review sites in orange box.

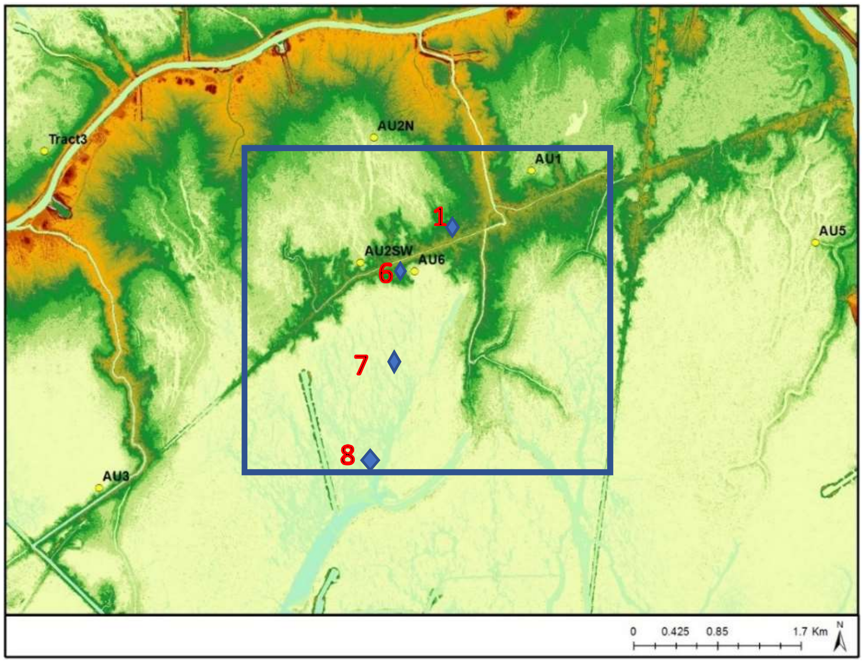

Figure A3. Four of Kong's 2016 sampling sites, namely sites 1, 6, 7, and 8, that are in the same region of the Basin as data collected by TNC at sites AU1, AU6, and AU2SW in 2017 and 2018. Note this is a LiDAR image and the richer the color the higher the elevations. Thus, all the TNC sites and Kong's 1, 6, and 7 are on the edges of levees even if they are subaqueous, at higher elevations that the interior backswamp in this portion of the Basin. Kong's site 8 is more of a backswamp location.

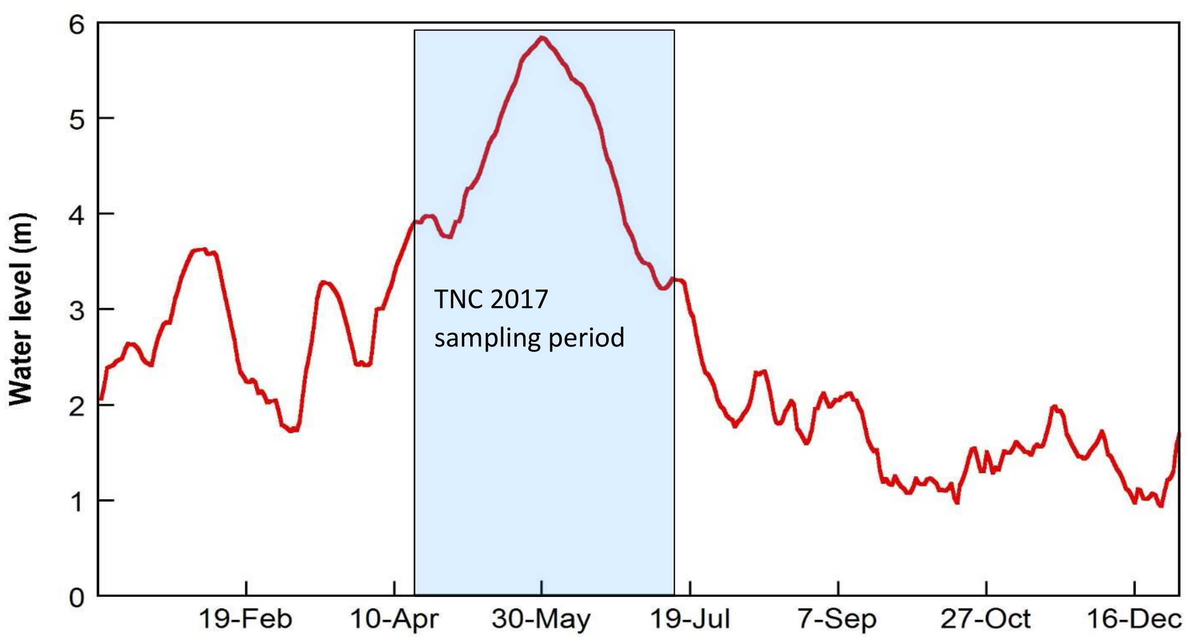

Figure A4. Daily mean water levels at Butte La Rose during 2017. Preliminary data from USGS gage 07381515 Atchafalaya River at Butte La Rose, LA.

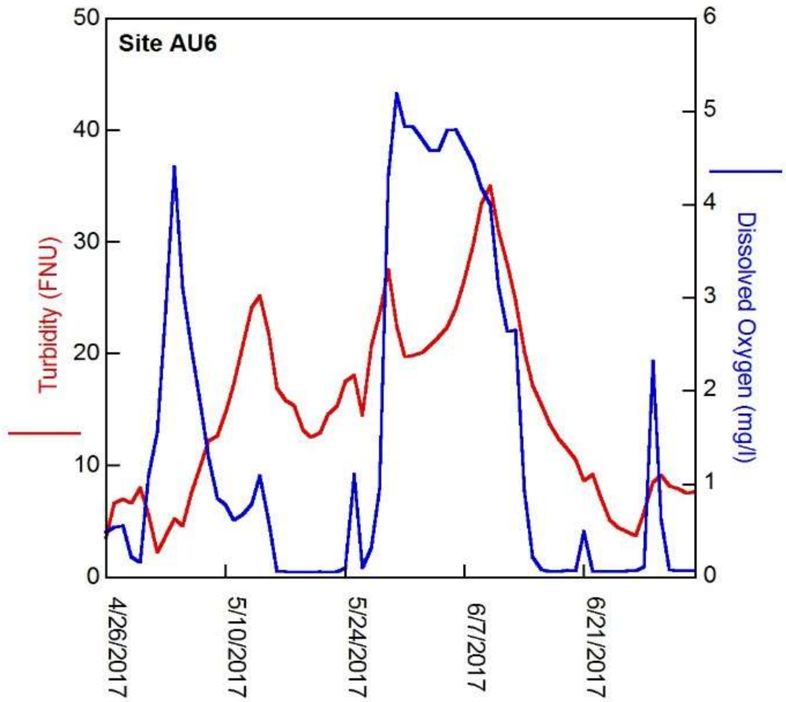

Figure A5. Turbidity and dissolved oxygen from April to July 2017. TNC Site AU6.

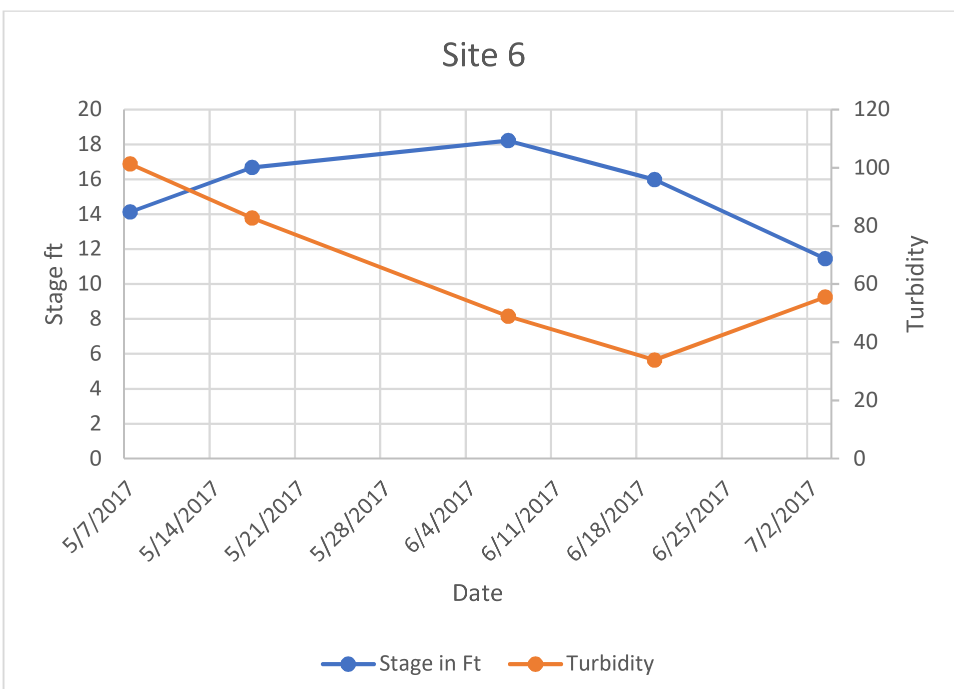

Figure A6. Stage in feet at Butte La Rose and Morgan City Turbidity for duration of 2017 study

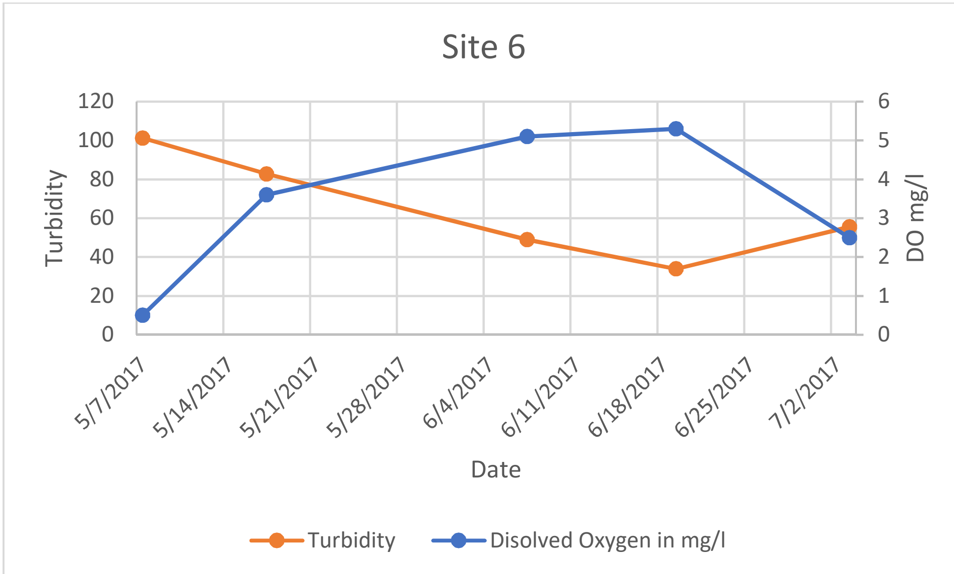

Figure A7. Plot of Dissolved Oxygen from Kong (2017) and Turbidity from Morgan City over the time data was collected for Site 6 in 2017.

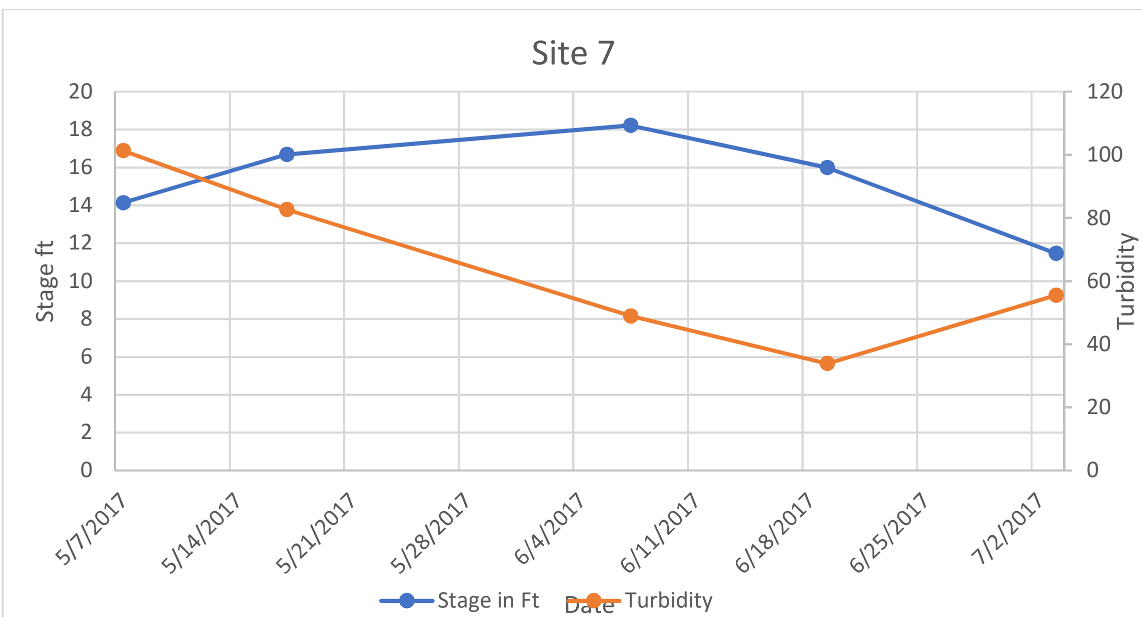

Figure A8. Site 7. Stage in feet at Butte La Rose and Morgan City Turbidity for duration of Kong 2017 study.

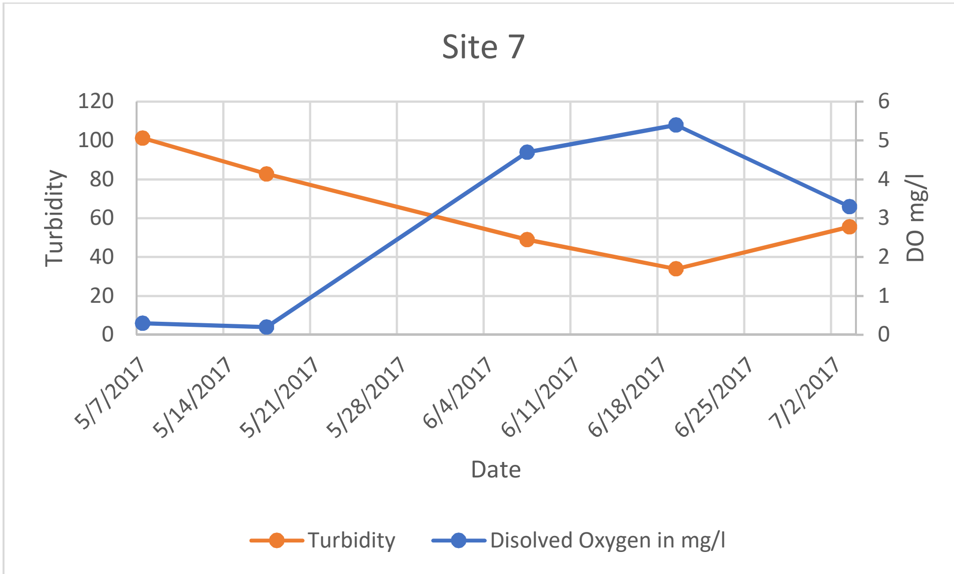

Figure A9. Plot of Dissolved Oxygen from Kong (2017) and Turbidity from Morgan City over the time data was collected for Site 7 in 2017.

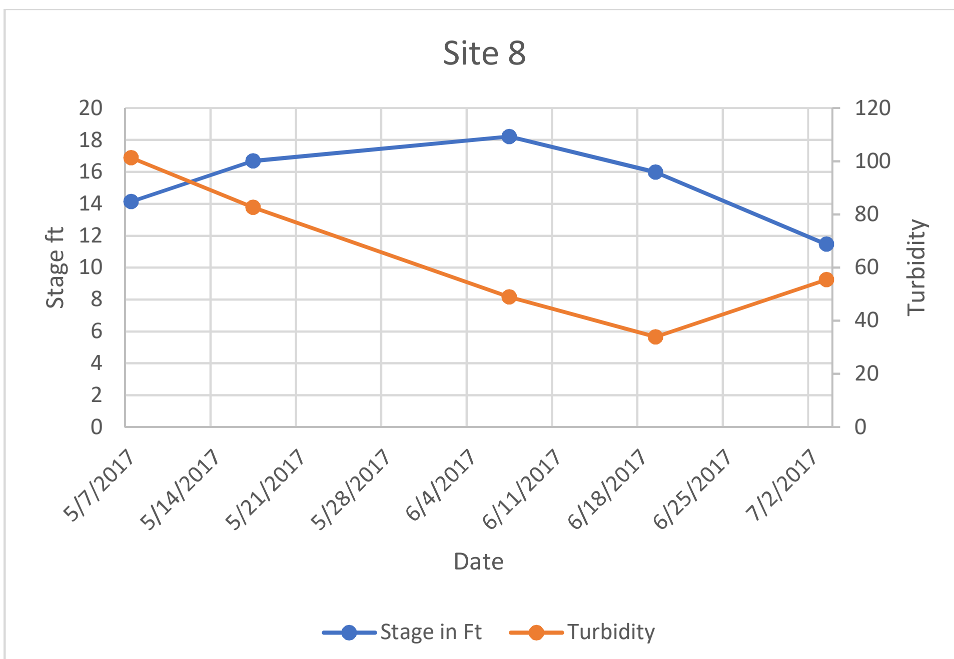

Figure A10. Site 8. Stage in feet at Butte La Rose and Morgan City Turbidity for duration of 2017 study.

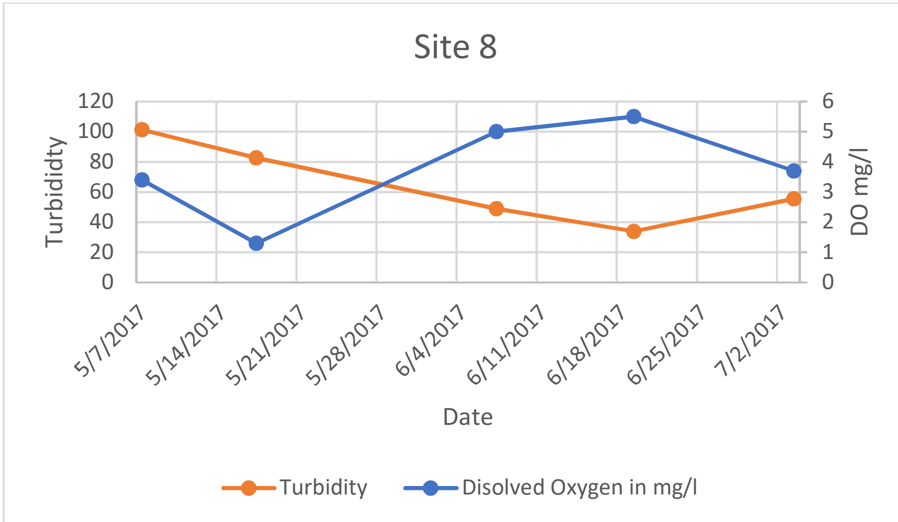

Figure A11. Site 8. Plot of Dissolved Oxygen from Kong (2017) and Turbidity from Morgan City over the time data was collected for Site 8 in 2017.

The TNC Data for 2018

This is only a very limited initial preview of the TNC 2018 data for reasons stated previously.

Not having enough time, I have not been able to dig into the 2018 flood (Figure A12) in any detail. The Butte la Rose stage data indicate that there were only about three months of low water (less than 3 m or 9.8 ft) (Figure A12). Initial review of flood literature suggests the early flood from February through mid-June was a Mississippi Catchment flood with an apparent strong contribution from the Upper Mississippi and Missouri Rivers. For ease of discussion this will be referred to as the "early" flood while that from October through the end of the year the "late" flood. Turbidity data from Morgan City (Figure A13) supports this view in that turbidities peaked at about 320 and were high for most of the early flood and rose again with the late flood. An eye ball average of about 100 appears fair for both floods. So, the 2018 flood from early February through mid-June was carrying high suspended sediment loads as well as nutrients (compare to 2016 and 2017 floods Section 3).

Figure A14 from TNC (2018) shows that at most of the TNC sites the DO rose in sympathy with the early flood but at half the sites the DO fell precipitously after a month (AU5, AU6, T3), and the rest stayed elevated until end of March for about two months (A1, AU2S, AU3). Can this discrepancy be explained? The upper DO sites, AU1, AU2S and AU3, are aligned along the Florida Gas pipeline canal a major flood feeder into these swamp areas. The close proximity would have maintained higher DO levels (for a month longer) until the consequences of eutrophication due to nutrient loading took its toll on the DO. TNC present evidence of algal blooms at site AU1, a reflection of the nutrient loading. The rest of the sites (AU5, AU6, T3) appear show a dramatic reduction in DO late March even though there is still about 3 feet of water over the bottom of the sites. Why? Site AU2N is not shown on Figure A14 but review of the data collected at this site shows that from 4/10/18 to 6/23/18, when the site became dry, it

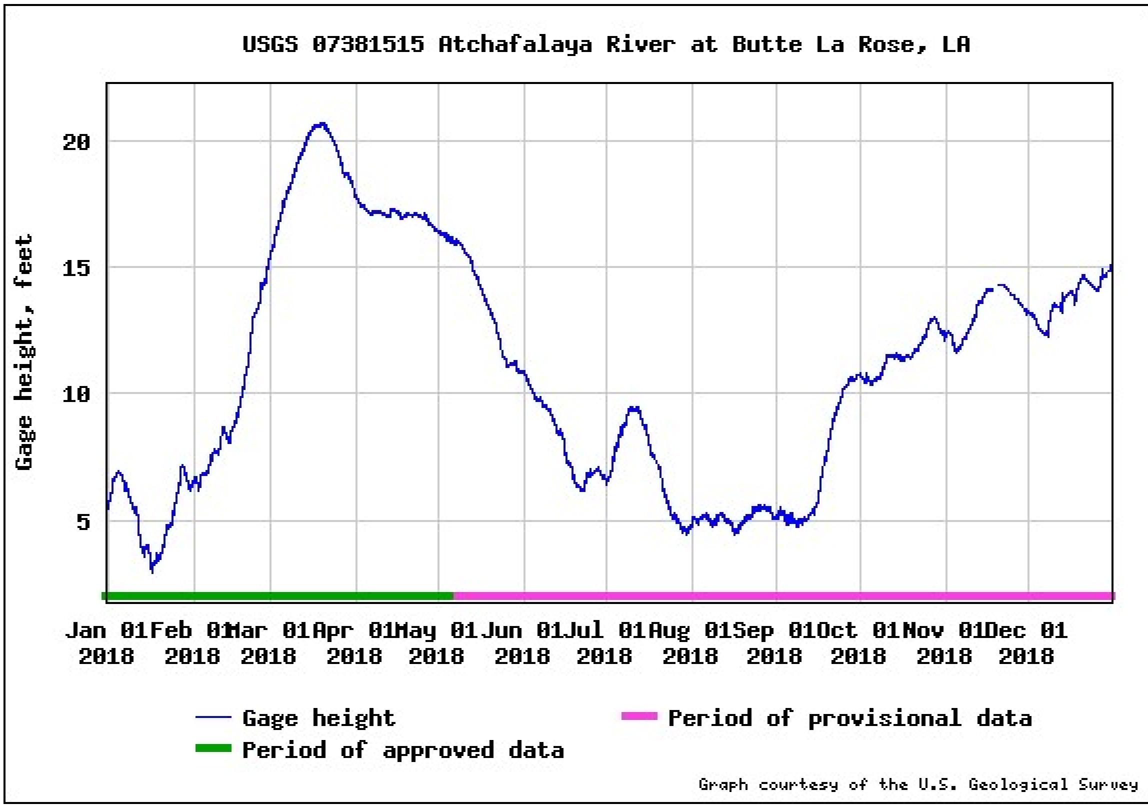

Figure A12. Atchafalaya River water levels at Butte La Rose (USGS Gage 07381515) in 2018

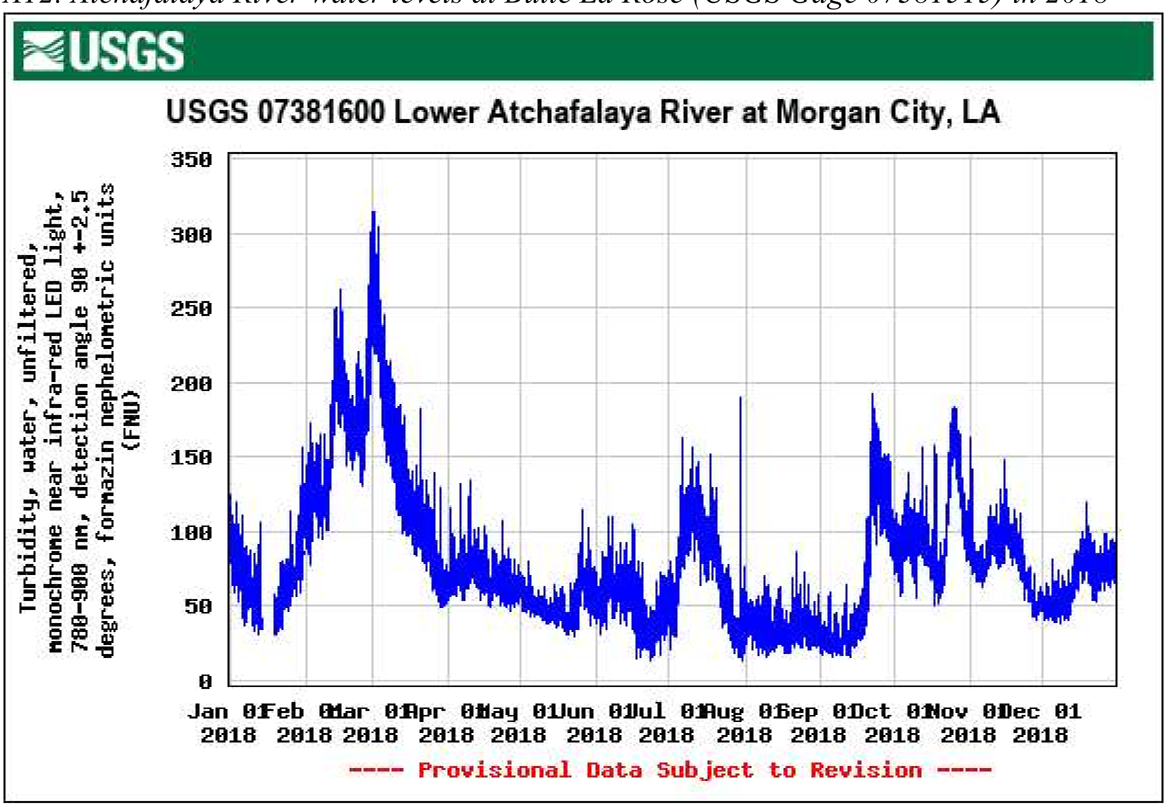

Figure A13. turbidity data for Morgan City for the year 2018.

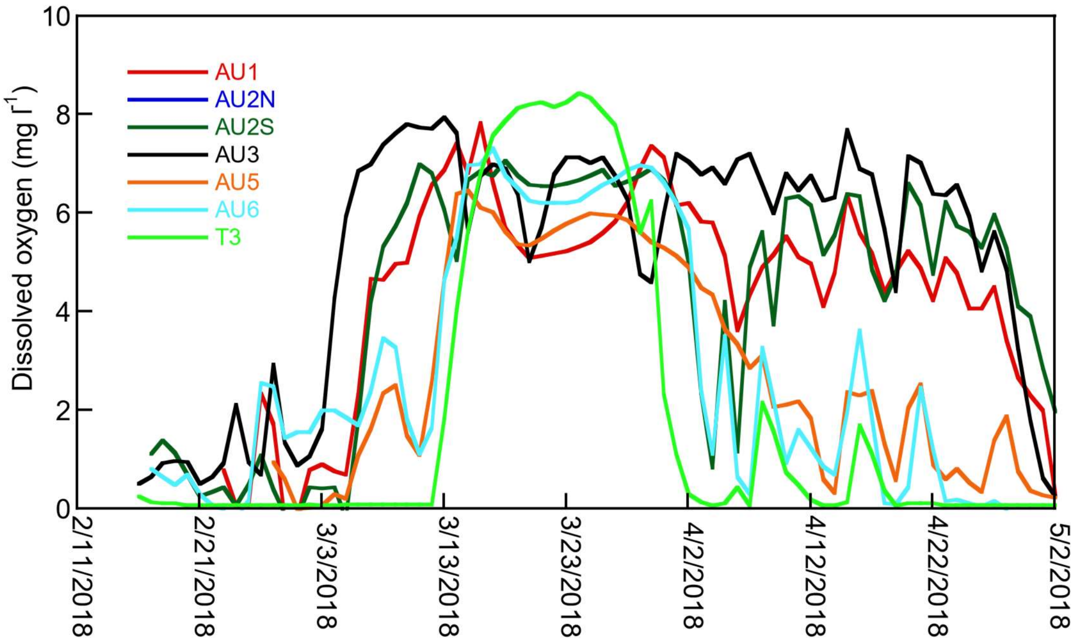

Figure A 14. Mean daily dissolved oxygen concentrations at the back swamp monitoring stations from February to May 2018. (From TNC 2018)

was Anoxic. It joins the lower group above. The data difference between the upper and lower group reveal that location is important in trying to understand the data and that the upper group are closer to a direct source of river flood water. The lower group because of the flood induced nutrient loading become Anoxic very rapidly. <u>If flooding with river water was healthy for the maintenance of oxygen levels in the swamps, then this precipitous fall in DO should not occur.</u>

Figures A15a is a plot of turbidity for the whole of 2018 for sites AU2S and AU6 while Figure A15b is a plot for the two same stations of DO. What is readily apparent is that towards the end of the year the DO at AU6 is better than AU2S, why one might ask? On 1 March 2019 an ABK crew went to try to find these two sites but were not successful. However, they did spend some time in the general area of these two instrument sites and reported that there was a strong south wind and waves were breaking on water areas south of the Florida Gas canal that were not heavily vegetated. Anyone who has spent any time in the Basin knows that wind causes ripples at the very least but can be rough when the wind is strong. They also noticed that near to AU2S water was flowing north into the Florida Gas canal being pushed by the wind.

Site AU2S is located north of the Florida Canal which is lined by high spoil banks, while AU6 is south of the is canal (Figure A3). The canal has an SW-NE orientation and south of it are a number of open water bodies with a fetch of about 4 miles before the next pipeline canal. A quick review of local weather data indicates that October through December were wet months with a total rain fall in excess of 18 inches, about 4 inches above normal, reflecting that a number of cold fronts crossed the area. Such would have produced strong south to southeasterly to east winds, so the raindrop splatter and the wind waves would have enhanced the dissolved oxygen content of these areas resulting in the DO being non-Anoxic for those three months. If this increase in DO was due to flood waters, then the AU2S site would have had a similar DO response.

This very quick initial review and attempt to interpret the TNC data reveal two very important aspects of the Basin. Firstly, flood water will locally improve DO for a short period but then the nutrient loading leads to eutrophication and eventually anoxic conditions develop. Secondly, other factors such as storm and wind events can have a dramatic impact on DO raising levels above the anoxic condition.

TNC do not give an explanation why the turbidity at site AU1 has spikes of up to 350 from 4/7/2018 to at least 5/2/2018 (Figure A16). Was this an instrument problem or was there some external process forcing this very high turbidity? Boat traffic maybe.

The bottom line is that this quick initial review shows the complexity of the Basin and that introduction of flood waters even with moderate floods will enhance Eutrophication and lead to anoxic conditions. A very different long-term approach is needed to manage the Atchafalaya Basin than that presently being implemented. Instrument calibration is extremely important.

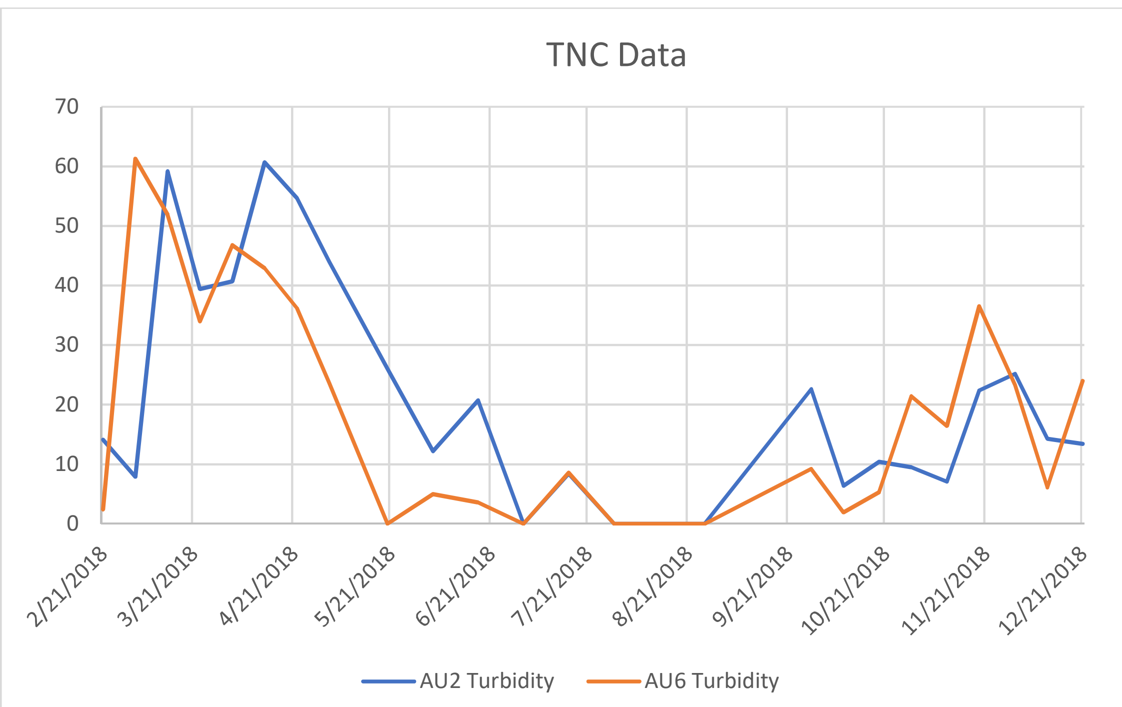

Figure A15a. Turbidity plots for sites AU2 and AU6 for the 2018-year, Source TNC 2018).

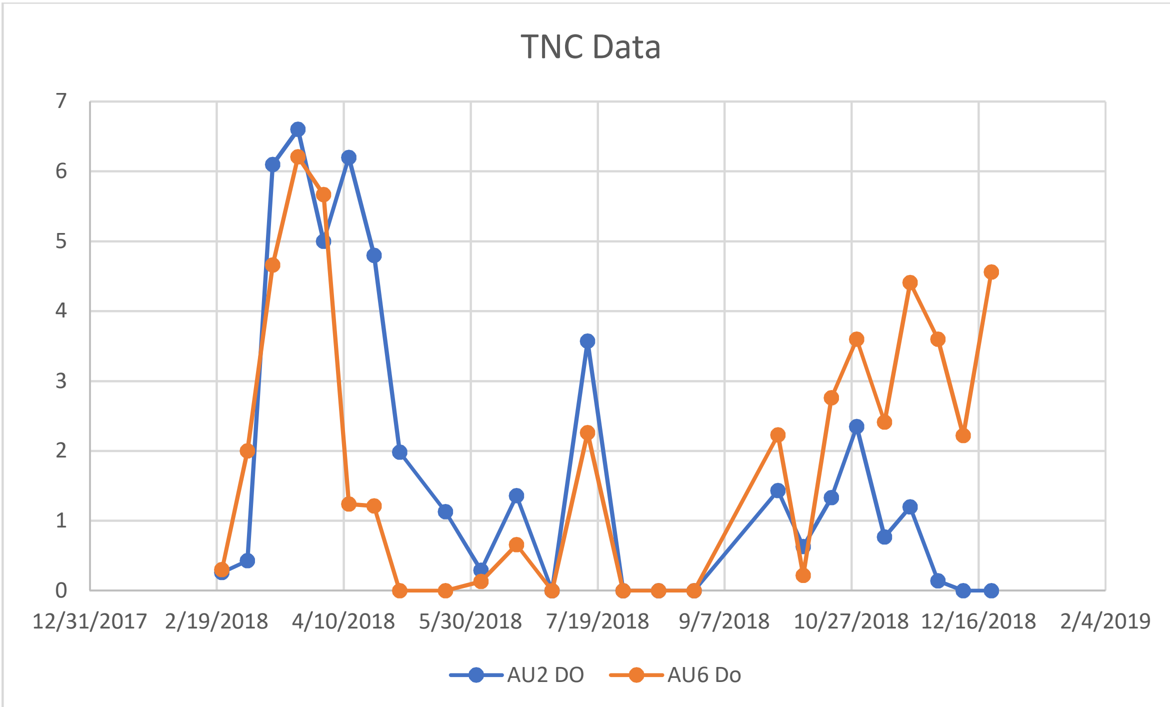

Figure A15. Dissolved oxygen plots for sites AU2 and AU6 for the 2018 year.(Source TNC 2018).

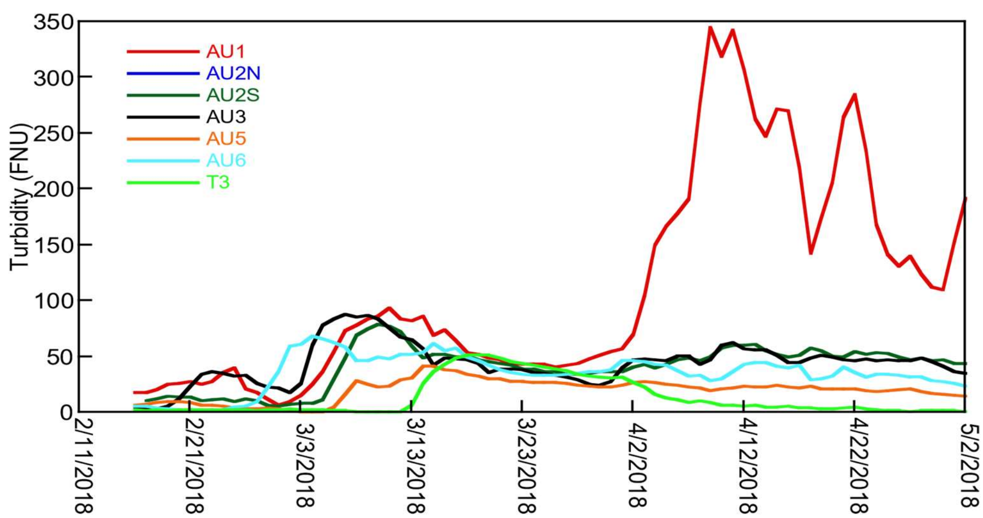

Figure A16. Mean daily turbidity at the backswamp monitoring stations from February to May 2018.

The Atchafalaya Basin Sediment Question – how much in, how much out, how much deposited?

It is important to understand the turbidity (suspended sediment and nutrient) concentrations of flood water of the Mississippi and is major distributary, the Atchafalaya. What is potentially being introduced to the back swamp through the numerous mostly man-made canals, channels, and, pipeline scars connected to the Atchafalaya River? Some pertinent data:-

1. 21% of the total sediment load entering the Atchafalaya Basin at its upper end is deposited in the Basin along with 50% of the sand. Roberts etal. (1978) revealed that 80% of the sand moves in suspension. As pointed out by the Louisiana Department of Natural Resources (LaDNR) (2019) these sediments do not reach the coast where they are needed. LaDNR further states, "Ongoing rapid and detrimental sedimentation in the Atchafalaya Basin fills swamps and waterways, impairs water quality, and degrades habitats. Conversely, areas of the Louisiana Coast outside the Atchafalaya Basin protection levees area experiencing erosion and subsidence and need sediment sources for restoration projects." This is the sad truth, we are compounding a public safety issue by our incorrect and short-sighted management of the Atchafalaya Basin.
2. Rosen (2013) states that average annual sedimentation rate in the Atcahafalaya River Basin is 30.4 to 79.1 mm/year or 1.2 to 3.1 inches a year or 12 to 31 inches a every 100 years. This rate is helped by the sediment distribution channels developed by the COE, pipeline channels and canals and back cuts. At this rate the Basin will cease to be a swamp in the very near future. Sediment retention in the Basin according to Rosen (2013) from 1996 to 2010 was 5.3 MT per year!
3. Hupp etal (2008) established 20 floodplain transects across the central Basin and determined mean sedimentation rates of 2 to 42/mm per year, not too dissimilar to the data collected by Rosen (2013). Sand moved as suspended load, content ranged from 5% to 44%. Hupp et al (2008) also state that areas with hydraulic connectivity to multiple sources of sediment laden water featured the highest sediment trapping. In other words, the more you connect a swamp to a channel the greater will be the sedimentation! Hupp et al (2008) sampled some sites close to the sampling sites occupied by TNC (2018) and Kong (2017) (Figure A17). Based on Hupp et al (2008) the sedimentation rate averaged 12.5 mm/year, basically a half inch a year or 5 inches in ten years. The highest rate was 1.5 in/year. The whole basin experiences inundation from Atcahafalaya River water; the whole basin is subject to high nutrient loading during flooding.
4. Before 1900, the Missouri–Mississippi River system transported an estimated 400 million metric tons per year of sediment from the interior of the United States to coastal Louisiana (Meade and Moody 2010, Kesel 2003, Mossa 1990,1996). During the last two decades (1987–2006), this transport has averaged 145 million metric tons per year (Figure A18). The cause for this substantial decrease in sediment has been attributed to the trapping characteristics of dams constructed on the muddy part of the Missouri River during the 1950s. However, reexamination of more than 60 years of water- and sediment-discharge data indicates that the dams alone are not the sole cause. These dams trap about 100–150 million metric tons per year, which represent about half the decrease in sediment discharge near the mouth of the Mississippi. Changes in relations between

water discharge and suspended-sediment concentration suggest that the Missouri–Mississippi has been transformed from a transport-limited to a supply-limited system. Thus, other engineering activities such as meander cutoffs, river-training structures, and bank revetments as well as soil erosion controls have trapped sediment, eliminated sediment sources, or protected sediment that was once available for transport episodically throughout the year (Meade and Moody 2010). According to Meade and Moody (2010), Removing major engineering structures to enhance sediment delivery to the Louisiana Coast such as dams probably would not restore sediment discharges to pre-1900 state, mainly because of the numerous smaller engineering structures and other soil-retention works throughout the Missouri–Mississippi system. Figure

5. Meade and Moody (2010) state with evidence from others that the actual true bedload (those sediments that roll or slide down the bottom of a channel) account for less than 5% of the total sediment discharge of the Mississippi River, rest is in the suspended mode.
6. Mossa (1989) revealed that the Atchafalaya and lower Mississippi rivers in south Louisiana show the following characteristics: a) Hysteresis effects are pronounced, especially during high discharge years where the sediment concentration and load maxima precede discharge maxima by several months and show decreased sediment concentrations by the time discharge peaks; b) The silt-clay and sand components of the suspended sediment operate distinctively; c) The total suspended-sediment concentration and the suspended silt-clay concentration follow quadratic power relationships; and d) downstream differences in discharge-sediment relationships are apparent.
7. The challenges of studying the Mississippi River are due to its complex sediment-water dynamics and the multiple (and often competing) uses of its resources. Flood control and navigation are primary factors that control how the river is managed. A third factor is the use of the river resources, namely water and sediment, for nourishing the degrading coastal wetlands of the states of Louisiana and Mississippi. As such, these factors must be fully considered and coordinated while developing techniques to harness the sediment resources of the River for coastal restoration (Mead etal, 2012).
8. Figure 11 below indicates that in the central portion of the Basin, over a 71-year period, 23 feet of sediment have accumulated in the Basin – strong evidence of physical change. I have not been able to date to get data to give me a better timeline of how much the average annual sediment deposition rate has changed over time, but strong physical evidence points to key levels of change.
   What is obvious is that there is ample sediment carried in the Atcahafalaya River to force marked physical changes on the Basin. Additionally, flood waters cover most of the basin annually.

   THIS RAISES A VERY IMPORTANT QUESTION: IS THE HYPOXIA PROBLEM IN THE BASIN TOTALLY THE ATCHAFALAYA RIVER'S FAULT? THE RIVER FLOODS EVERYWHERE AND NUTRIENT LOADING OCCURS AND THEN EUTROPHICATION RESULTS! PERHAPS WE ARE LOOKING UNDER THE WRONG TREE FOR SOLUTIONS!

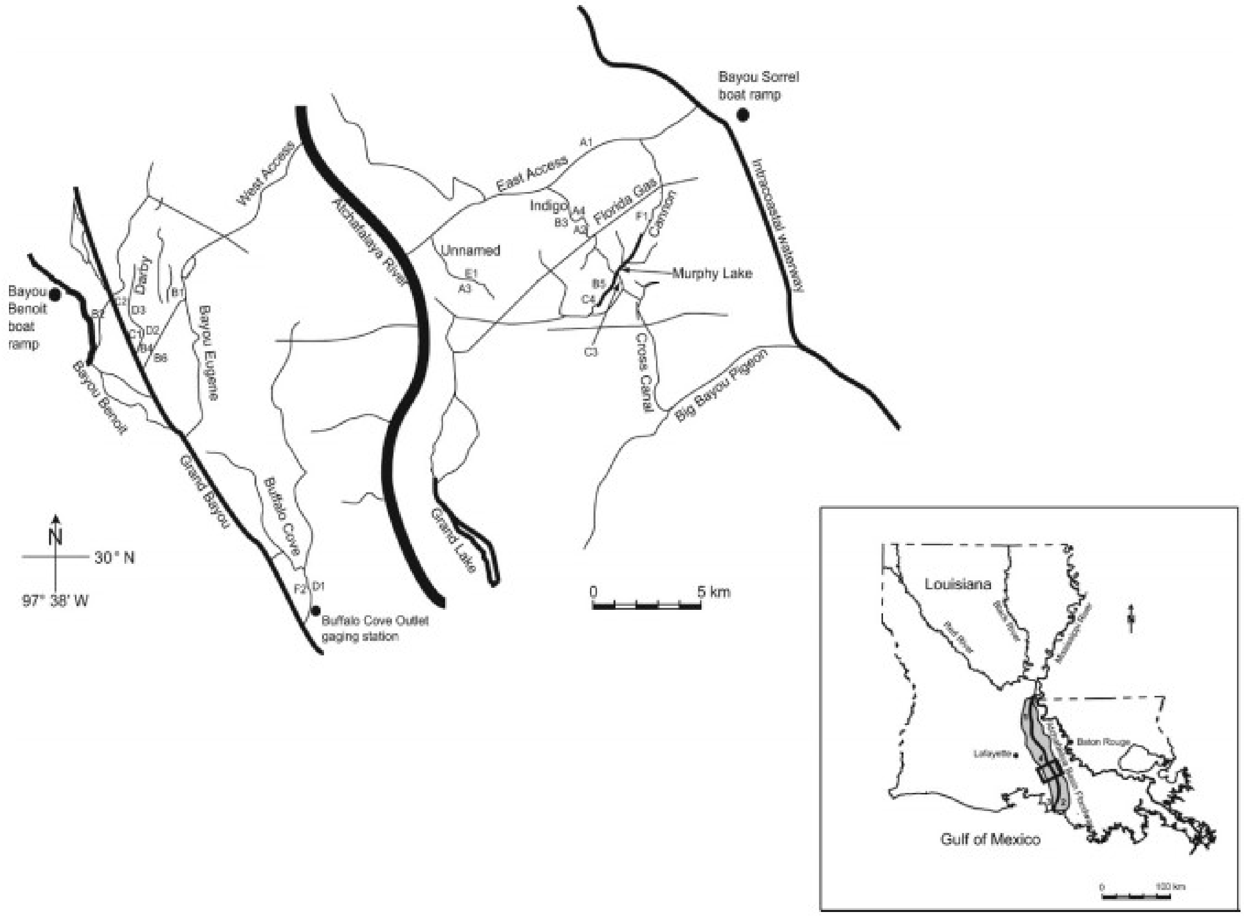

Figure A17 . Hupp et al (2008) sampling sites in the EGL project area.

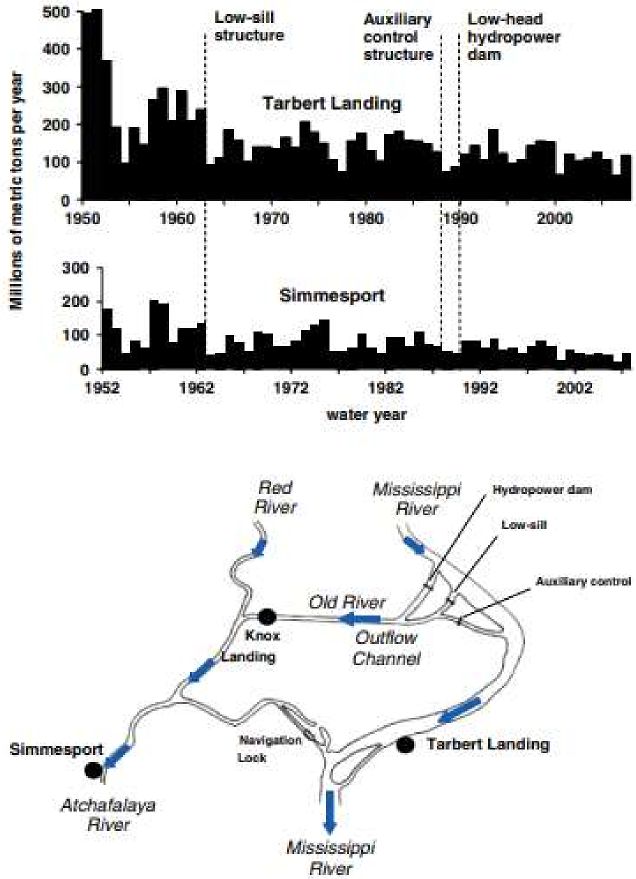

Figure 9. Suspended-sediment discharge, 1950–2007, Mississippi River at Tarbert Landing and Atchafalaya River at Simmesport. The map shows the present configuration of rivers and control structures at Old River, Louisiana. Flow measured at Simmesport is the sum of Red River plus the water and sediment diverted from the Mississippi River. The sum of the measurements made at Simmesport and Tarbert Landing, therefore, is the best available indication of the total amount of sediment being delivered by the combined Red River and mainstem Mississippi River to coastal Louisiana

Figure A18 . From Meade and Moody, 2010.

<u>The TNC Sediment Data</u>

The TNC data are presented in Table A1. Unfortunately, there is very little background data as to location, exposure time when dry, potential erosion during storms and such, so until such information is forthcoming the only attribute of the data is that the numbers are not to dissimilar to those recorded by researchers who have published in the scientific literature. Suffice to say, Atcahafalaya River water is flooding everywhere the EGL project is proposed and the reader’s attention tis drawn to the capitalized conclusion presented above.

Table A12. Cumulative surface accretion over a two-year period that included two flood events. Measurements of accretion were taken in August 2018.

Station	2-year Surface accretion (cm)	Annual Sedimentation rate in mm
R-1	0.2	1
R-2	6.8	34
R-3	2.0	10
C-1	5.8	29
C-2	1.3	6.5
C-3	4.6	23

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APPENDIX B

Review of
"RECENT SEDIMENTATION PATTERNS WITHIN THE CENTRAL ATCHAFALAYA BASIN, LOUISIANA"
by Cliff R. Hupp etal, 2008 (USGS Report)

by

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June 2019

The Atchafalaya Basin is filling with sediment at the fastest rate of all similar Basins in the US. About 14% of the annual sediment load of the Atchafalaya River is deposited in the Basin due to man's disruption of the natural system. Deposition is the highest in back swamp areas as compared to elsewhere, by orders of magnitude, reflecting suspended sediment input through mostly man-made channels and cuts. A totally new approach to managing this Basin is needed, post haste.

Introduction

Hupp etal (2008) start off by stating that over the past several decades the Atchafalaya Basin has experienced rapid and substantial amounts of sediment deposition. Many open water areas in the Basin have now filled (Roberts et al. 1980, Tye and Coleman 1989, McManus 2002); regionally, the Basin provides a sharp contrast to most of the remaining Louisiana coastal area, which is sediment starved and experiences subsidence and coastal erosion. They further state that the Atchafalaya Basin (Figure 1) is a complex of many meandering bayous and lakes that have been altered dramatically by natural processes and human impacts resulting from channel construction for oil and gas exploration and transmission, timber extraction, flood control, and navigation.

A brief depositional history of the Basin

Some of this discussion comes from my PhD Thesis (van Heerden 1983). From about 1550 to 1952 there was very little sedimentation in Atchafalaya Bay from the River. Most of the River sediment was deposited in the Atchafalaya Basin which was a wide shallow depression something like a combination of the present day Maurepas Swamp and Lake Pontchartrain. By 1952 it had almost reached a "sediment filled" state and that's when sediment started to make it way to the Bay. In 1962 we see the first real evidence of shallowing of the bay and distinct delta deposition and by 1973 the two deltas had started to emerge – the subaerial phase. If left alone there would still have been some deposition in the Basin into the surrounding swamps. But

Man's intervention has caused the sedimentation in the basin to continue long after it would have been reduced to very little. So, the overall dynamic of the Basin was and still is to advect the sediments along its main channels to the coast. The USGS data bears this out. However, and especially locally where cuts and man-made channels lead off the main channel, sedimentation has been rapid and gets into interior swamps.

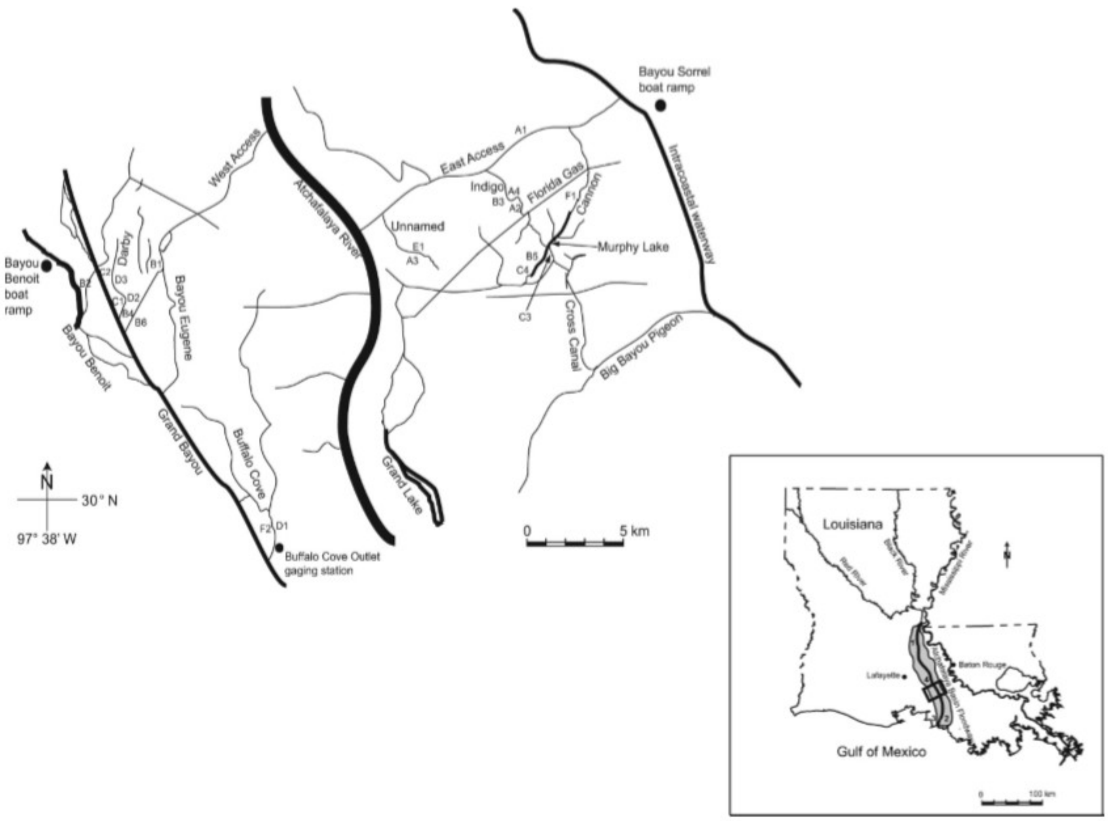

Figure 1. Map and detail of study area; Atchafalaya River divides the study area into east and west sides. Transect (site) locations are shown and correspond to abbreviations provided in Table 1. Flow on the Atchafalaya River is from north to south; the Butte La Rose stage gage is located about 25 river km upstream of the study area. Inset: State of Louisiana, study area is enclosed in box. Gaging stations are numbered: 1) Simmesport, 2) Morgan City, 3) Wax Lake Outlet, and 4) Butte La Rose.

In the past there would have been a north to south annual flood freshwater flush of the swamps with river water with very low nutrient levels. Now we have man enhanced flushes with high nutrient loads and Hypoxia is a concern.

<u>A short description of the USGS Study</u>

Hupp etal (2008) established 20 floodplain transects (Figure 1) that they felt reflected the distribution of depositional environments within the central Atchafalaya Basin and monitored general and local sediment deposition patterns over a three-year period (2000–2003). Deposition rate, sediment texture, bulk density, and loss on ignition (LOI, percent organic material) were determined near or just above artificial markers (clay pads) located at each station per transect. USGS selected 20 sediment monitoring transects (sites) aligned perpendicular to a canal or bayou that began on the channel edge (usually a levee) and continued into the low backswamp area. Each transect typically had four to six sampling points where periodic measurements were made of deposition rate (clay pad), texture, and composition; these sampling points were numbered consecutively starting with the lowest number nearest the channel. Transects ranged from 100–300 m in length; all levee stations along a transect are within 65 m of the adjacent channel.

Each transect was differentially leveled in detail using a laser level. Bank heights were measured near the beginning of each transect from the top of the bank (usually levee) to the low water elevation; all bank height and elevation measurements were corrected for water stage using the stage-only gage at Butte La Rose as a reference for the given date of measurement. Datum for the Butte La Rose gage is sea level (NGVD of 1929) (This is what I did for the EGL project review). All leveled sites were corrected to the Butte La Rose gage, such that a bank (levee) height of 3 m, for example, is assumed to be 3 m above sea level. This allows for site cross sectional information to be directly related to the gage and its documented stage-percent exceedance relation (hydroperiod – basically how long it is inundated by flood waters). Several site elevations were checked against the Butte La Rose gage at the time of measurement; there is an apparent water-surface drop in elevation between 0.076 and 0.15 m from the gage to any of the study sites.

<u>USGS pertinent results summarized below.</u>

Data are presented in Table 1. Cumulative deposition along transects (sampling stations from channel edge to backswamp) varied over the three-year period from 0 to 295 mm. Transect B1, B2, C2, and A4 had inaccessibility or other issues. Deposition rates varied along transect revealing three distinct spatial patterns: 1) uniform or no clear trend from levee to backswamp, 2) deposition mostly on levees decreasing toward the backswamp, and 3) little deposition on levee and increasing toward the backswamp (C3, D1, and F1, respectively as examples, Figure 2). There were no strong temporal patterns over the study period except that sampling dates in 2001 (calendar year) include part of a previous drought (Figure 2); samplings in 2002 and 2003, during near normal years, tend to show higher deposition at most sampling stations than 2001.

Percent exceedance is the percent of time, annually, that an elevation is equaled or exceeded by the flow stage; it is inundated. Elevations and percent exceedance ranged from about 4.6 to 1.3 m and 13% to 85%, respectively. Some USGS sites with high relief ranged about 3.5 m, while relatively flat sites ranged only about 0.5 m. Sites with low relief typically do not have substantial levee development. High deposition tended to occur on sites with low elevation and low relief.

Therefore, sites with relatively high elevation above typical bank heights (now past active levee building when deposition rates on the levee may have being high) tend to experience less sediment deposition than low sites with long hydroperiods as long as the sites have a good degree of connectivity to river water. On average, most of the USGS sites experienced flooding in the backswamps when the stage gage at Butte La Rose was about 2.8 m and the banks were overtopped about the 3.7 m stage, representing the 40% and 30% flow durations (percent exceedance), respectively. This elevation of when back flooding occurred in backswamps is very similar to the elevation van Heerden (2019) determined for the TNC and Kong sampling sites, using a slightly different method.

Table 1. Transect abbreviation, location, deposition rate, bulk density, percent organic material (LOI), percent sand (> 63 μ), and bank height (in relation to sea level) for 20 sites.

Site	Deposition Mm/yr	Bulk Density	LOI, percent	Percent > 63 microns	Bank Height, meters
A1 – Bayou Sorrel	1.8	0.95	28.2	15.4	4.21
A2 – Florida Gas canal off Indigo	2.2	1.08	24.1	13.3	*
A3 – Unnamed Bayou, West	2.2	1.12	14.9	16.5	3.90
A4 – Indigo Bayou, Old (A4)	2.4	1.10	21.4	16.0	*
B1 – West Access near Bayou Eugene	6.4	0.80	13.8	6.9	4.23
B2 – Bayou Benoit	7.3	0.38	*	4.7	1.30
B3 – Indigo Bayou, West	7.4	0.97	18.6	16.2	3.58
B4 – West Access Dog Beat, North	7.9	1.00	14.2	16.6	3.28
B5 – Murphy Lake, Daniel Hoover	9.9	0.59	13.8	14.1	1.67
B6 – West Access Dog Beat, South	10.1	1.12	8.8	10.1	3.09
C1 – Bayou Darby, 1 West	13.6	0.99	7.1	10.2	2.90
C2 – Bayou Darby, 2 West	14.1	1.11	1.8	40.7	2.29
C3 – Murphy Lake, Cross Canal	14.5	0.84	7.9	10.6	2.16
C4 – Murphy Lake, Point Bar	14.9	0.92	10.0	32.0	0.91
D1 – Buffalo Cove, South	19.2	0.88	9.1	7.5	2.41
D2 – Bayou Darby, 1 East	19.3	1.02	7.2	17.8	3.05
D3 – Bayou Darby, 2 East	20.7	1.00	5.7	9.2	2.21
E1 – Unnamed Bayou, East	26.3	1.31	2.4	43.6	3.68
F1 – Florida Gas at old Bayou Canon	36.5	1.02	15.8	12.3	4.74
F2 – Buffalo Cove, North	42.0	1.11	7.0	4.9	2.08

*Missing values at A2 and A4 resulted from incomplete surveys, B2 was inaccessible during sampling period; none of these sites were used in detailed analyses, as explained in text.

The USGS study showed that sites that showed all the conditions to facilitate sediment deposition: 1) high connectivity to sediment-laden water, 2) long hydroperiod (low banks), 3) multiple sources of flow, and perhaps most importantly, 4) hydraulic damming or better described as a stilling basin, had very high annual deposition rates.

Transect mean sedimentation rates ranged from about 2 to 42 mm/yr., mean percent organic material ranged from about 7% to 28%, mean percent sand (≥63 μ) ranged from about 5% to 44%, and bulk density varied from about 0.4 to 1.3. Sites with low elevation (long hydroperiod), high hydraulic connectivity to multiple sources of sediment-laden water, and hydraulic damming (flow stagnation in a stilling pond) featured the highest amounts of sediment trapping; the converse in any of these factors typically diminished sediment trapping. Based on aerial extent of clusters, the study area potentially traps 6,720,000 Mg of sediment annually, of which, 820,000

Mg represent organic materials. Thus, the Atchafalaya Basin plays a substantial role in lowland sediment (and associated contaminant) storage, including the sequestration of carbon.

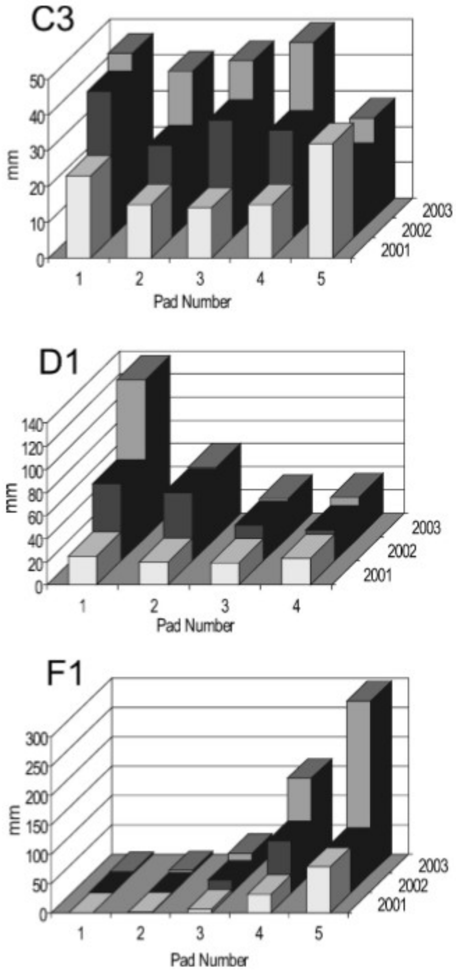

Figure 2. Temporal and spatial sediment deposition patterns for selected sites that represent three distinct trends along transect; transect C3 with even or no spatial pattern, transect D1 with deposition decreasing from the levee to the backswamp, and transect F1 with deposition increasing from the levee to the backswamp. Cumulative net deposition (over three years) above each clay pad in a transect

How does the 2018 TNC Sediment data relate to the Hupp (2008) study?

Figure 3 from the 2018 TNC Report displays their sample sites. However, this report does not supply any site specifics information such as GPS coordinates, elevations, nature of vegetation, substrate and such. These sort of description data are essential if one is to assess the TNC data. In order to try and arrive at some of this information the TNC sites were plotted as best as possible on a 1998 Google Image of the Basin (Figure 4). This black and white image was chosen as it readily showed the different plant patterns and some of the channels. The actual cumulative surface accretion data are presented in Table 2.

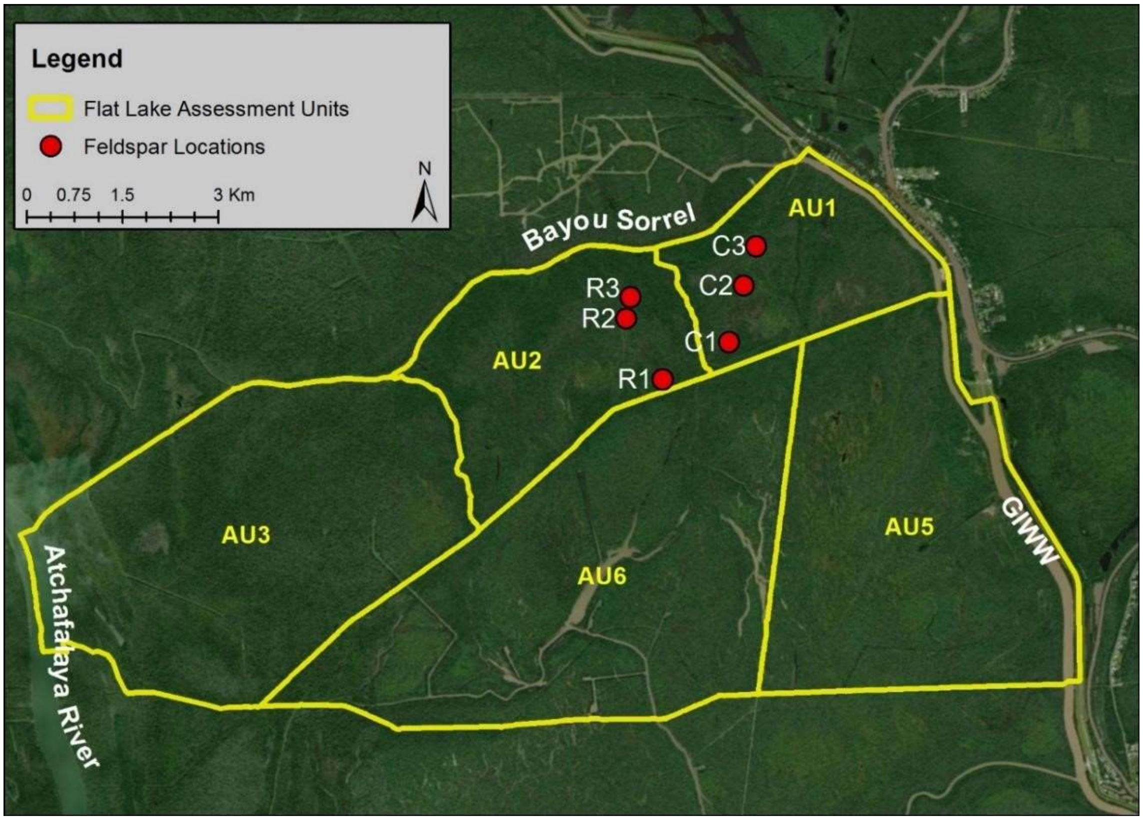

Figure 3. Location of the TNC 2018 sediment sites. These are all east of the data collected by the USGS but in the central portion of the Basin

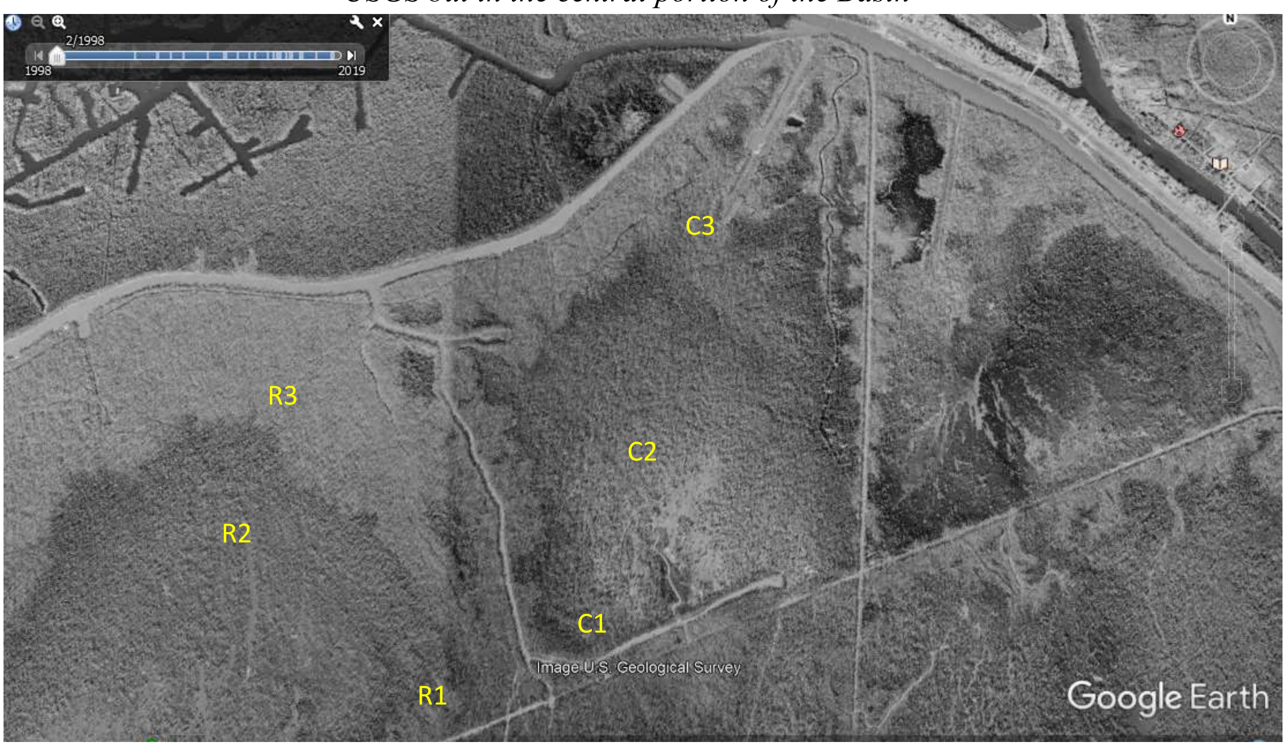

Figure 4. The 2018 TNC sediment sites replotted on a 1998 Google Earth image.

Table 2. Cumulative surface accretion over a two-year period that included two flood events. Measurements of accretion were taken in August 2018.

Station	2-year Surface accretion (cm)	Annual Sedimentation rate in mm
R-1	0.2	1
R-2	6.8	34
R-3	2.0	10
C-1	5.8	29
C-2	1.3	6.5
C-3	4.6	23

Sites C1, C2 and C3 are located in a 'polder' that is completely encircled by man-made channel or pipeline excavations and as such would be bound to some extend by spoil pile levees. So, there would be a tendency for whatever suspended sediment got into the polder stay within its boundaries. To the north is Bayou Sorrel and the east Humbolt Canal and northeast the GIWW, all significant carriers of suspended sediment during floods. So, this polder would get flooding from both Bayou Sorrel and the larger GIWW. Two major sources.

Site R1, R2, and R3 are located in a much larger polder than their C cousins, a polder that is almost three times as large, has less defined channel boundaries and hence levees (Figure 3, 4, and 5). It is also only 'connected' to Bayou Sorrel, as mentioned earlier a carrier of less sediment that the GIWW. So, one would assume that the C suite would have higher sedimentation rates that the R suite.

The TNC sites C3 and R3 appear to be on higher ground but close to canals or sloughs connected to the main channel (Bayou Sorrel) north of them. The annual sedimentation rates as measured by TNC are 23 mm/yr. and 10 mm/yr. respectively. C3, which has the highest annual sedimentation rate, is close to or within what appears to be a man-made channel in this levee lined 'polder' section of the basin. The USGS data refer to these sites as pointbars and generally have deposition rates in excess of 20 mm/yr. The interior portions of the polder appear to be cypress trees. The C3 and R3 TNC data are inline with that reported for levee locations, with low relief, in the USGS 2008 study.

TNC C2 (Figure 4) and R2 (Figures 4 and 5) are seemingly backswamp locations with C2 again within a much better defined and smaller polder. The TNC annual sedimentation rates were 6.5 mm/yr. and 34 mm/yr. respectively. Site R2 is in line with the USGS data collected in similar sites in that most of the sedimentation occurs in the backswamp reflecting the hydraulic blocking, the stilling effect of the low flow environments. Site C2 seemingly reflects the levee scenario presented by the USGS (Figure 2), where sedimentation falls off with distance from the channel.

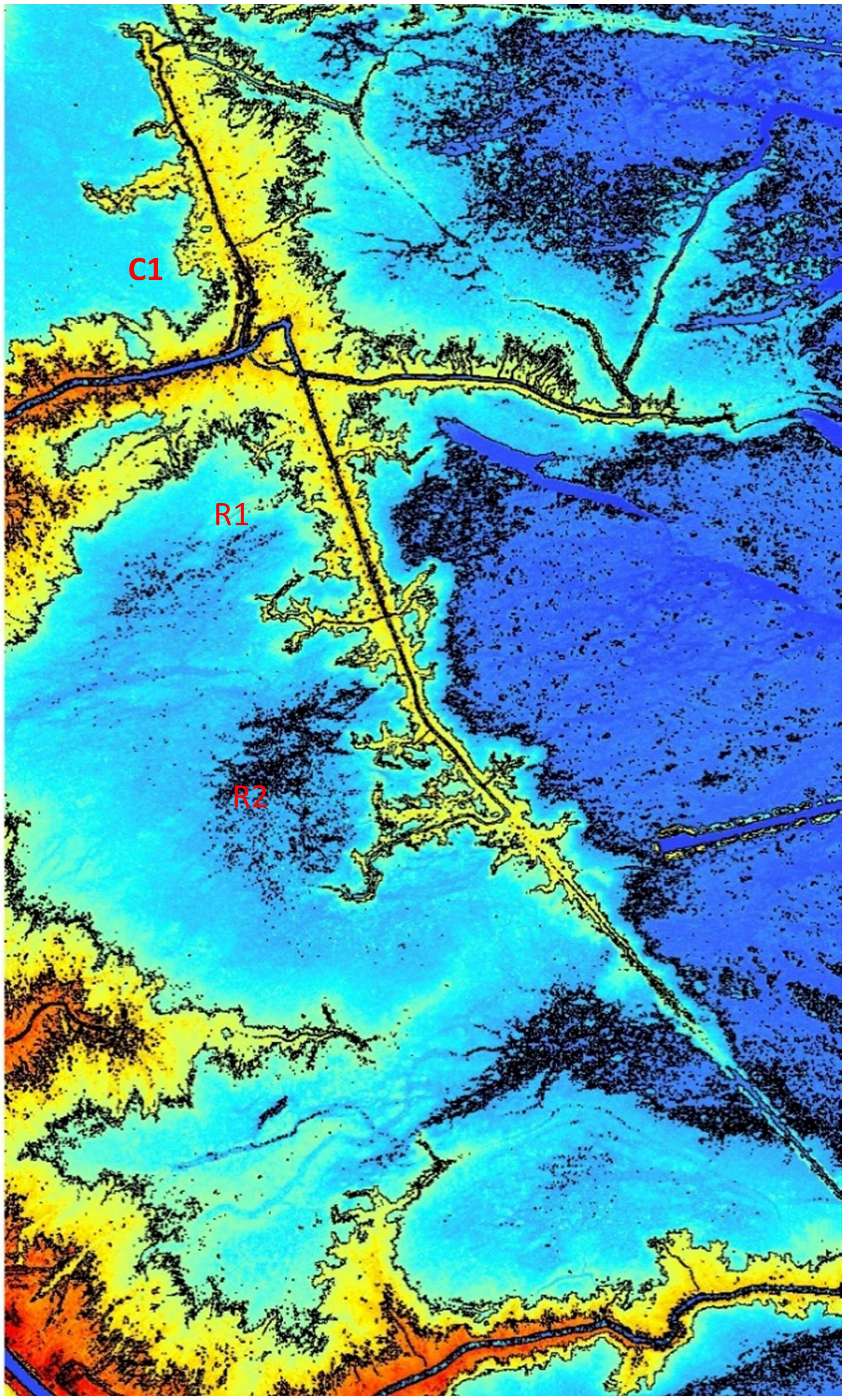

Figure 5. LiDAR Image on the intersection of Salt Mine and Florida Pipeline Channel, Note the sediment fingers extending in three directions and the significant sedimentation that has occurred on both banks of Salt Mine. North to left. Brighter the color the higher the land. Ci, R1 and R2 shown (Modified from van Heerden 2019).

TNC C1 and R1 are located at some distance from the main sediment sources (Figures 4 and 5). In the case of C1 there are channels that basically wrap around the location which, because it is at the southern edge of the polder, would have a lower elevation (Figure 5). This location is a trap site and as such the sedimentation rate is high, namely 29 mm/yr.; higher than the direct channel location of C3 further to the north. Site R1 is the furthest of all R sites from the main suspended sediment feeder channel and as such would receive the least amount of sediment annually (Figures 4 and 5). Additionally, it would appear that this polder's boundary levees are not closed, in other words flow entering this polder from the north can exit to the south west.

This review of the USGS paper and the sedimentation data advanced by TNC in 2018 reveals that there are a number of factors that determine the sedimentation rate at any particular site and that it is not transferable from one site to the next. Inundation period, closeness to sediment sources, back swamp or levee, and stilling basin damming all enhance sedimentation. Most importantly the USGS and TNC data prove that backswamps generally trap the greatest rates of suspended sediment deposition given their near perfect conditions for such.

<u>Important Implications and Aspects of This Paper</u>

1. Suspended sediment may be the most important water-quality concern in the United States today (USEPA 1994). Increases in suspended sediment, directly and indirectly affects aquatic plants and animals. In critical riparian areas, high sediment deposition rates may damage other living resources such as riparian vegetation. Additionally, fine suspended sediment is the transport medium for hydrophobic forms of nutrients and pesticides, and most trace elements (Horowitz 1991).
2. Growth of the Atchafalaya and Wax Lake Deltas indicates a substantial supply of sediment leaving the Basin. Mean daily discharge (6,031 cms) of water passing the Simmesport gaging station (1, Figure 1) located near the head of the Basin (inflow) for the period of the USGS study (2000– 2003) approximates the sum of discharges leaving the Basin (6,066 cms) past the Wax Lake and Morgan City gaging stations (3 and 4, Figure 1, respectively). This same approximation is demonstrated in daily suspended load for the three gaging stations; 124,352 Mg enters the Basin (1, Figure 1) while 134,986 Mg exits the Basin (3 and 4, Figure 1). Thus, during the USGS study period there was no net storage of sediment in the Basin; indeed, there was a small surplus that aids the prograding deltas in Atchafalaya Bay. However, within the Basin millions of megagrams of sediment are trapped annually, suggesting there is compensating erosion and resupply of sediment from elsewhere in the Basin. Presumably, the sediment load leaving the Basin is derived mostly from in-channel stores and functions much like a reservoir in equilibrium, where sediment trapping is matched by sediment transport out of the Basin Hupp etal 2008).

3. All flow within the Basin is regulated by structures upstream operated by the U.S. Army Corps of Engineers. Much of the flow in all of the waterways has been altered through various activities (opening cuts, blocking channels) to divert water through the system for various management options (typically for access, pipeline construction, or channel maintenance). Flow in many of the bayous and canals carries high sediment loads resulting from the ambient alluvial nature of both the Mississippi and Red rivers and, in some cases, due to substantial resuspension of channel sediment.
4. From about 1550 to 1952 there was very little sedimentation in Atchafalaya Bay from the River. Most of the River sediment was deposited in the Atchafalaya Basin which was a wide shallow depression something like a combination of the Maurepas Swamp and Lake Pontchartrain. By 1952 it had almost reached a "sediment filled" state and that’s when sediment started to make it way to the Bay. In 1962 we see the first real evidence of shallowing of the bay and distinct delta deposition and by 1973 the two deltas had started to emerge subaerially. If left alone there would still have been some deposition in the Basin into the surrounding swamps. But Man's intervention has caused the sedimentation in the basin to continue long after it would have been reduced to very little. So, the overall dynamic of the Basin was and still is to advect the sediments along its main channels to the coast. The USGS data bears this out. However, and especially locally where cuts and man-made channels lead off the main channel, sedimentation has been rapid and gets into interior swamps.
5. In the past there would have been a north to south freshwater flush of the swamps with river water with very low nutrient levels. Now we have man enhanced flushes with high nutrient loads.
6. The USGS claim the Basin is 5,670 sq. km or about 140,000 acres. The USGS data basically shows that most of the sediment moves through the Basin to the coast but what gets out of the channels does have serious impacts for the Basin. The USGS suggests that about 10% of the total sediment load of the river, based on their deposition rate data, is deposited in their 98,000-acre study area (about 70% of what they claim is the area of the Basin). So, assuming the Basin is 140,000 acres, then the whole Basin trapped about 14% of the total Atchafalaya sediment load. But the river 'robs' this 'lost' sediment from somewhere else such as channel sides and bottoms (according to USGS) so that what comes into the basin leaves the basin at the bottom end, to the Bay. Without redoing all their math, it seems their number is a bit high. suffice to say, even if it is 14% of the annual sediment load it is much higher than if man had not interfered with the dynamics of the Basin.
7. The USGS study showed that sites with all the conditions to facilitate sediment deposition: 1) high connectivity to sediment-laden water, 2) long hydroperiod (low banks), 3) multiple sources of flow, and perhaps most importantly, 4) hydraulic damming or better described as a stilling basin, had very high annual deposition rates.

This USGS sedimentation data along with the TNC sedimentation data as well as the study of the cause of Hypoxia by van Heerden (2019) utilizing Kong's 2017 data as well as that from TNC for 2016, 2017, and 2018, very strongly expose that utilizing channel cuts, levee shaves or breaches , or permitting anymore pipeline channels will lead to further irreparable destruction of this very unique and God given wilderness. Numbers are just numbers unless one tries to understand the dynamics that drives the system. "The catalyst to compromise is a through understand of the science."

The moral of the story is that the Atchafalaya Basin is infilling with sediment at an alarming rate that reflects the mis management of man. It is critical that a new science driven Big-Picture approach be formulated and implemented as soon as possible.

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