EXPERT REPORT

of

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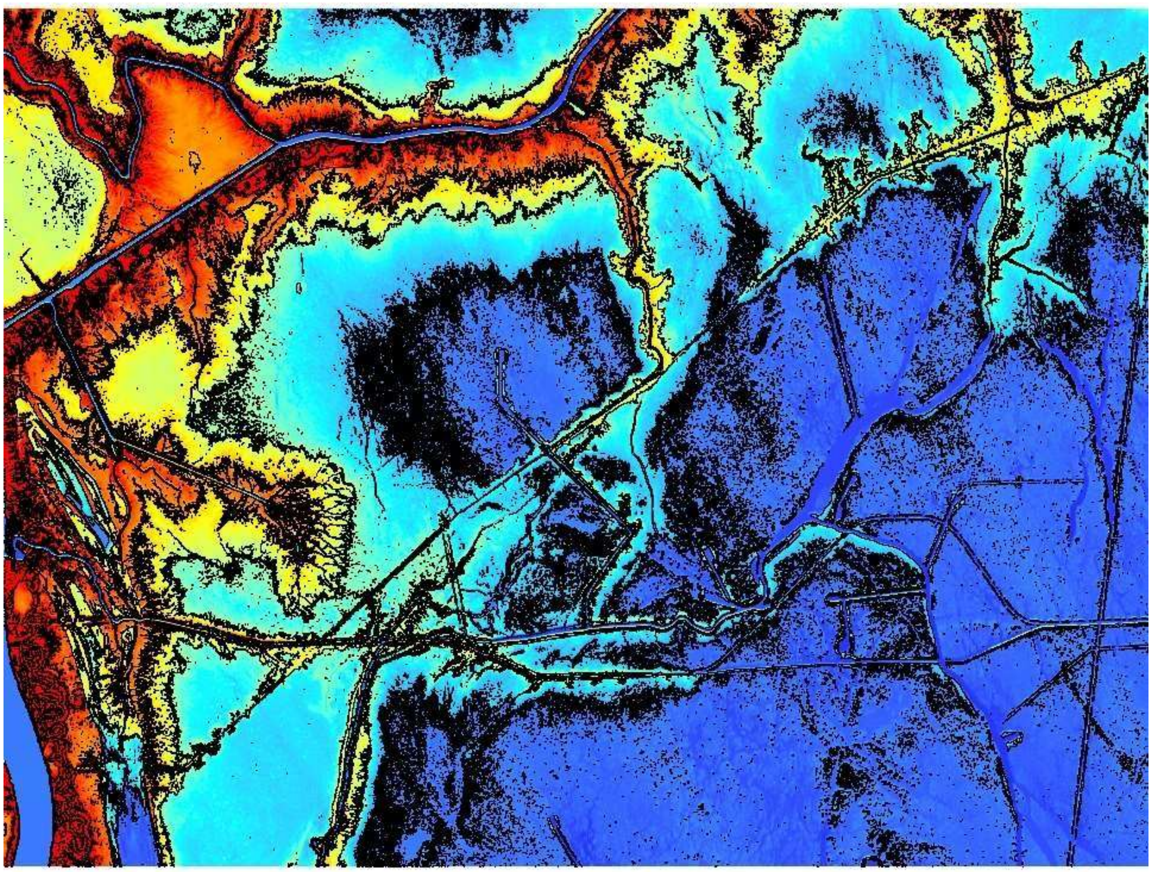
Agulhas Ventures, Inc

Reedville VA 22539

ON BEHALF OF ATCHAFALAYA BASINKEEPER ET AL

MVN-2016-01163-CM



2nd April 2018

EXPERT REPORT ON PROPOSED EAST GRAND LAKE PROJECT (EGL)

Ivor L. van Heerden, Ph.D.

INTRODUCTION

The EGL project consist of 13 sites where altering the environment is proposed, generally to increase the flow of suspended sediment-laden waters from channels into cypress swamps (Figure 1), to their long-term detriment.

This document consists of two Sections. The first discusses the proposed EGL project directly; the second details some of the fundamental ecological/geomorphological concepts related to the Basin; relevant background.

The Atchafalaya Basin, South Central Louisiana, is truly one of the ecological wonders of the Earth. Man is 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, 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.

Sediments originally from the Atchafalaya River move along man-made canals and channels in suspended sediment mode – they are well mixed through the water column - and if the channel is confined can travel tens of miles in suspension. Wherever the channel goes from a confined to an unconfined state sedimentation is very rapid forming delta like deposits (See Figure 1). During Atchafalaya River Flood stages (late winter, spring, early summer) these suspended sediment laden waters also overflow the banks and suspended sediment deposition leads to levee aggradation. Thus, in one flood season suspended sediments using these linear intrabasin connections can be deposited over large areas and lead to significant shallowing and physical change. Any channel/canal with lateral cuts is a very efficient conduit to transport sediment into the interior locations of the Basin. Any cut made through a levee, whether man-made or natural, enhances suspended sediment deposition in the cypress swamps.

Even if a channel is blocked off from the main river, once the Atchafalaya River starts to overtop its banks with a rising flood, these flood waters will preferentially flow towards the channel and use it; the channel offering an efficient linear low friction pathway for flood waters to flow into interior portions of the cypress swamp.

THE PROPOSED EGL PROJECT

The Louisiana Department of Natural Resources, c/o Sigma Consulting Group, Inc. seeks permits and certification for its proposed swamp enhancement project in the Bayou Sorrel area of the Atchafalaya Basin, hereinafter referred to as the "East Grand Lake" or "EGL" project. The character of work for which the applicant seeks permits from the Corps and DEQ, as described in the March 19, 2018 Joint Public Notice, is to clear, grade, excavate, dredge, and place fill within the Atchafalaya Basin, to include Bayou Sorrel, the Gulf Intracoastal Waterway and the Florida Pipeline Canal. The work will include shaving and dredging existing spoil banks, clearing, snagging, excavation, dredging and placement of spoils in designated areas. The Notice provides that 25,535 yards of native material will be excavated and re-deposited to complete the project, and that 2.4 acres of jurisdictional wetlands will be directly impacted by clearing and conversion to open water, that approximately 8.3 acres of jurisdictional forested wetlands will be cleared and excavated to become open water, and approximately 5.8 acres of jurisdictional forested wetlands will be cleared and filled. The Permit Application concedes that the project footprint will impact 16.51 acres of wetlands. See ENG FORM 4345, Application for Department of the Army Permit, MVN 2016-01163-CY, Feb. 19, 2018, at 2, para. 23.

The purported purpose of the project is "to improve the north to south hydrologic flow in Bayou Sorrel during moderate river stages to improve the circulation and ecological function through the back swamp of the East Grand Lake Area of the Atchafalaya Basin." The Notice suggests that the area that stands to benefit from the proposed activity's "hydrologic restoration" in EGL includes "approximately 5,560 acres of swamp habitat" and that the project will "enhance and improve existing forested wetlands." Joint Public Notice, March 19, 2018.

The EGL project consist of 13 sites where altering the environment is proposed, generally to increase the flow of suspended sediment-laden from channels into backwater swamp locations (Figure 1).

SECTION 1. THE EGL PROJECT AND ITS CONSEQUENCES - WHY ARE CUT CHANNELS SO HARMFUL?

In reviewing this Application, I relied upon field trips in September 2017 and again in January 2018, my many previous visits to the area over the last 40 years and research, the Joint Public Notice (March 19, 2018) and the scientific literature. In terms of the Joint Public Notice I could not find any documentation as to the scientific reasoning for the assumed benefits, no apparent understanding of the impacts of the suspended sediment and its transport mechanisms. Engineering design diagrams are not science.

Cypress swamps are fragile, require very unique conditions of hydrology, geomorphology and sedimentation to germinate, sprout and grow. If the environment is kept pristine in that the

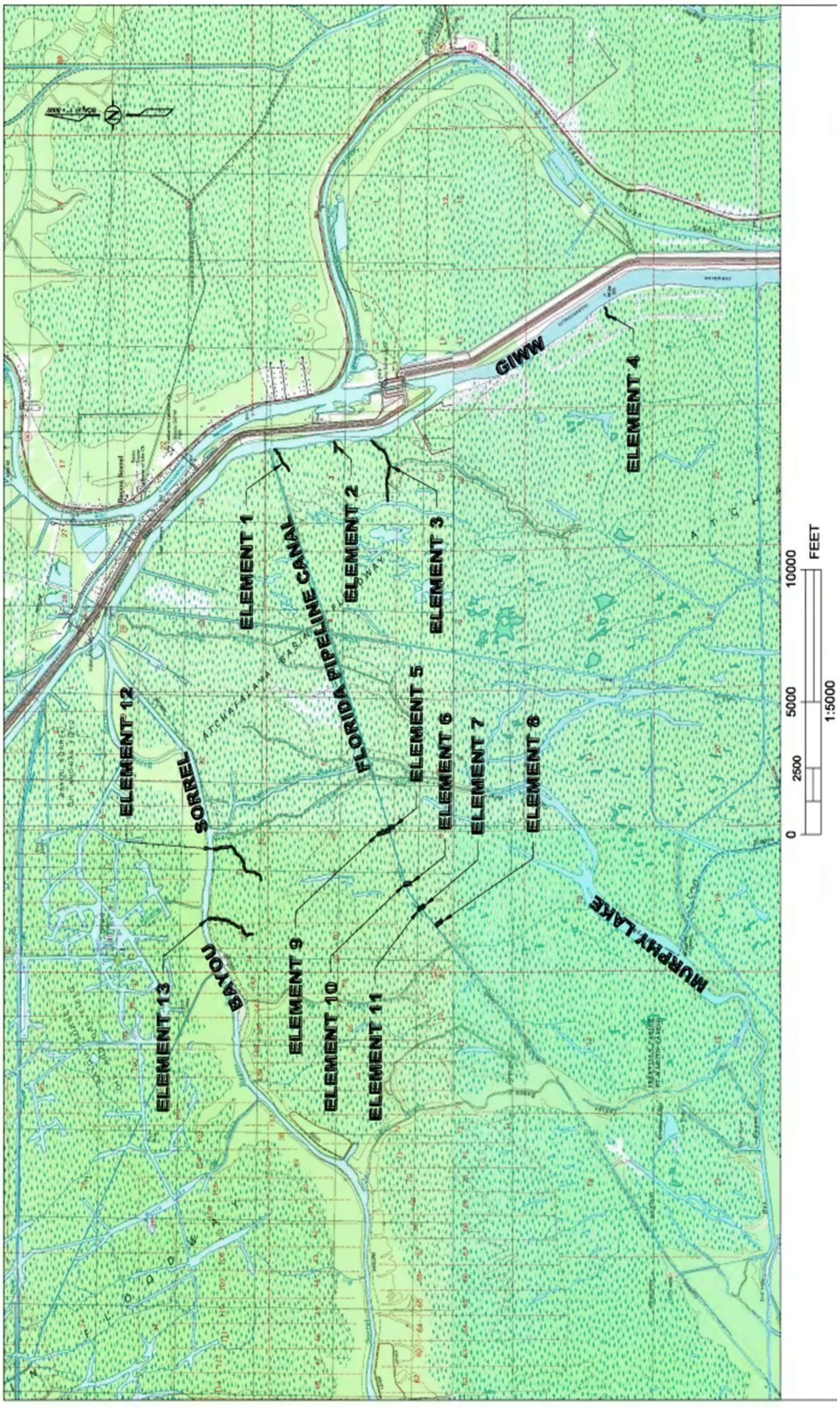


Figure 1. Location of EGL project in Atchafalaya Basin

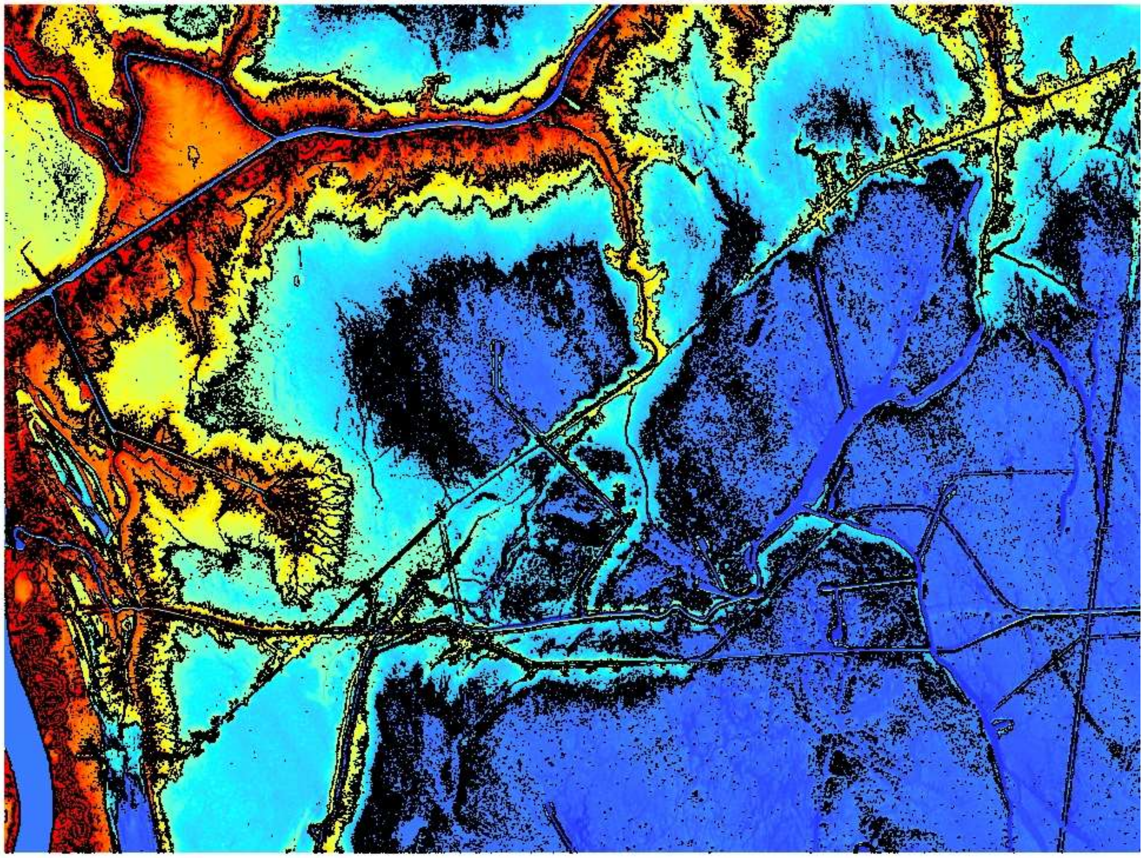


Figure 2. LiDAR image of Atchafalaya Basin centered on the Florida Pipeline Canal. Note the higher elevations spreading out from channels and canals (light blue to yellow to brown).

physics do not change then these swamps can survive for thousands of years. Louisiana was blessed with millions of acres of these biological wonders, but man, through altering the physics and the physical environment, has destroyed most of these swamps. The Atchafalaya Swamps are under direct threat as the physics of the environment undergoes dramatic changes. These swamps survived by limited over bank (levee) flows during periods of high river stages where the suspended sediment was deposited on the natural basin levees and some fine-grained clays, organic matter and nutrients would, through overbank flow, enter the Basin and slowly drain out at its seaward ends, maintaining the health and integrity of the system. Hydrology and circulation is aided by the 60 plus inches of rain that falls in the Basin each year. So over 5 feet everywhere. A North to South flow existed reflecting the natural slope of the Basin. That is not the case today as will be discussed below.

In excavating channels, whether 100 yards or many miles in length, cypress trees some over 1500 years old and mostly more than 100 years old are shredded, the mulch created adding to the organic load of the system enhancing the capacity for anoxic low oxygen (hypoxia) conditions to form. The result of just removing the tress is a major reduction in friction along the 'channel' enhancing the ability of suspended sediment laden flow to use this treeless conduit to reach interior portions of the swamp. Generally, a canal is excavated with spoil placed on either one side or both sides of the channel and a deep straight conduit will result with the capacity to transport many miles any suspended sediment load that enters the channel. Removing a linear pathway of trees and then excavating a channel complement each other (Figure2). Many times, “blame’ is just placed on the excavated channel, and little or any consideration is given to creating of the treeless conduit, which becomes very functional during periods of high River stages when the water level exceeds base level. As presented in Section 2, we know that 100% of the sediment that moves down cuts, channels, canals in the Basin moves in the suspended mode, especially in high River stages. The probability of transport of tons of suspended sediment with the Atchafalaya River now on the rising part of its hydrograph cycle is very high. Thus, any channel or canal, is a very efficient conduit, will transport large volumes of sediment into interior portions of the Basin enhancing the infilling of the swamp and its rapid demise. Typically, spoil is not colonized by cypress trees; rather willows, sycamores and other invasive trees that detrimentally impact native organisms will take root. The impacts of this EGL project will be permanent.

THE LiDAR SAYS IT ALL.

LiDAR, which stands for Light Detection and Ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. It is very accurate and is now the tool of choice in mapping and producing elevation maps of the Earth. Figure 3a covers a section of the Basin from Bayou Sorrel including the Florida Pipeline Canal. The yellow and brown areas represent higher land always on either side of canals/channels. The wider or more robust high areas are all associated with Bayou Sorrel. This is to be expected as this Bayou is the source of the suspended sediments that enter the Bayou from the Atchafalaya River/Whiskey Bay Pilot Channel. The mechanisms for suspended sediment movement and the

Figure 2. A typical channel after excavation and cypress tree removal. A low friction conduit.

role the misaligned Bayou Sorrel plays in capturing tons of suspended sediment from the River are discussed in detail in Section 2. Suffice to say one can see ample evidence of these sediment fingers stretching into and delivering sediment to inner parts of the swamp (Figure 3a – brown, yellow, light blue pixels). Wherever there is a channel/canal connecting to the Bayou’s sediment laden waters; these function to divert flow downgradient into the swamps. This is the real curse of the way the Basin has been managed. While the realignment and opening up of Bayou Sorrel was originally claimed to be a water quality project it was in fact a sediment introduction project (See Section 2.) Where channels connecting to the Bayou have some cross section mini delta lobes have formed (Figure 3a, lower mid of image).

The lower left part of Figure 3b shows a basin delta that has formed at the end of a pipeline canal that is connected to Bayou Sorrel very close to the take off point the COE excavated in the outer bend of an Atchafalaya River meander. It is a text book example of such a basin delta or delta lobe and exhibits bifurcating channels and crevasse splay type channels upstream of the delta. To the west of this pipeline channel are three similar channel deposits but because of their smaller size are not elongating as deltas by as sinuous channels but never-the-less elongating into the Basin.

The bottom line; you create a sediment conduit by both removing trees and excavating a channel and the suspended sediment will take advantage and deposits will elongate into the Basin. The sad fact is that the Atchafalaya Basin is geological and geomorphological unique, we will never make another. The sediment introduction is permanent and irreparable.

Figure 3c is a close up of the junction of Salt Mine and Florida Pipeline Canal. It represents an area getting sediment from Bayou Sorrel via Salt Mine and the GIWW via Florida Pipeline Canal. Note the sediment fingers extending in three directions and the significant sedimentation that has occurred on both banks of Salt Mine. This is again direct proof that Salt Mine connected to Bayou Sorrel, and Florida Pipeline Canal connected to GIWW, are very significant transporters of suspended sediment from their source channels into the interior swamps; swamps that are now lost forever. This is again ample evidence that if you interfere with natural processes there will be drastic physical results. The negative impacts of these canals whether Bayou Sorrel, the GIWW, or Salt Mine, or Florida Pipeline Canal, is that these will only enhance the negative impacts of allowing suspended sediment flows to enter interior portions of the swamps. Excavate or build them and there will be negative consequences for the Basin.

Figure 3d is the end of the navigable western end of the Florida Pipeline Channel. Note how the suspended sediment flows have taken advantage of any opening to create sinuous basin directed delivery systems. The LIDAR imagery does not lie, allow any connection to the River and its extremely high suspended sediment load, create the efficient transport conduits, and you will add to the rapid deposition and loss of the swamps.

POTENTIAL SUSPENDED SEDIMENT LOADING OF INTERIOR SWAMPS AS A CONSEQUENCE OF EGL PROJECT.

This discussion is based on data principally collected by the US Geological Survey and is a first cut at determining the depositional impacts of the EGL project, deposition of sediment that is in interior swamps. Welch, etal (2014) present data on suspended sediments, Nitrogen and Phosphorus, amongst others during the 2011 Mississippi River flood which occurred from April

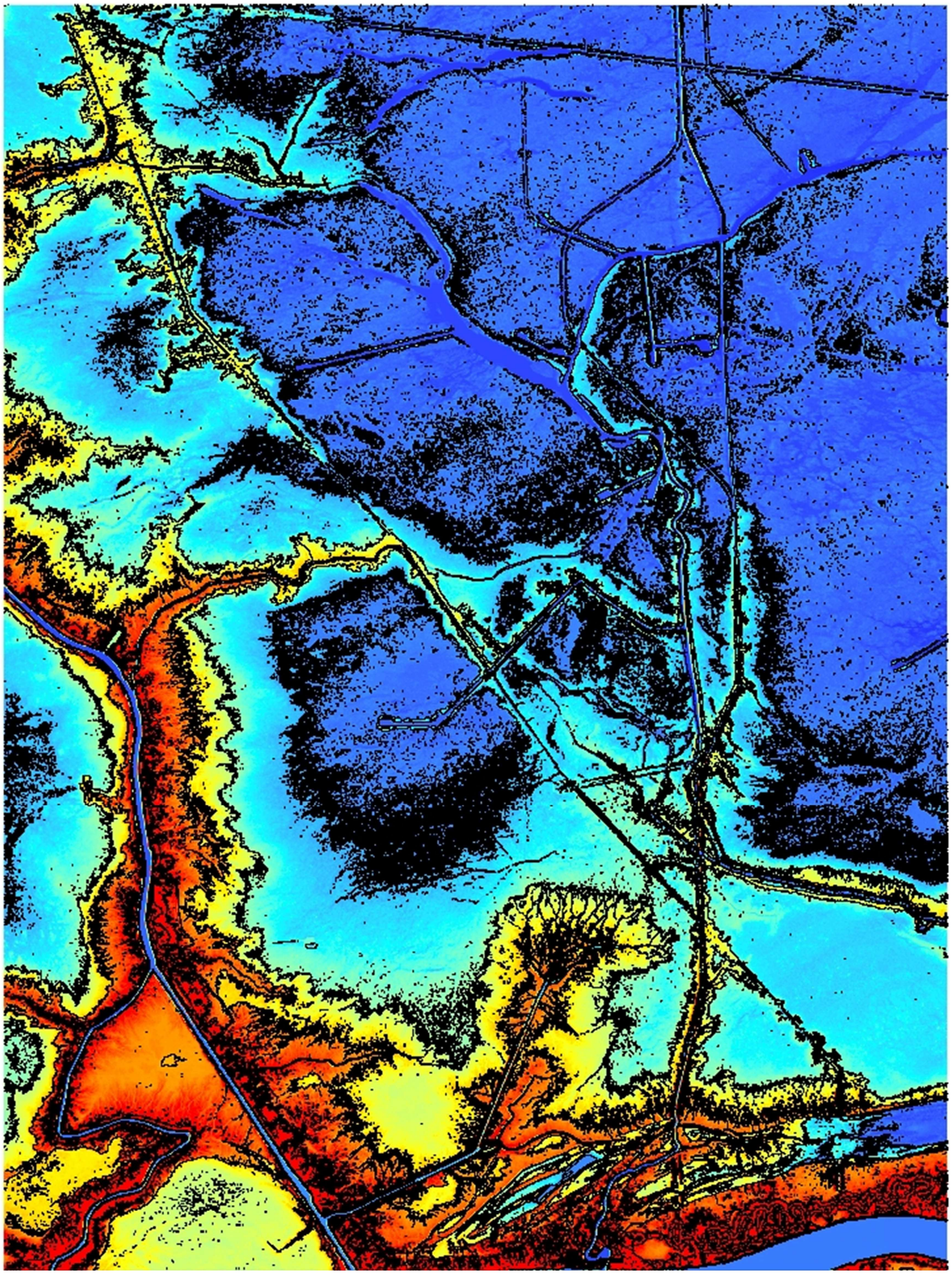


Figure 3a. LiDAR image that extends from Bayou Sorrel in the North southwards with the Florida Pipeline Canal crossing from NE to SW. Image orientated with North to left.

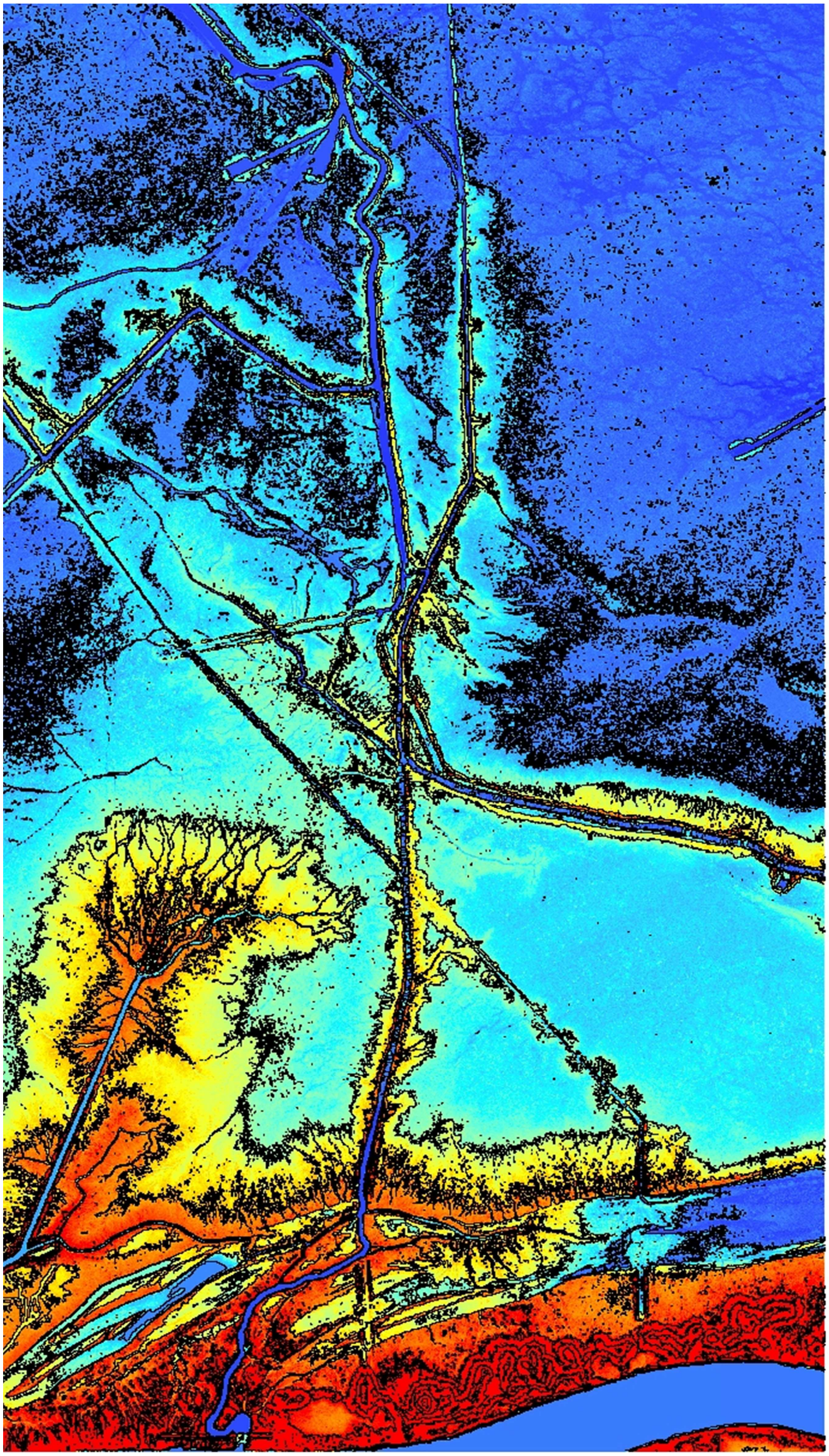


Figure 3b. LiDAR image of the western portion of Figure 3a. North to the Sediment sources to the area come from the Atchafalaya River/Whiskey Bay Pilot Channel. It includes Bayou Sorrel down to the GIWW (Gulf Intracoastal Waterway).

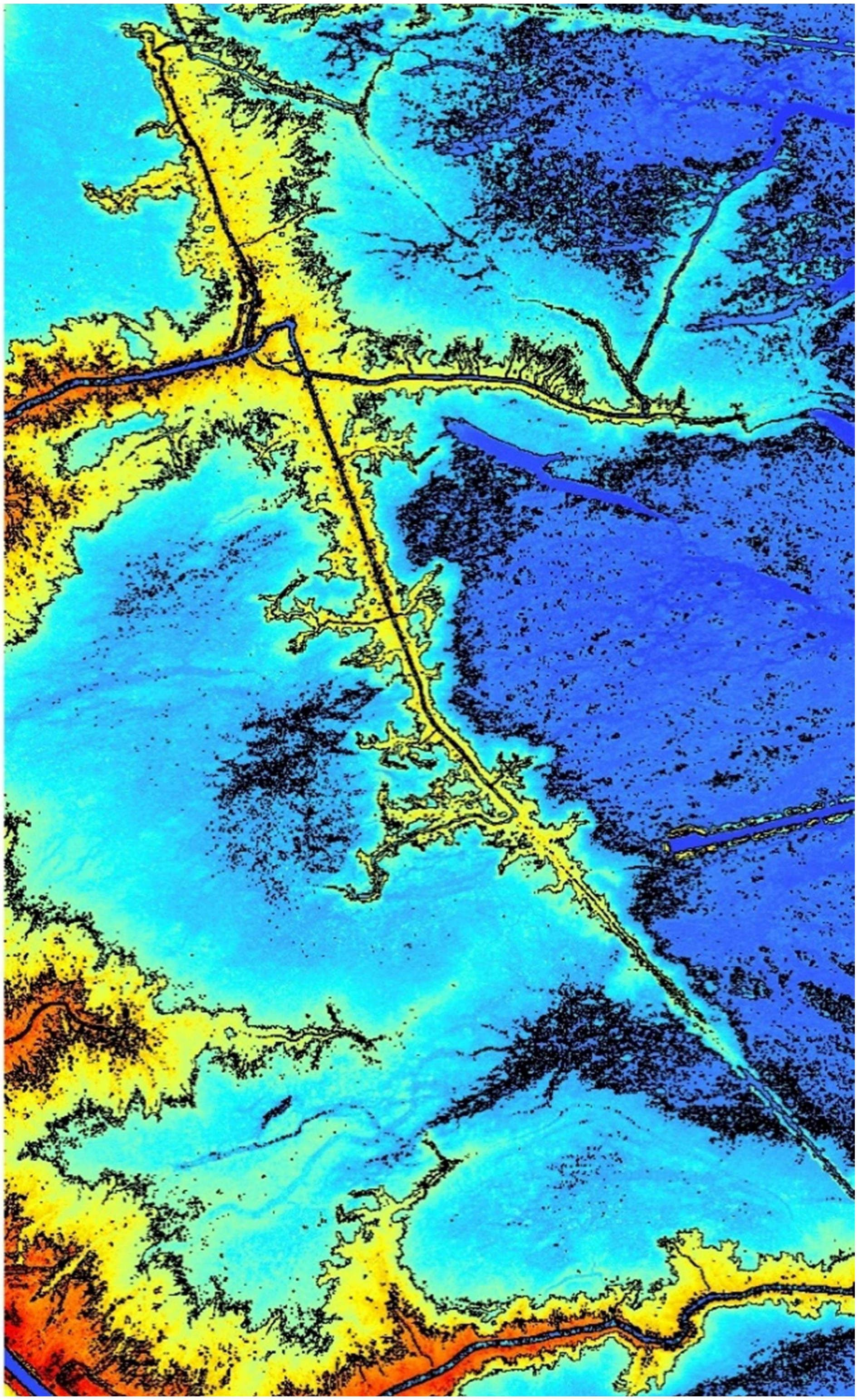


Figure 3c, Intersection of Salt Mine and Florida Pipeline Channel, Note the sediment fingers extending in three directions and the significant sedimentation that has occurred on both banks of Salt Mine. North to left.

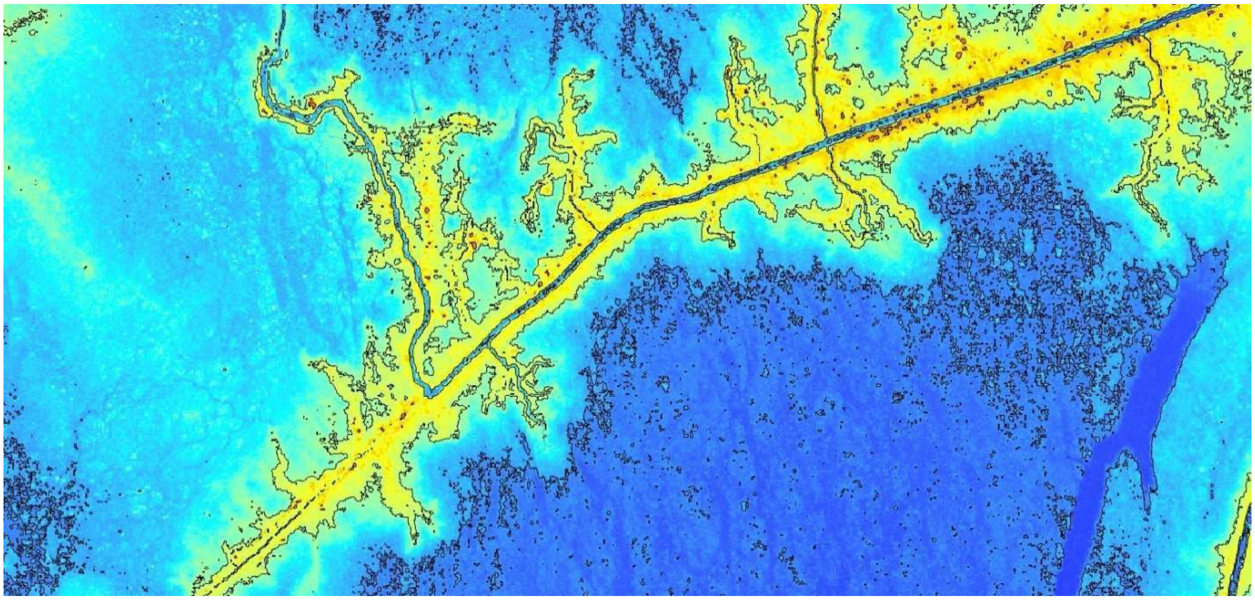


Figure 3d. LiDAR image of a section of Florida Pipeline Canal. Note the many sinuous sediment delivery conduits into the swamps.

through July of that year. They reveal that the mean suspended sediment concentration in the Lower Atchafalaya River at Morgan City for this flood event was 133 microgram/liter (mg/l) and for Wax Lake at Calumet was 143 mg/l, and these numbers are similar to lower Mississippi River concentrations. For the basis of the following calculations I will use a median of 138 mg/l suspended sediment concentrations for the Atchafalaya Basin. The Median percent suspended sand was about 22% (Table 1). We will now go through the process to determine what the sediment loading, or in other words how much sedimentation, could have entered the swamp from the 13 proposed cuts (dredge sections – Figure 1) taken from the Joint Public Notice; during a flood such as the 2011 flood.

First assuming an average flood velocity in the cuts of 1 m/sec, which is common in these sized channels, one can calculate that for every square meter of cross sections of a channel; in one second 138,000 milligrams/sec of suspended sediment moved towards the swamp. Thus, the Mass of sediment moved is 138 grams/m^2/sec. As we are going to be looking at volumes of sediment deposited we need to convert this Mass to a Volume. Density equals Mass/Volume and we know from years of study that the density of suspended sediment is 1602 kg/m^3.

Doing the math gives us that the volume of suspended sediment per square meter of channel cross section in 1 second is 8.621×10^{-5} cubic meters. So how much suspended sediment by volume moves through our 1 square meter of channel in a 24 hour day (24x60x60 = 86,400 seconds); thus, the volume is 8.621×10^{-5} multiplied by 86,400 = 7.43 cubic meters per 24 hour day per square meter of channel.

For a 120 day (four-month flood) the volume of sediment flowing through 1 square meter of channel is 7.43 multiply by 120 = 897 cubic meters of sediment. So, what happens to this sediment? Well there is ample research and as discussed in Section 2, and as evident from the LiDAR imagery, it gets deposited as it goes from the confined main channel to the unconfirmed open waters (swamp). It gets deposited rapidly. So, if we assume these 897 cubic meters of suspended sediment is equally deposited over the basin off the channel mouth as a layer 10 centimeters thick (4 Inches) then how big an area (horizontal bottom) will be covered by this sediment moving through 1 square meter of channel cross section in a four month period? Calculating this number and then dividing by 4046, being the number of horizontal square meters in an acre, gives a result of 2.22 acres of swamp bottom with be covered by sediment 10 cm/4 inches thick this for our four-month flood; per square meter of channel cut.

In reviewing the Dredge Sections as presented in the Joint Public Notice we see that 6 Elements (1, 2, 3,4,12,13) have an average width of about 39 feet (10 meter) while 7 Elements (5, 6, 7, 8, 9, 10, 11) have an average width of about 108 feet (30 meter). If we are conservative and assume 2.0 m of flow depth on average then the combined cross section of all these channels, 6 at 10x2 = 20 square meters; and, 7 at 30x2 = 60 square meters means the total combined cross section of the EGL elements is 120 + 420 = 540 square meters. Thus, in the four months flood these channels combined deliver enough sediment to cover the bottom, an even 4 inches thick, over an area of 540 x 2.22 = 1188 acres.

So, this EGL project, in just a four-month flood based on 2011 data (Welch etal, 2014) **covers 1188 acres with at least 4 inches of sediment, and this is a very conservative estimate.** If you review Table 3 (Stations 10 and 11) you will see that the suspended sediment loads measured during the 2011 flood were well below the median of the historical data. Welch etal (2014) account for this lower than normal suspended sediment concentrations because most of the flood water was coming from the Ohio River that contained lower concentrations of suspended sediment, pesticides, and nutrients that water from the Mississippi River. They go on to state that the 4-month flood of 2011 contributed about 50% of the estimated annual suspended sediment, nitrate, and total phosphorous fluxes in 2011. What about the rest of the year? Discharges are lower, but the period is twice as long (8-months) and in that 8-month period the suspended sediment flux is the same as the 4-month flood. Without going into the math, one could conclude that <u>the 13 dredge elements of the EGL project in one year could cover 2400 acres of swamp bottom with 4 inches of sediment or 1200 acres with 8 inches and so on.</u> This is a very significant alteration, modification of the natural environment and will force habitat and hence ecological changes especially if you follow these numbers out 10 years. The LiDAR data is very, very clear. Allow suspended sediment out of the River and you will destroy this swamp, something that is happening right now, and this Project will exacerbate the loss of this swamp.

The lack of science in trying to justify this project is glaring. I have seen some data but there is no indication of the conditions that samples were taken, for instance was it raining, was it windy, what about the day, or week before and so on.

In summary, elements 1,2,3,4, will enhance sediment delivery into the adjacent swamps sources being Grande River and Bayou Sorrel.

Element 12 and 13 will introduce River water directly from a sediment source, Bayou Sorrel, into back swamps, creating deltas and sinus conduits filling in those wetlands with clays, silts and fine sand.

Elements 5,6,7,8,9,10 and 11 will introduce River water laden with suspended sediment coming down from Bayou Sorrel down Salt Mine and/or along the Florida Pipeline Canal pipeline into the back swamps, creating deltas and rapidly infilling in wetlands with clays, silt and fine sand.

It is very important to note again that linear channels in a setting such as the Atchafalaya Basin are very efficient at transporting suspended sediments long distances with a real threat to surrounding cypress swamps (See also Section 2). The impacts of the EGL project excavations and channel once in place will not be temporary. The cuts whether channels or bank shavings will have the capacity to transport significant amounts of suspended sediments especially during floods – sediment that would never be there if it weren't for the channel! Flood waters overtopping the Atchafalaya River seek out linear efficient flow pathways such as pipeline canals and channels to flow downhill from the river. Flow through vegetated areas, especially trees, is greatly reduced due to the friction the trees and brush offer to flow. In some ways the trees are like a 'wall' and 'steer' the flood discharge towards the canal or channel.

If contaminated sediment is excavated this would have to be physically removed from the area. We know that oil and gas production have occurred in the Basin for many years and there have been oil spills and the release of drilling mud and brine/produced waters. We don't know everywhere these have occurred. I don't see any discussion of how this removal of contaminated sediment or material would be achieved or how testing will be undertaken.

[Suspended-sediment concentrations are in milligrams per liter (mg/L). USGS, U.S. Geological Survey; mi², square mile; N, number of samples; Min, minimum; Max, maximum; Med, median; --, not available]

Water-quality station number	USGS station name	USGS station number	Drainage area (mi²)	Suspended sediment concentration				Percent sand			
				N	Min	Max	Med	N	Min	Max	Med
1	Mississippi River at Thebes, Illinois (Upper Mississippi River)	07022000	713,200	7	127	448	317	8	6	45	13
2	Ohio River at Dam 53 near Grand Chain, Illinois[a] (Ohio River)	03612500	203,100	7	30	109	96	6	0	18	3
3	Arkansas River at David D Terry Lock and Dam below Little Rock, Arkansas[b]	07263620	158,429	5	12	303	38	5	2	75	10
4	Yazoo River below Steele Bayou near Long Lake, Mississippi	07288955	13,355	10	9	83	33	6	0	3	0
5	Mississippi River above Vicksburg at mile 438, Mississippi[c]	322023090544500	1,144,500	12	63	164	122	12	11	57	26
6	Mississippi River near St. Francisville, Louisiana[d]	07373420	1,125,300	12	46	179	83	10	12	50	26.5
7	Mississippi River at Baton Rouge, Louisiana	07374000	1,125,800	6	88	168	134	6	11	63	56.5
8	Mississippi River at Belle Chasse, Louisiana	07374525	1,130,000	12	114	206	135	11	2	40	34
9	Atchafalaya River at Melville, Louisiana[e]	07381495	93,316	12	70	261	144	10	3	61	20
10	Lower Atchafalaya River at Morgan City, Louisiana	07381600	--	12	76	338	133	11	1	53	25
11	Wax Lake Outlet at Calumet, Louisiana	07381590	--	12	94	262	143	11	2	34	23
12	Atchafalaya Floodway near Ramah, Louisiana North of I–10[f] (Morganza Floodway)	302410091305201	--	24	8	31	16.5	24	0	14	0.5
13	Bonnet Carré Spillway at US Hwy #61near Norco, Louisiana (Bonnet Carré Spillway)	300115090245000	--	28	43	133	111	28	1	13	6

[a]Flow from the Ohio River at Metropolis, Illinois (03611500).
[b]Flow from the Arkansas River at Murray Dam near Little Rock, Arkansas (07263450).
[c]Flow from the Mississippi River at Vicksburg (07289000).
[d]Flow from the Mississippi River at Tarbert Landing, Mississippi (U.S. Army Corps of Engineers site 01100).
[e]Flow from the Atchafalaya River at Simmesport, Louisiana (U.S. Army Corps of Engineers site 03045).
[f]Flow from the Morganza Spillway at Hwy 190 near Lottie, Louisiana (07381530).

Table 1. Water-quality stations sampled in the lower Mississippi-Atchafalaya River subbasin during the 2011 flood, April through July, and summary statistics for suspended sediment and percent sand (Welch etal, 2014).

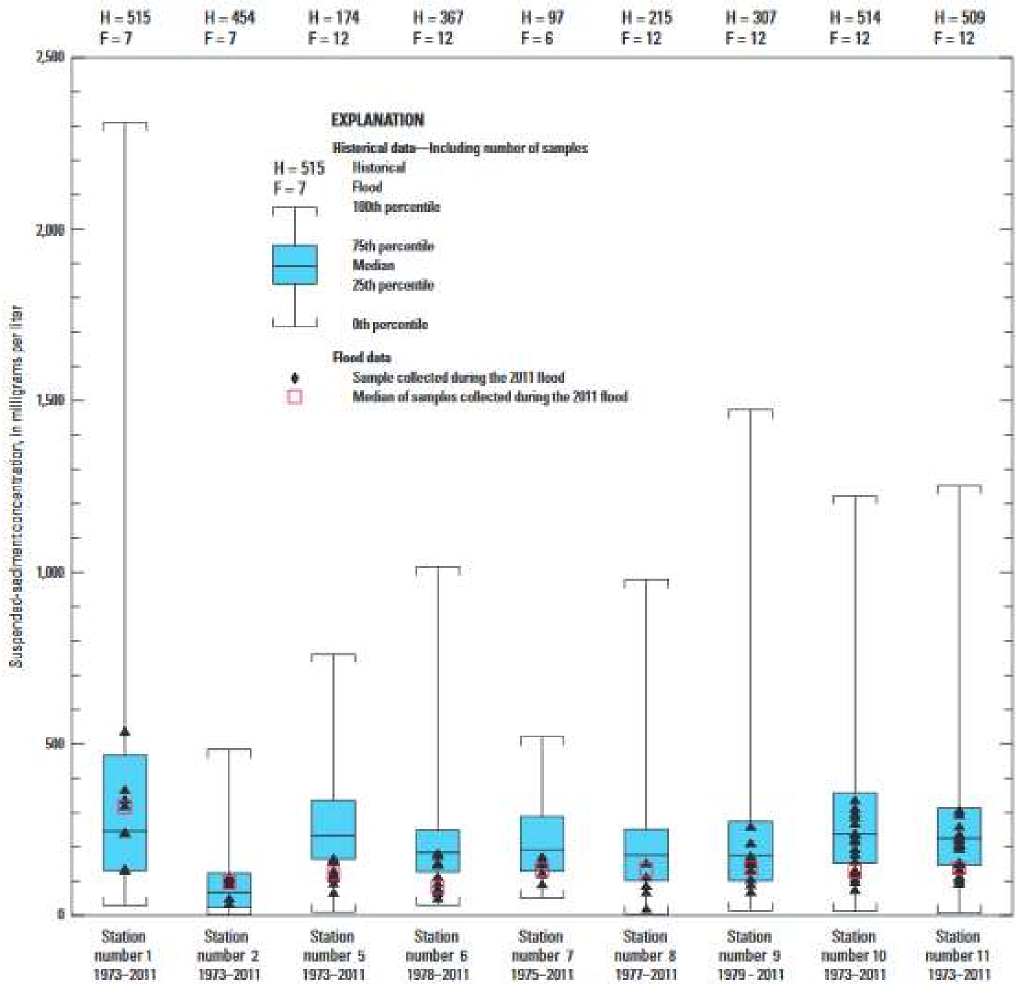


Figure 4. Concentrations of suspended sediment measured during the 2011 flood compared to concentrations measured at these stations in the lower Mississippi-Atchafalaya River subbasin for the period of record (Welch etal, 2014).

NUTRIENT LOADING DUE TO CHANNEL CUTS

Welch etal (2014) present data related to nutrient loading of the Basin during the 2011 flood, data that has to be considered in evaluating the impacts of the EGL project. It is important to note they only sampled main river channels and not any swamp sites. They point out that Nitrate composed about 70% of the total Nitrogen Flux and that there were no substantial losses or gains in the Atchafalaya or Lower Mississippi Rivers. But what happens to the nitrogen when it enters the still water of an interior swamp? It has nowhere to go so nitrogen loading of the swamp takes place – a cause of hypoxia. Welch etal (2014) point out that when suspended sediment fluxes increase, agricultural chemicals attached to sediment can be readily transported downstream and may further exacerbate water quality problems in receiving surface-water bodies. So, if you increase the discharge of suspended sediments into interior swamps you are going to exacerbate water quality problems. Horowitz (2010) concludes that suspended sediments delivers about 85% of the annual phosphorous flux and 30% of the annual Nitrogen flux to the region.

Welch etal (2014) point out that as streamflow was decreasing in the 2011 flood in the Lower Mississippi River - Atchafalaya River sub basin, orthophosphate composed an increasing percentage of the total phosphorous concentration, probably because of return of waters low in oxygen concentration from areas such as inundated lands, backwater streams, and floodways. These poorly oxygenated waters promote the release of sediment-bound phosphorous into the more -readily available dissolved form. So, the data collected by the USGS during the 2011 flood reveal that Atchafalaya River water entering a swamp had a low oxygen concentration that promoted the release of phosphorous. This is a double whammy – the waters that would have enter the interior swamps from the 13 EGL elements would have had low oxygen concentrations, and in addition, this condition would have enhanced the release of a nutrient, phosphorous. So instead of improving water quality, we are enhancing hypoxia! It is incredibly important that before one messes with the natural environment that one understand the consequences. For every action there is a reaction.

I am aware that there have been some who have advocated that to reduce the hypoxia in the northern Gulf of Mexico we should try to capture the nutrients before such exit the Atchafalaya and Missisppi Rivers. One thought has been that projects such as the EGL project will lead to capture of these nutrients and help the Gulf. However, if one really wants to capture the nutrients one needs to attack them at their source – upcountry farmlands. The political will does not seem to be there to achieve this so instead we should concentrate on building as many Atchafalaya and Wax Lake deltas along our coast to try to reduce or stem coastal land loss (so necessary for coastal Louisiana’s future) and tie up the nutrients here where they will stimulate marsh growth, instead of filling up the Atchafalaya Basin with suspended sediments. The Basin once lost will never be returned or restored. It will be lost forever.

In the past, discharges in the Grand River channel have been almost 10% of the Atchafalaya flow with stages of at least +11 feet (as is evidenced by the levees depicted in Figure 12b – Section 2). This year NOAA is predicting wetter than normal conditions for a large part of the Mississippi Valley. We have already seen this winter that changes in the Jet Stream are causing weather features such as cold fronts to move much slower than normal. There is a high probability of major flooding on the Mississippi and hence Atchafalaya Rivers this season.

Cypress swamps are fragile, require very unique conditions of hydrology, geomorphology and sedimentation to germinate, sprout and grow. If the environment is kept pristine in that the physics do not change then these swamps can survive for thousands of years. Louisiana was blessed with hundreds of thousands of acres of these biological wonders, but man through altering the physics and the physical environment has destroyed most of these swamps. The Atchafalaya Swamps are under direct threat as the physics of the environment undergoes dramatic changes. These swamps survived by limited suspended sediment being deposited on the natural Basin levees and some fine-grained clays, organic matter and nutrients would through overbank flow enter the basin and slowly drain out at its seaward ends, maintaining the health and integrity of the system. Sixty plus inches of rain p.a. aided the natural hydrology.

That is not the case today.

The Corps of Engineers' management of the Basin discussed in greater detail in Section 2 is accelerating the physical change due to significantly enhancing sedimentation rates within the Basin. This is the death knell of cypress swamps – it is also developing a substantial public safety issue as we fill the "tank" that is supposed to hold Mississippi and Atchafalaya flood waters – the Floodways purpose – that is being accelerated by rapidly rising sea levels off the Louisiana coast. All decreasing the functionality of the Floodway each year—a looming public safety issue.

So, change the physics, change the physical environment and the biology will change. Can we really afford to lose this American Gem?

CONCLUSIONS

It is my opinion that the EGL project will have the following negative consequences for the Atchafalaya River Swamp: -

1. Long term and very significant suspended sediment loading will occur in an area of thousands of acres of swamp converting these to less productive bottomland hardwoods.
2. There will be a dramatic and permanent loss of productive swamp habitat with resultant loss in productivity and ecological value.
3. Loss of productivity and water bottoms will severely curtail the traditional and cultural harvest of wild crawfish, amongst other species.
4. There will be an attendant loss in recreational income for the region as the swamps become bottom land hardwoods.
5. The LiDAR and other data reveal just how much mis directed suspended sediments have led to swamp loss, thousands and thousands of acres.
6. There is a high probability that this project will lead to greater water quality problems and increased hypoxia events, especially after major flooding events.
7. There is no recognition that in these shallow still water areas with a thick submerged carpet of organic matter that hypoxia will occur from time to time due to events such as storms, wind outbursts, and human interference sometimes as simple as boat wash or wakes; subsurface faulting and so on. Hypoxia events are a part of the natural landscape.

My suggestion moving forwards is to develop a long-term science-based management plan with a focus of reducing sediment input, reconnecting former waterways with gated structures if necessary, minimize the impacts of existing pipeline channels; and similar projects. Such a planning effort would recognize that the River sediment is needed at the coast, not infilling a floodway basin, a looming public safety problem.

SECTION 2. SOME PERTINENT ECOLOGICAL/GEOMORPHOLOGICAL/ HYDRODYNAMIC PRINCIPALS; RELEVANT BACKGROUND

To understand the potential irreparable harm of this project on the Basin, one needs a basic understanding of how an aquatic environment such as a mature cypress interdistributary basin swamp responds to changes in the physical environment whether sedimentation of and from pipeline excavations, man-made canals, or from levee cuts.

1. The biology is mostly a response to the physical environment.

If I set up a fish tank of only water with no sediment on the bottom with an inflow of 100 gallons a day and a similar outflow I can support 'open water' aquatic species that depend upon sunlight and nutrients introduced by the 100 gallons of inflow to support the lower forms of life such as algae and plankton that in turn form the food base to nourish all upper forms of aquatic life. The fact that there is no sediment on the bottom means that these organisms in total have evolved to live in this open water environment and breed, mature, survive and so on.

Now if I set up a second tank with a different physical environment by filling half the tank with sediment so the surface is half water and half subaerial 'land' with the subaerial part of the surface but a few inches above the water level and with the 100 gallons in and 100 gallons out; in this fish tank, I now can support some but not all the open water species from Tank 1, and a new suite of organisms that utilize the sediment in addition to sunlight and nutrients to breed, mature, survive and so on. Additionally, a wetland will develop on this low-lying land with all the benefits that wetlands bring to the food chain including nutrients and the host of organisms that will thrive in the wetland. So, the biology responds to the change in the physical environment; in this case, adding sediment to the tank. This different set of organisms will utilize this different environment to breed, mature, survive and so on. If my want is to protect open water species, obviously the physical change due to the sediment has killed that goal or objective.

Now if I set up a third tank that is half filled with sediment but now elevated many feet, still 100 gallons in and 100 gallons out, I have a different biology. No more wetland plants, instead trees and grass so the 'land' biology will be dominated by upland species that survive in such. The aquatic species will be diminished some because of the lack of wetland and a different suite of organisms will inhabit the aquatic environment. If my want is to protect open water species, obviously the physical change due to the sediment has killed that goal or objective. Similarly, if my objective was wetlands and aquatic species the elevated sediment (land) has consequently put an end to that desire or goal.

Now if I set up a fourth tank that is filled with sediment and supports only upland species but has a stream flowing through with 100 gallons in and 100 gallons out I end up with no wetland and a very limited stream bank aquatic species. The change means I cannot achieve my goals for any of the previous three tank setups.

This rather simplistic depiction very strongly reveals how the biology is a direct response to the physical. Change the physical environment and you will alter the biology. Other than extreme hurricanes, major earth quakes, and volcanoes, man is the most effective force in changing the physical landscape of this planet. Just recognize what one day's work with a bull dozer can do to a landscape. What the Lord created over thousands and thousands of years can be changed almost in an instant.

2. Suspended sediment versus Bedload sediment.

As sediment, or too much thereof, is the death knell of a cypress swamp, we need to better understand the sediment regime of the Basin as a background to assessing the impacts of channels, pipelines canals and excavations. The **suspended** load of a flow of fluid, such as a river, is the portion of its sediment uplifted by the fluid's flow in the process of **sediment** transportation. It is kept suspended by the fluid's turbulence. The **suspended** load generally consists of smaller particles, like Clay, Silt, and fine Sands.

The term **bedload** describes particles in a flowing fluid (usually water) that are transported along the bed. **Bedload** is complementary to suspended load and wash load. **Bedload** moves by rolling, sliding, and/or saltating (hopping). In other words, sand (medium or coarse), gravel, boulders, or other debris is transported by rolling or sliding along the bottom of a stream.

The always brown color of the Mississippi and Atchafalaya Rivers is made up of suspended sediment that is well mixed up throughout the water column; there being virtually no bedload in the Mississippi and Atchafalaya Rivers other than waterlogged vegetation. Below the Old River Control Structure what bedload is in the Mississippi River does not get past the sill into the Atchafalaya River, but continues down the Mississippi. Numerous studies have reached this conclusion (van Heerden, 1983.) This is a crucial point in understanding sediment deposition in Louisiana, how our deltas grow and why we have these huge interdistributary basin swamps such as the Atchafalaya, Maurepas and others including the huge cypress swamp that used to protect New Orleans from hurricane surges until saltwater destroyed it after the Corp constructed the ill-advised MRGO (van Heerden and Bryan, 2006, van Heerden, 2007).

An important difference between the two types of sediments is that bedload requires a lot of velocity in the bottom waters of a river to move. Rivers dominated by bedload do not have natural levees. Just think of most of the rivers you see outside of coastal areas like Louisiana. Louisiana coastal rivers and bayous all have natural levees – this is because the latter carry suspended sediment and the mechanism under which the sediment is deposited. Suspended sediment as the definition above describes requires turbulence to stay in suspension as the water moves along. However, once the sediment is in suspension it does not require a lot of current and hence flow to stay in suspension. Suspended sediment thus confined in any sort of channel can be transported a long way. This ability to travel a long distance is one of the reasons that we have seen such dramatic changes in the Atchafalaya Basin within the confines of the artificial flood control levees due to man-made channels and cuts. More on that to follow. Additionally, the suspended sediment loads are very high when the rivers are in flood, pushed by connections to the Mississippi River as it floods each year after the snow melts inland, as well of course by storm rainfall-induced floods. The Atchafalaya River does get a sediment contribution from the Red River which has decreased because of the locks and dams that have been built on the Red River in recent years.

For suspended sediments to be deposited, for them to drop out of the water column requires friction. Friction kills turbulence. The central portions of most Louisiana channels do not have enough friction for the suspended sediment, mostly silts and fine sands, to be deposited and that is why most channels have dark brown to black clay bottoms. Notably, the clays are mostly deposited in the low water months. Look at your anchor next time you anchor in a Louisiana coastal channel. The maximum friction is along the sides of the channel especially the natural levees. As the river flow starts to reach up the levees and especially when the levees are overtopped suspended sediment deposition can be very rapid. In areas like the Atchafalaya Delta one flood can cause up to three feet of deposition (van Heerden, 1983). Here as the water shallows the friction effects of the side of the channel dramatically reduce turbulence. Each deposition cycle has a distinct morphology, the base being fine sand that is then covered with silts and finally a clay top. Geomorphologists refer to the as "Upward fining flood cycles." In my research in the Atchafalaya Delta starting in 1977 (van Heerden, 1983, 1994) we were able to map out individual flood deposits for each year, thickness generally relating to the size and longevity of the flood. Figure 5 is an example of such upward fining cycles from the levee inside the floodway along the channel fed from the Grand Bayou take off from the Atchafalaya River many miles upstream. This is one key component of understanding how channels infill the Basin.

So, during floods, the friction along the bank reduces flow turbulence and the suspended sediment is preferentially deposited on the sides and top and overbank of the natural levee systems. This is the origin of all our natural levee systems. If not for the fact that suspended load can be transported hundreds of miles in a confined channel, if not for our low-lying wetlands that are excellent sites for levees to form, as there is a slope gradient in the wetland away from the channel; if not for the subsequent reduction in turbulence, there would be no levees and very little colonization of coastal Louisiana.

Figure 5. Suspended sediment deposits in the levee along the Bayou Sorrel channel within floodway showing different sedimentation cycles. Spade handle for scale.

When you go from a deeper confined channel into an open generally shallower bay with no confinement, the river flow can spread laterally sometimes through an arc of more than 180 degrees. This then becomes and ideal situation for suspended sediment deposition and that is the origin of all our deltas, whether large scale features such as the Mississippi or Atchafalaya or the Wax lake deltas; or small deltas off channels or bank cuts 10's of feet wide (Figures 3a, 3b, 3c, 3d). Wherever suspended sediment flow goes from the confined to the unconfined, rapid deposition results. This is the second key component of understanding how channels (in this case with cuts) can lead to deposition in the Basin. The reason that the rapid deposition does not choke off and seal the channel is that due to minor subsurface undulations, secondary delta channels form (van Heerden, 1983 amongst others). This is partially related to something called the "Bernoulli's Effect." I don't want to get into too much detail here as it will mean exploring some math. Basically, this is the principal that defines an aircraft wing. As the air flow is compressed on the wing it accelerates and creates lift. So, as the flow lines are compressed in a delta (from deep to shallow) they speed up maintaining some level of turbulence which results in the finger like spread of distributary channels at mouths of deltas and means that these deltas keep growing seaward or into the basin they occupy. Thus, a delta is not a plug, it is rather a very efficient mechanism of spreading sediment over a large area as the distributary delivery channels maintain themselves. Deposition is thus very different between a confined versus a non-confined channel. The former builds levees with minor sedimentation in the interior swamps due to the sheet flow into bays or swamp basins (van Heerden, 1983). Where the levees are vegetated, the lateral flow into the basins is minimal, as the vegetation adds a whole lot more friction and suspended deposition that is mostly confined to the levee itself.

Going from confined to unconfined flow means delta growth and deposition spread over a wide area. As the whole suspended load is involved, not just that portion along a levee, deposition can be very significant, and the system has an in-built mechanism to keep growing outwards due to Bernoulli's effect and delta channel development.

Confined channels can transport suspend load great distances; but moving from a confined to an unconfined situation results in deposition of most of the suspend sediment load near the opening/spreading of the flow—a delta (See LiDAR imagery figures 3a-d).

Sediments originally from the Atchafalaya River move along man-made canals and channels in suspended sediment mode – they are well mixed through the water column - and as long as the channel is confined can travel tens of miles in suspension. Wherever the channel goes from a confined to an unconfined state sedimentation is very rapid forming delta like deposits. Thus, in one flood season suspended sediments using these linear intrabasin connections can be deposited over large areas and lead to significant shallowing and physical change. Pipeline and similar cuts **are** very efficient conduits to transport sediment into the interior locations of Basins.

Even if the canal or channel is blocked off from the main river, once the River starts to overtop its banks with a rising flood, these flood waters will preferentially flow towards the channel and use it; the channel being treeless offering an efficient linear low friction pathway for flood waters to flow into interior portions of the cypress swamp.

It goes without saying that the higher the velocity the higher the turbulence, the higher the potential sediment load. This gets us to our next principal.

3. Discharge, velocity, and sediment concentration in a meandering channel such as the Atchafalaya.

As is shown in Figure 6 (below) the velocity distribution in a straight channel (Section A-A') distant from a river meander is uniform across channel with the highest velocities, and hence sediment load, in the central portion of the channel. This is very typical as determined in hundreds of velocity profiles taken across rivers over the years. However, the distribution of flow velocity and sediment load is very different in a meander. When in a car taking a sharp turn your body (mass) it pulled to the outside of the curve basically due to centrifugal force; in a minuscule way too, the outer edge of your body is moving faster than the inner edge of your body as the former must go through a longer curve. In a similar way, the same thing happens in a meander channel. Sediment moving say from point A to B in Figure 6 below has a longer curve (way) to move that sediment from point A' to B'. It thus speeds up and along with the centrifugal force means that strongest velocities and hence most of the sediment is now concentrated in the outer portion of the bend as shown in Sections B - B' and C – C'. So, if you want to divert water from the Atchafalaya River, and have the lowest sediment load possible, then you would take the flow from the edge of a straight channel such as A - A'. Taking it from the outside of a meander channel would be the worst-case scenario; it would enhance sediment transport out of the main river channel. We will come back to this in a moment.

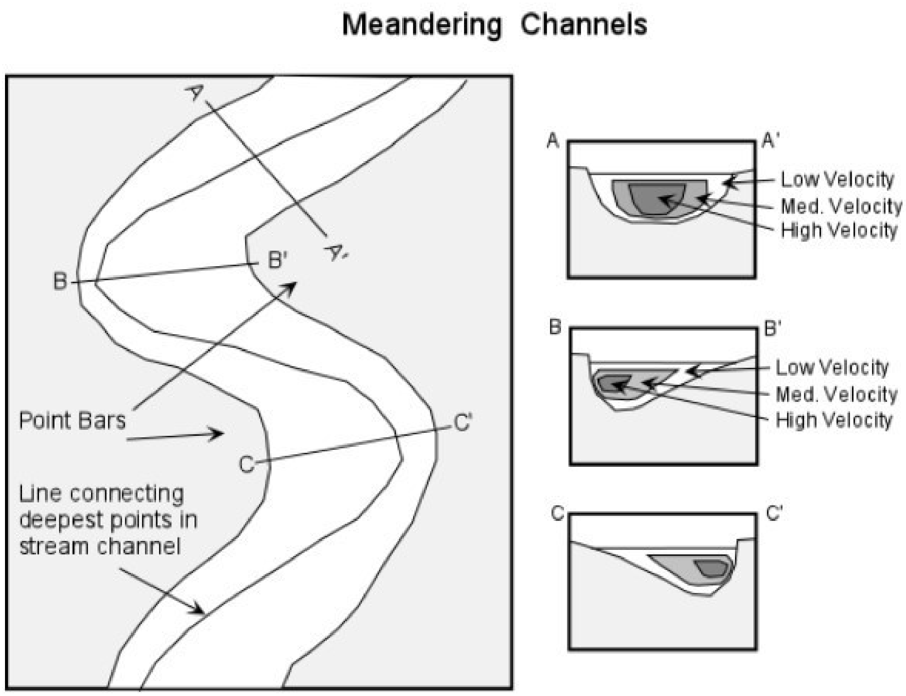


Figure 6. Typical velocity sections across a river including a river meander.

4. <u>Mismanagement of the Atchafalaya by the US Army Corps of Engineers exacerbates pipeline and other channel-like impacts</u>

The Atchafalaya River runs through an inland basin of swampland and lakes with the edges of the original Basin, pre-M R & T levees, being defined by the alluvial ridges formed from two abandoned distributaries of the Mississippi River, the Teche-Mississippi ridge to the west and south, as well as the younger, modern Mississippi and the Lafourche ridges to the east (Figure 7). Geomorphologically it is a classic delta interdistributary swamp basin. The surface lies at an approximate elevation of 42ft above mean sea level near Krotz Springs in the northern end of the Basin and slopes seaward, reaching sea level near the southern termination of Grand Lake.

In the mid-1500s, the Atchafalaya River started to capture flow from the Mississippi River due to a distinct gradient advantage because of a shorter course to the Gulf. With capture of Mississippi flow came Mississippi sediment and the Basin started to slowly fill with sediments from the north. By the early 1960's the Atchafalaya had captured 30% of the Mississippi flow creating concerns about how long New Orleans could operate as a port. The federal government then constrained the Atchafalaya distributary by building a structure at the point of diversion from the Mississippi in 1963, artificially controlling the flow down the Atchafalaya at 30% of the Mississippi. They also constructed guide levees to contain Atchafalaya Floods within a Floodway basically cutting the size of the receiving Basin by 50% (Figure 7).

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

The Corps' two main functions are to control river flooding and aid commercial navigation. In the Atchafalaya system this required the M R &T artificial levees and the Atchafalaya Floodway. The navigation component requires keeping the various navigation channels in the Basin open and making sure there is a deep connection from the Morgan City/Berwick industrial hub to the Gulf of Mexico. The latter involves dredging and maintaining a channel through the Atchafalaya Delta. As pointed out previously deltas are net deposition sites for suspended sediment with a series of shallow finger channels feeding the sediment load to each channel's natural levees as well as to its most bayward edges. It is a very efficient system at moving sediment; that is why they keep growing. Typically, these finger channels or distributaries are no more than 6 ft. deep and about 2000 feet wide—a distinct difference from the Atchafalaya River Mouth which is some 90 feet deep and about 6 miles wide (Figure 8).

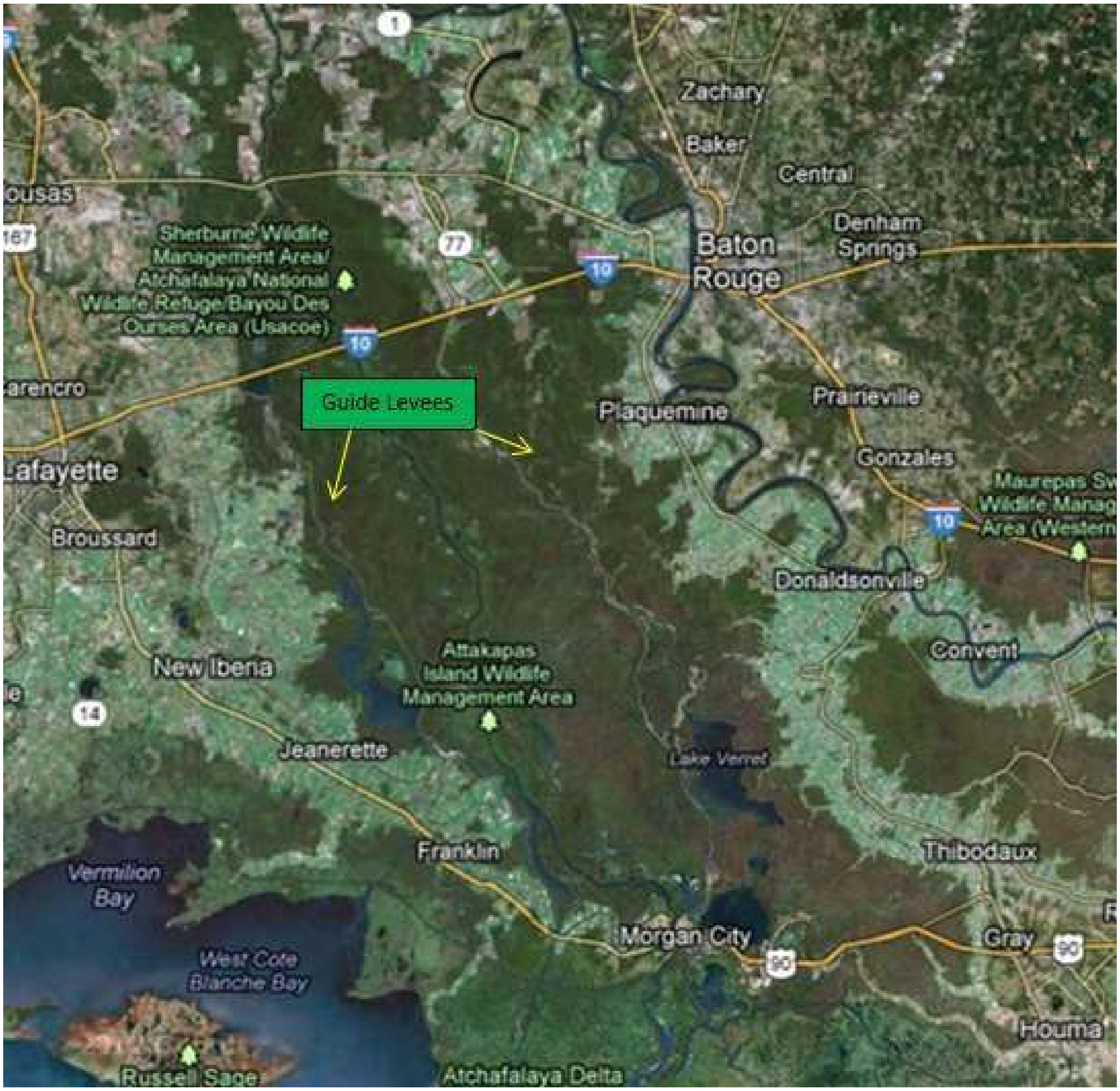


Figure 7. Atchafalaya Basin, south central Louisiana. Note the large area of swampland outside the M R & T guide levees.

Figure 8. Mouth of Atchafalaya River (top of figure) and the Atchafalaya Delta. Note the narrow shallow finger distributary channels and the wide deep main channel cutting through the delta. The latter is a dredged feature.

The Corps of Engineers must regularly dredge millions of cubic yards of suspended sediment that has been deposited in the deep navigation channel and place in spoil piles. Basically, the natural system wants a shallow bay and each time the Corps digs a hole, the navigation channel, nature tries to fill it up. This Atchafalaya River Navigation channel is conceptually directly opposite to delta building, and it is very expensive to maintain. Thus, whatever the Corps can do to reduce the sediment deposited in its delta navigation channel the Corps will try. So, it looks at the Atchafalaya Basin, and manages the Basin as not only a floodway but also as a sediment trap for retention of suspended load sediments that it would have to dredge if they made their way to the river mouth.

5. <u>Water diversions or really sediment diversions?</u>

Over the last fifty years the Corps has opened and dredged channels from the main stem of the Atchafalaya River into the Basin. The stated aim was to enhance fresh water flows into the Basin while reducing sedimentation in the swamps.

The two principal cuts into our area of concern are the Grand River diversion in the north and the Bayou Sorrel connection in the south. Pipeline and other channels intersects these, and these two channels are what connects the total EGL project to the river. Each will be discussed separately but the reader's attention is drawn to the section above discussing sediment movement in meander channels.

6. Grand River cut and sediment diversion.

This cut and associated dredged channel were proposed to divert fresh water from the Atchafalaya River into the upper eastern portions of the Atchafalaya Basin (Figure 9).

Figure 9. Grand River cut, the 'reopening' of Little Tensas Bayou.

If you note the original Little Tensas Bayou connection (from SE to NW on right) was in a straight section of the Atchafalaya River (Figure 9) where the maximum flows and hence sediment load would have been confined to the central parts of the channel as depicted in Figure 6 Section A – A'. Additionally, the channel had a reverse takeoff, that is the connection had a northerly or 'upstream' bend at the connection. This Bayou as it was connected would have carried flows mostly year-round that had very little sediment loads and most of the suspended sediment would have been deposited on the natural levees of the Little Tensas Bayou. Instead the Corps created a new connection further upstream but most importantly on the outer bend of a meander, a situation such as Section C – C' in Figure 6. Such a location would place the diversion or takeoff point right adjacent to the maximum flows and sediment load, ensuring that a much greater sediment load now entered the system in what is now called Grand River, enhancing sedimentation into the basin. The Corps dredged a straight connection to the old bayou with an upstream facing or scoop connection. This configuration only enhances sediment capture and diversions down the new bayou – Grand River – perhaps aptly named. Below we will show evidence of the enhanced sedimentation associated with the very efficient connection to the Basin. This river diversion connects to the GIWW.

However, the COE also needed a 'sediment diversion' in the lower half of the Basin – Bayou Sorrel.

7. Bayou Sorrel cut and 'sediment diversion'.

The original Bayou Sorrel (Figure 10) was in the upper right part of figure and was a rather sinuous channel that originally headed off in a south easterly direction. Its takeoff point was along a straight section of the Atchafalaya River thus predominantly capturing low sediment load discharge such as depicted in Figure 6, Section A – A'. The suspended load would mostly have been deposited on its natural levees with fresh water and nutrients flowing to the Basin on each side during period of high river flows.

Instead the Corps cut was made somewhat downstream on the outer bend of a meander, cutting off a long sinuous section of Bayou Sorrel, in a situation similar to the Grand River cut (See Figure 6, Section C - C'), enhancing sediment diversion through the cut. A straight efficient connection was then dredged between the new cut and Bayou Sorrel – a very efficient sediment transport connection.

Thus, the Corps, through these two actions, set the stage for rapid infilling of parts of the Basin while achieving their goal of reducing potential sediment deposition in the Atchafalaya Delta Navigation Channel. This sediment loading is enhancing in many areas the loss of cypress swamp. The late 1980's Corps Design Memorandum mentions the loss or modification of 21,000 acres of wetland aquatic habitat because of these projects. Again, change the physics and the biology will respond.

The Corps of Engineers has created a situation whereby the impacts of oil and gas pipeline canals are enhanced because of the very real use of the canals as sediment conduits during flood periods; confined conduits carrying suspended sediments to portions of the Basin far removed from the source, the Atchafalaya River—to the detriment of the delicate natural balance that ensures cypress swamps can flourish. Excavation of these 13 EGL sediment delivery channels and levee height shavings just enhance the sedimentation into the cypress swamps.

Figure 10. The Bayou Sorrel realignment and new diversion cut. Original Bayou sinuous feature on right from NE to SW on right. New linear diversion channel in lower portion of figure right.

<u>Sedimentation in the Basin as a result of Man's Actions</u>.

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.

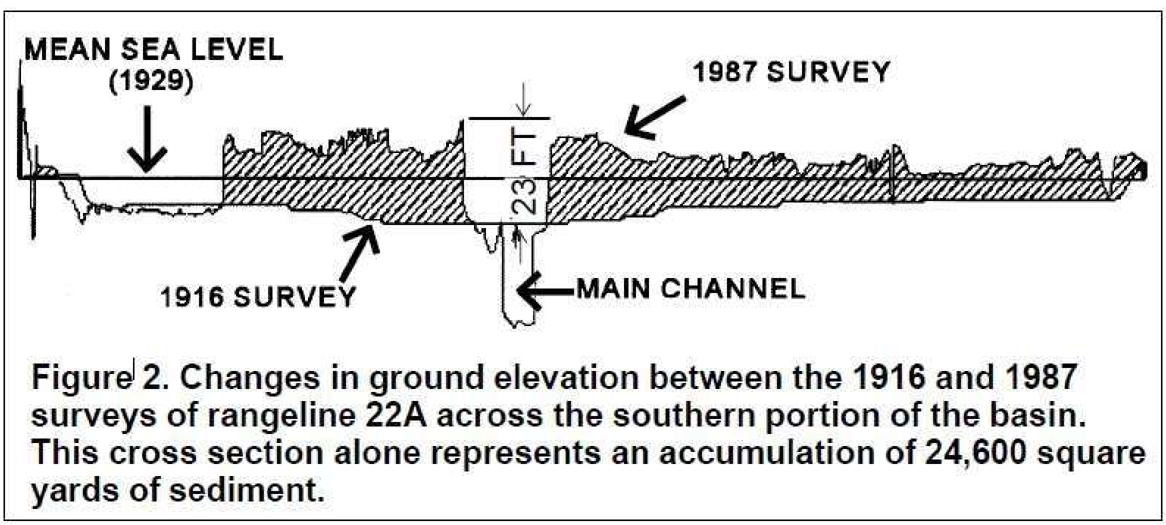


Figure 11. Cross-section of southern past of Basin showing sediment accumulation.

The reader is asked to again review the LiDAR images presented earlier!

Figures 12a and 12b where taken within an hour of each other on a field investigation undertaken 7th January 2017, at almost the same latitude in the Basin. Figure 12a was taken outside the Basin, in that area outside the flood way along the bank of Bayou Sorrel, the water stage was +4.8 feet. The natural levees with annual sediment deposition rates reminiscent of in the past were only 1.5 feet above the water level, so at a crest elevation of + 6.3 foot. (The M R & T levee cut off a section of the original Bayou Sorrel, so some of original bayou in and some outside the Floodway.)

Figure 12b is a photo of the Bayou Sorrel channel inside of the Basin, in an area receiving suspended sediments directly through the cut and distribution channel shown in Figure 6b; the stage was +4.0 feet and the levees were 7.0 feet on average above the water level, so a crest elevation of + 11.0 foot. This is a very significant observation and directly reveals just how much suspended sediment load the Corps' sediment diversion cut at Bayou Sorrel is delivering to locations far removed in the Basin. Suffice to say at the latter location there were no cypress trees, the canopy dominated by willows and sycamores.

Bayou Sorrel discharge ends up in the GIWW.

Figure 12a. Photograph of the natural levees along Bayou Sorrel outside of the Atchafalaya Floodway. Bayou stage was +4.8 feet on 7th January 2018 and levees about 1.5 feet above stage. Note abundance of cypress trees. Approximately same latitude as Figure 12b.

Figure 12b. Photograph of the levees along Bayou Sorrel Diversion Channel inside of the Atchafalaya Floodway. Bayou stage was +4.0 feet on 7th January 2018 and levees about 7.0 feet above stage. Approximately same latitude as Figure 12a.

5. <u>The Beauty of the Basin.</u>

In dealing with the Atchafalaya System there is sometimes confusing use of the term 'basin.' For this report the term Basin is used to represent the full original size of the Basin before levee systems were constructed. The term Atchafalaya Floodway is used to represent those areas of the Basin within the confining flood protection levees associated with the Mississippi River and Tributaries Flood Control system (M R & T). Both the Basin and the Floodway include the deltas developing at the coast, Atchafalaya and Wax Lake, as these are an integral part of the dynamics of the whole Atchafalaya system.

The Atchafalaya Basin Swamp, is the largest river swamp (in excess of 1 million acres) in the United States. Located in South Central Louisiana, the Basin is made up of a combination of wetlands and river delta area where the Atchafalaya River and the Gulf of Mexico converge. The Atchafalaya Floodway bounded by the M R & T system levees within the Basin encompasses approximately 512,000 acres of fresh marsh, bottomland hardwoods, cypress swamps, and open water and contains the largest contiguous tract of coastal fresh marsh in the state, combined a valuable national resource. An American-Indian word, "Atchafalaya" (ah-CHA-fa-LIE-ah) means *long river*.

Established in 2006, the Atchafalaya National Heritage Area stretches across 14 parishes in south-central Louisiana. It is among the most culturally rich and ecologically varied regions in the United States, home to the widely recognized Cajun culture as well as a diverse population of people of European, African, Caribbean and Native-American descent.

The Atchafalaya Basin is one of the last great wildernesses remaining in the continental United States as identified by the United States Corps of Engineers (USACE). The Basin includes the largest contiguous wetlands in the Mississippi River Valley and includes 10 distinct aquatic & terrestrial habitats ranging from large rivers to backwater swamps. The Basin is most noted for its Cypress-Tupelo Gum swamp habitat and its Cajun heritage.

<u>A Short Fact Sheet</u>

- Located between Baton Rouge, Louisiana to the east and Lafayette, Louisiana to the west
- More than 1 million acres in size, comprising the largest floodway in North America
- Consists of three floodways: Morganza Floodway, West Atchafalaya Floodway and Atchafalaya Basin Floodway
- Largest river swamp in North America
- Home to nine Federal and State listed endangered/threatened wildlife species
- Over 250 bird species located in the Basin
- Important wintering grounds for the birds of the Mississippi Flyway
- Major wintering concentration of wood ducks, mallards and woodcocks
- Largest contiguous bottomland hardwood forest for forest interior nesting species
- Highest nest production for Louisiana species
- Home to six endangered/threatened species of birds and 29 rookeries
- Diversity of wetlands, 500,000 acres of hydric soils, provide habitat for 14 wading bird rookeries
- Home to numerous bald eagle nests
- More than 50 mammalian species
- More than 40 reptilian and 20 amphibian species
- More than 100 species of fin fish and shellfish
- The Atchafalaya River is one of the top five rivers in terms of discharge in the United States; average annual flow is 180,000 cubic feet per second
- Important component of the USACE M R & T Flood Control Project. At times that the full basin is used as a Floodway, the maximum projected flood flow is 1.5 million cubic feet per second
- Most active growing delta (land accretion) in the continental United States
- Produces over $123 million annually from recreational activities
- Nature study averages 49,000 hours per year
- Produces $5 – $6 million annually from commercial fishing & crawfishing
- Produces more than 1000 pounds of fin fish per acre in certain water bodies in the lower Basin – greater than any reservoir in the Southeastern United States
- More than 500,000 user days of sport fishing recreational activity each year – over 8000 hours per month in just a 17-square mile area which is only 2% of the Basin
- More than 164,000 user days of hunting activity each year

- Deer hunters on the Sherburne Wildlife Management Area/Atchafalaya National Wildlife Refuge contributed over $1 million to the state's economy
- 25% of Louisiana's commercial forest lands and 51% of the state's hardwood forest are located in the basin
- Oil & gas pipelines cross the basin
- More than 300 active oil & gas wells are located in the Basin
- Atchafalaya River is a vital port for the oil & gas industries in the Gulf of Mexico
- More vessels pass Morgan City annually than Baton Rouge, the sixth largest port in the country
- Important in the development of unique cultures of Acadians & Native Americans
- Location of several hundred archeological sites, including several prehistoric sites.

From January to June 2015, landings of wild crawfish in the Atchafalaya Basin equaled 2,412,183 pounds with a dockside value of $3,148,755, according to a preliminary analysis of trip ticket data by the LA Dept. of Wildlife and Fisheries.

Total Travel Expenditures in the Eight Atchafalaya Basin Parishes: 2008: $ 451 million 2009: $ 435 million 2010: $ 450 million 2011: $ 468 million 2012: $ 464 million 2013: $ 470 million 2014: $ 483 million. Tourism in the Atchafalaya Basin Visitors to Atchafalaya Welcome Center June 2004- July 2015: 1.3 million people Visitors to Lake Fausse Pointe State Park FY 2004 - FY 2015: 890,770.

Although this river-swamp system is an integral part of Louisiana's history and natural resource heritage, changes in the Basin due to human activity during the last century are rapidly eroding the natural beauty, biotic diversity, and wildlife and fisheries productivity of this unique ecosystem (Kelso et al., 1997).

REFERENCES

Horowitz, A.J., 2010, A quarter century of declining suspended sediment fluxes in the Mississippi River and the effect of the 1993 flood: Hydrological Processes, v. 24, p. 13–34.

Kelso, E., Rutherford, C., and Hale, L., 1997. The Atchafalaya basin: An Ecosystem in Peril. Louisiana Agriculture, Vol. 40, No. 3, Summer 1997.

van Heerden, I. LL, 1983. Deltaic sedimentation in eastern Atchafalaya Bay, Louisiana. Special Grant Publication. Baton Rouge, LA.: Center for Wetland Resources, Louisiana State University.

van Heerden, I. Ll., 1994. A long-term, comprehensive management plan for coastal Louisiana to ensure sustainable biological productivity, economic growth, and the continued existence of its unique culture and heritage. NSMEP, Center for Coastal, Energy, and Environmental Resources, Louisiana State University, Baton Rouge, LA, 45 pp. http://www.worldcat.org/title/longterm-comprehensive-management-plan-for-coastal-louisiana-to-ensure-sustainable-biologicalproductivity-economic-growth-and-the-continued-existence-of-its-unique-culture-andheritage/oclc/30617836

van Heerden, I. L. 2007. The Failure of the New Orleans Levee System Following Hurricane Katrina and the Pathw3ay Forward. Public Administration review, Supp. to Vol.67, Dec 2007.

van Heerden, I.L. and M. Bryan, 2006. The Storm - What Went Wrong and Why during Hurricane Katrina - the Inside Story from One Louisiana Scientist Publ. Penguin/Viking, New York, New York, 308pp.

Welch, H. L., R. H. Coupe, and B. T. Aulenbach, 2014. Concentrations and Transport of Suspended Sediment, Nutrients, and Pesticides in the Lower Mississippi Atchafalaya River Subbasin During the 2011 Mississippi River Flood, April Through July. Scientific Investigations Report 2014–5100, U.S. Department of the Interior U.S. Geological Survey.

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