Comments to the U.S. Army Corps of Engineers, New Orleans Division
in reference to
The Environmental Impact Statement for
The Mid-Barataria Sediment Diversion

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These comments focus on the importance of subsurface geology in the planning, design, construction and adaptive management of the *Mid-Barataria Sediment Diversion (MBSD). The Mid-Barataria Sediment Diversion - Final Draft Executive Summary Report 30% Basis of Design* (CPRA, 2014a) states that "The MBSD, as envisioned in the Alternative 1 base design and the VE alternatives, would function as an artificial crevasse—transferring river power, sediment, and freshwater into a tidally influenced deltaic plain within Barataria Basin." In other words, the premise of the diversion is to recreate the natural land-building processes of the delta plain.

The natural surface processes of the deltaic plain cannot be properly understood outside of the context of subsurface geology. The geological history of the Mississippi River Delta Plain, and older sediments that underlie it, record an inter-dependence between the river, its delta and geological features such as faults and salt structures. The historical role of the river has been to link the sediment delivery system of its vast tributary network to the space available for deposition provided by the sedimentary basins formed by underlying faults and salt structures. Movement of the faults and salt throughout the history of the delta plain has been primarily controlled by differential sediment loading at the site of deltaic deposition.

An essential summary of the role of subsurface geology is provided by the USACE-contracted report:

ACTIVE GEOLOGICAL FAULTS AND LAND CHANGE IN SOUTHEASTERN LOUISIANA - A Study of the Contribution of Faulting to Relative Subsidence Rates, Land Loss, and Resulting Effects on Flood Control, Navigation, Hurricane Protection and Coastal Restoration Projects, U. S. Army Corps of Engineers, New Orleans District, Contract No. DACW 29-00-C-0034, Gagliano et al., 2003.

This report reaches five fundamental conclusions:

1. Submergence of coastal wetlands due to a combination of compaction, sea level rise and fault slip has been the major cause of land loss in the delta plain during the 20th century.
2. Fault movement in the area of the modern delta plain has been continual and episodic for millions of years. Episodes of active fault movement are separated by dormant periods when movement persists as slow creep. An episode of fault slip between 1964 and 1980 appears to be associated with significant land loss on downthrown sides of faults.
3. There is a relationship between faults and salt structures. Ductile, incompressible, low density salt moves relative to surrounding compacting sediments; and this movement of salt interacts with faults associated with the salt structures.
4. Continual episodic and slow creep fault slip may cause preferentially thicker accumulations of compactible organic clays and peats on the downthrown side of the faults, thereby delineating areas where subsidence rates may be higher due to the greater compactibility of the soil column.
5. Faulting poses a natural hazard in southeastern Louisiana, and the findings of the report have direct applications to the planning and design of coastal restoration efforts, including infrastructure elements.

Each of these conclusions is directly applicable to a thorough assessment of the subsurface geology in the vicinity of the Mid-Barataria Sediment Diversion (MBSD).

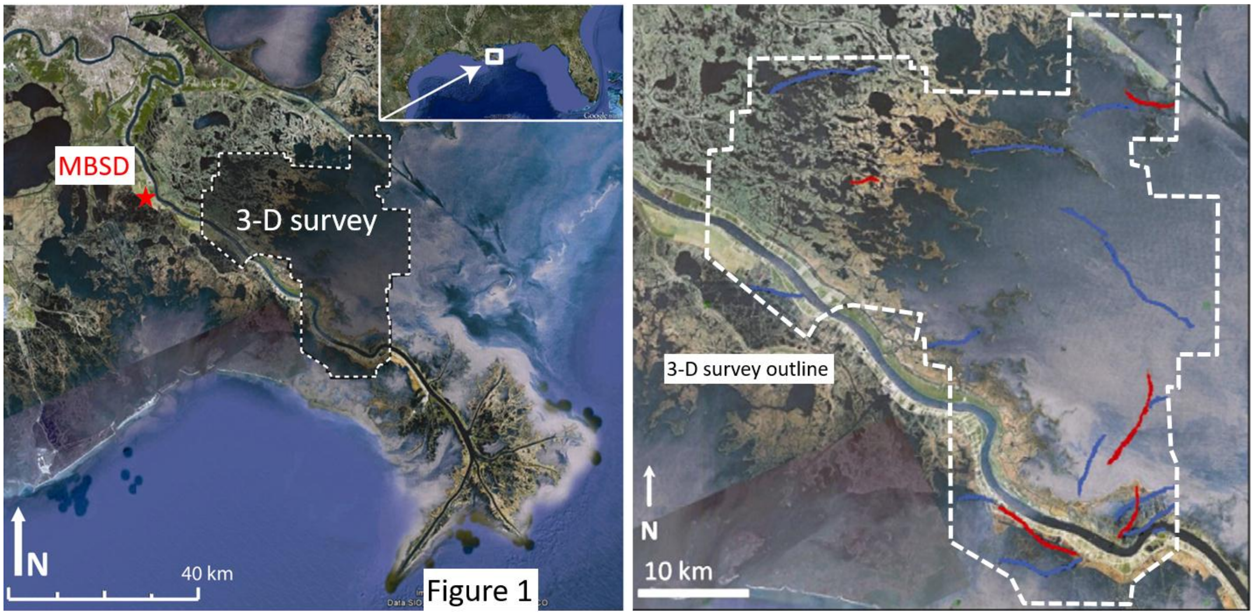


Figure 1

The ability to map faults and salt structures, and to interpret their historical patterns of movement, is substantially enhanced by the subsurface imaging capabilities of oil and gas industry 3-D seismic surveys. The first peer-reviewed scientific study to use industry-grade 3-D seismic data to study the surface impacts of faults in southeast Louisiana was Armstrong et al. (2014). Figure 1 shows the outline of the 3-D seismic survey used in their study, just east and south of the site of the Mid-Barataria Sediment Diversion. The researchers used the seismic volume to image approximately 28 faults. They found that most seismically imaged faults appear to extend to the modern land surface, and two of those are coincident with faults interpreted by Gagliano et al. (2003). Gagliano et al. measured vertical displacement of the land surface by these faults of over one meter. Without attempting to measure vertical offset, the Armstrong et al. (2014) study noted that several other faults correspond to abrupt shifts from emergent wetlands to fully submerged areas of open water. The right panel of Figure 1 shows the Armstrong et al. interpretation of surface fault traces. Blue traces are down-dropped to the south. Red traces are down-dropped to the north. Figure 2 shows a combination of surface fault traces

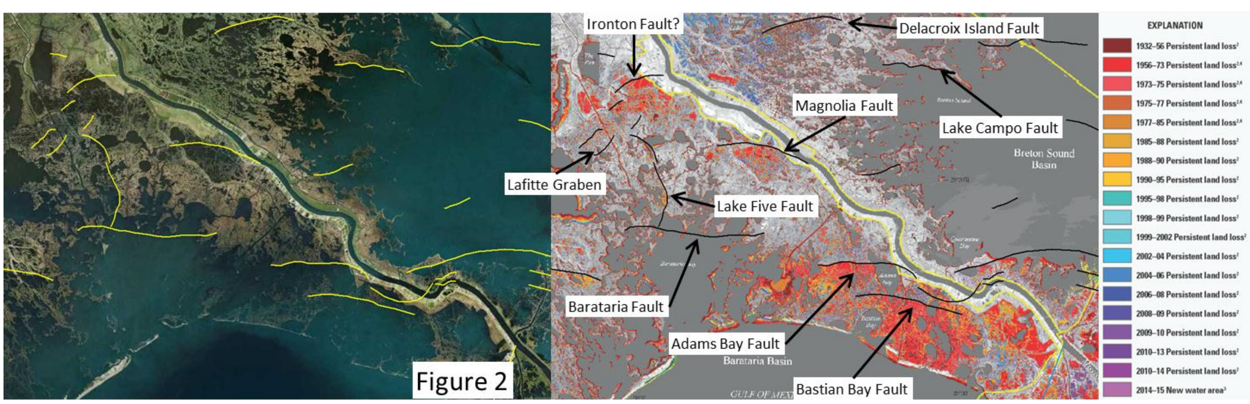


Figure 2

interpreted by Armstrong et al. (2014) and Gagliano et al. (2003). The figure also shows the surface traces of the Lafitte graben faults taken from Greene (1998), and the Barataria Bay fault and Lake Five fault (McLindon, 2017). In this figure the correspondence of several of the fault traces with abrupt shifts from emergent wetlands to fully submerged areas of open water is obvious. There is also a very clear relationship between the submergence of the wetlands along the downthrown sides of these faults and the land loss that occurred in the 1960s and 1970s, as seen on the right panel of Figure 2 taken from Couvillion et al. (2017).

Similarities between the known deltaic faults noted above and patterns of wetland loss in the immediate vicinity of the MBSD suggest the existence of a similar fault - **the Ironton fault**, which may have also experienced a recent episode of fault slip. This fault appears on an early fault map (Wallace, 1962) with an orientation, length and down-to-the-south movement sense consistent with Figure 2. Figure 3 shows the profile of a compilation of USACE borings along the west bank river levee (Stanley et al., 1996). This profile shows the vertical offset of the late Pleistocene surface associated with the Magnolia and Adams Bay faults. It also suggests a vertical displacement that may be associated with the Ironton fault near the site of the planned MBSD conveyance structure.

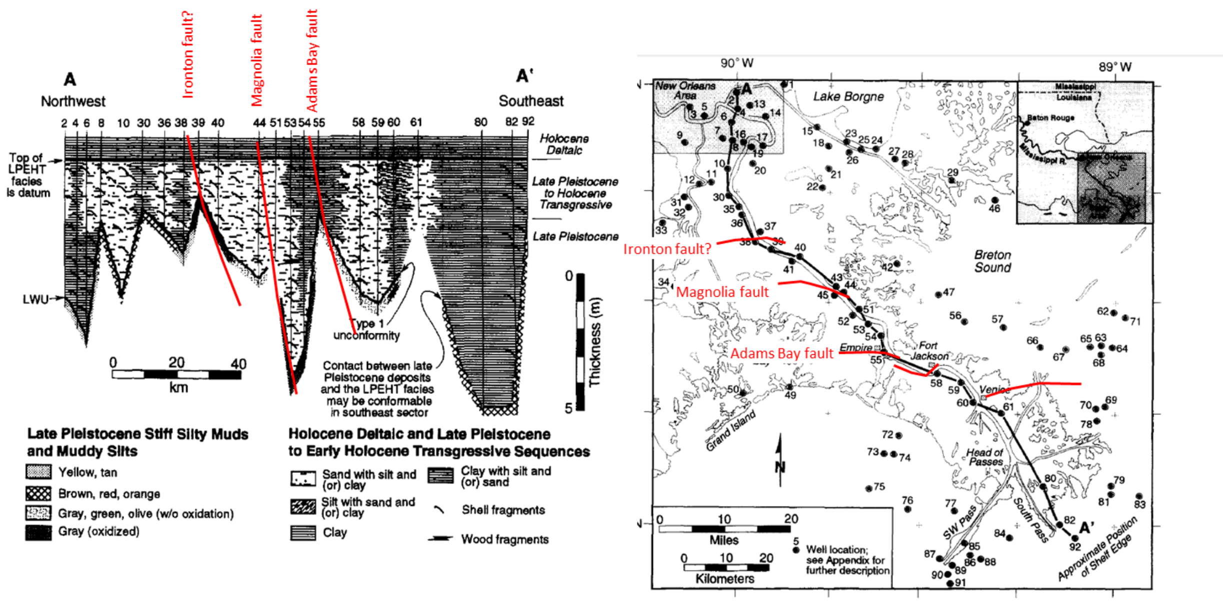


Figure 3

Fig. 1. Map of the southeast Mississippi deltaic plain showing positions of the 92 cores considered in this study (database in Table 1). Cross-section along transect A–A' is depicted in Fig. 9.

The interrelationship between faults and a salt structure in the immediate vicinity of the MBSD was documented by Greene (1998). Figure 4 shows a seismic profile from the Lafitte 3-D survey across the salt structure. The black and red seismic reflectors have a genetic relationship to sedimentary layers (imaged by differences in density and acoustic wave velocity) and are used to map subsurface geologic structures. The gently arcing red, green and black lines are faults that offset the seismic reflectors. The vertical yellow lines indicate wellbores that are in the immediate vicinity of the seismic profile. The short, colored line segments perpendicular to the wellbores indicate biostratigraphic markers, i.e. correlations constrained paleontologically. The Lafitte salt structure is outlined in a purple dashed line. The faults form a classic graben structure above the salt. In a graben configuration the downthrown sides of the two primary bounding faults (the red and green faults) face each other so that the central graben region is down-dropped relative to both faults ("graben" is derived from the German word for grave). The subsurface depths of the color-coded biostratigraphic markers indicate that shallower

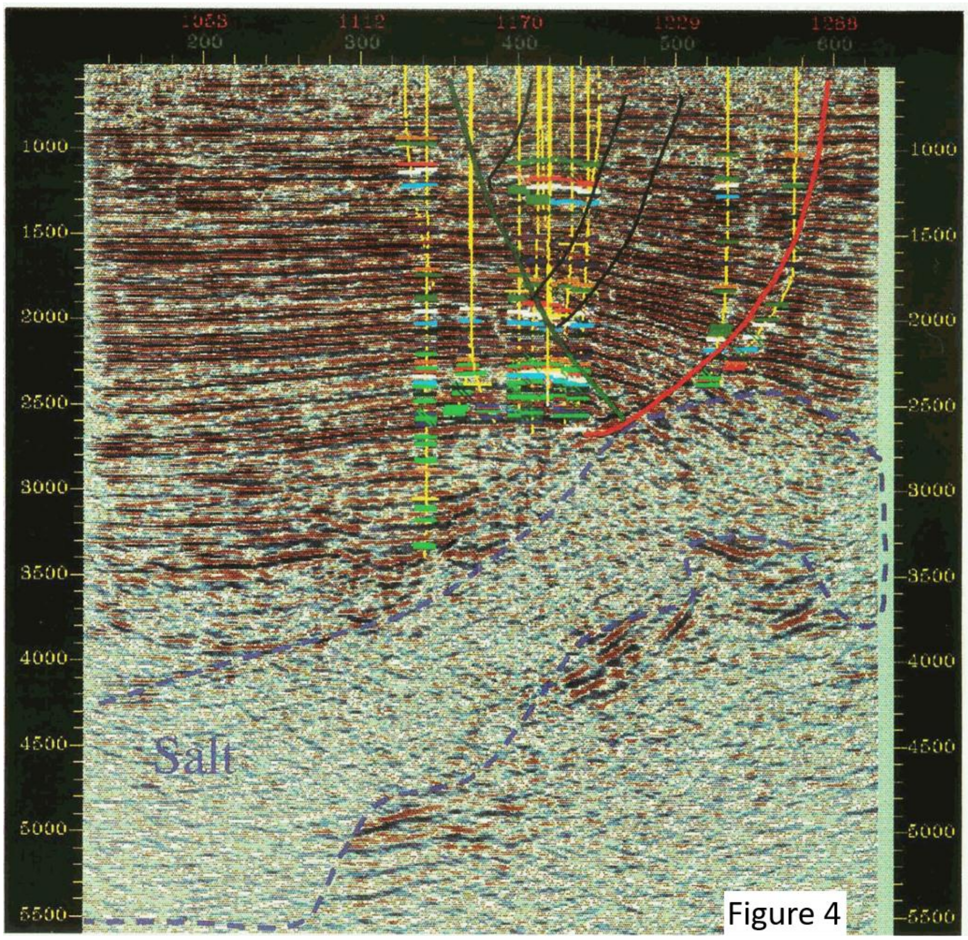
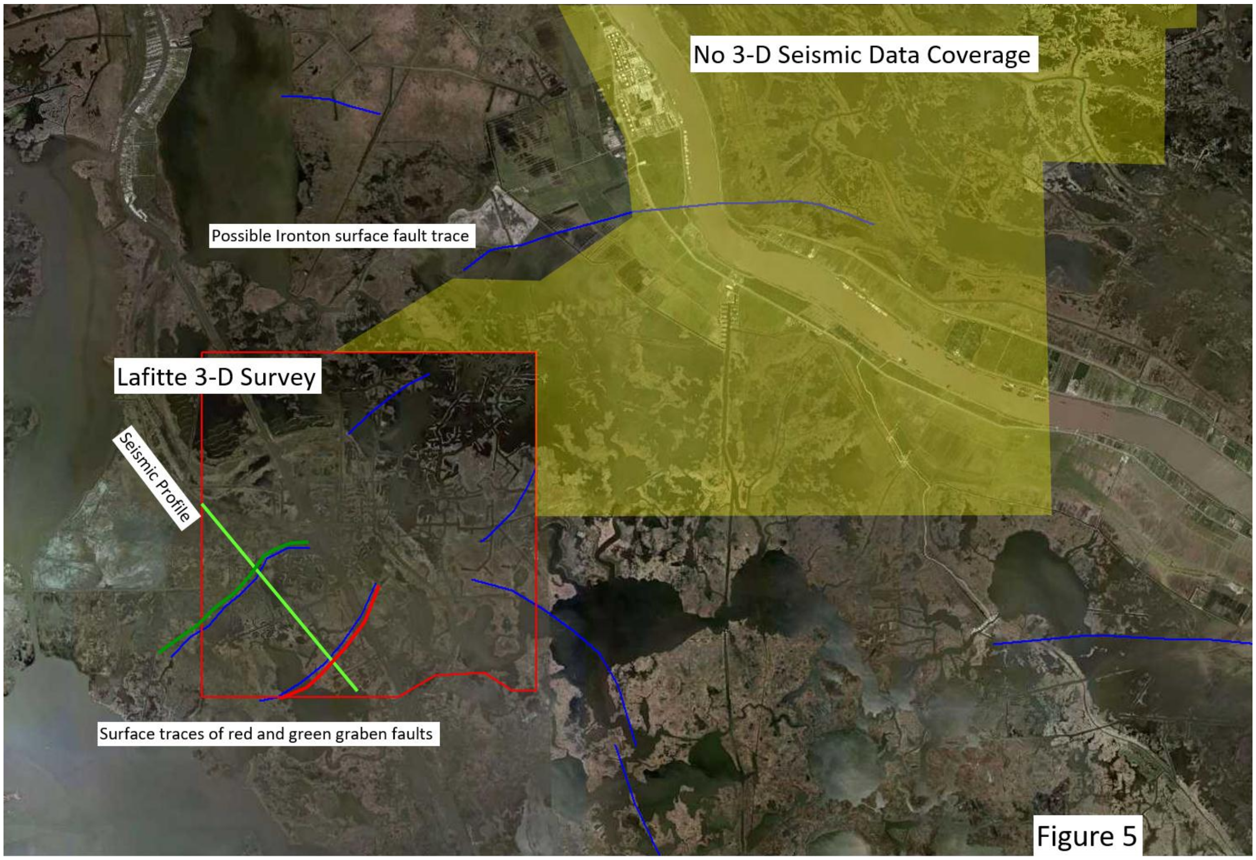


Figure 4

sedimentary layers are thicker within the graben indicating higher rates of subsidence and sediment accumulation within the graben continuing from the Miocene to recent geologic past.

The bounding red and green graben faults extend vertically toward the land surface; these faults and the salt structure may have deflected the course of Bayou Barataria (DeBlieux, 1962). Figure 5 shows the approximate location of the seismic profile in Figure 4, and the extrapolated surface traces of these faults. If the graben faults have experienced active slip in the very recent past, it is possible that the central graben region between them may have experienced higher rates of recent subsidence than areas outside of the graben. It may also be possible that **the entire Lafitte graben structure may respond to sediment loading with a higher rate of subsidence than other areas**. The interpretation of these faults and their extrapolated surface traces is limited by the boundaries of the Lafitte 3-D survey shown in Figure 5. There are other 3-D surveys in the area, but the yellow color-filled area in Figure 5 indicates an area of no 3-D data coverage. Currently there is a very limited capability to map faults or to extrapolate surface traces in the immediate vicinity of the MBSD diversion structure. **The only way to properly image faults in area with no 3-D seismic data coverage is to acquire new seismic data. In this case, the acquisition of new high resolution 2-D seismic data is recommended.**

The CPRA documents of the Mid-Barataria Sediment Diversion include several references to the significance of faulting in the design of the diversion, including the specific need for additional work



on faulting. There are no indications of any efforts to determine the location of any possible faults in the area of the diversion project as a part of the preparation for design and planning.

The *Mid-Barataria Sediment Diversion Geotechnical Report 30% Basis of Design* (CPRA, 2014b) references faults in Section 4 – Geology and Geomorphology:

"As discussed by Gagliano et al. (2003), a series of growth faults have developed in the underlying Pleistocene and older basement soils as the Mississippi River Delta has progressed southward. Due to the young age of the sediments resulting in self weight settlement and movement on the growth faults in response to the growth of the delta, the area is experiencing regional subsidence. The rate of subsidence is reported as being a rate of 2 to 4 feet per century for the MBSD site vicinity.

Regional seismicity is controlled by the New Madrid Fault Zone in Missouri. USGS estimates that peak ground accelerations of less than 2 percent of gravity would occur in the vicinity of the MBSD site. Therefore, the risk of strong ground shaking at the site is judged to be very low."

In fact, the Gagliano et al. (2003) report makes no determination of the rate of subsidence in the MBSD site vicinity. There are wide-ranging estimates for subsidence rates using various methodologies from studies in the general vicinity of the MBSD site (Zou et al., 2015; Jones et al., 2016; Nienhuis et al., 2017). The Myrtle Grove Superstation (Bridgeman et al., 2016) is in the early stages of collecting subsidence data near the site of the diversion, but there have been no efforts to determine variations in historical rates of subsidence relative to geologic structure across the area of the MBSD site. This geotechnical report also appears to infer that fault movement in the area of MBSD could only be induced by strong ground shaking due to regional seismicity. While there have been suggestions that regional seismicity from very large earthquakes may be a triggering mechanism for fault slip on the Mississippi River Delta Plain, it is not a requirement for fault movement. Episodic or slow fault creep may occur without the induction by or the creation of seismicity.

The same geotechnical report includes this summary from Section 6.1 – Geotechnical Feasibility:

"From a geotechnical engineering basis the MBSD project is judged to be feasible. However, there are significant short-term and long-term constraints associated with constructing large civil works projects within the relative young lower Mississippi River delta. The geotechnical site conditions and associated constraints must be incorporated into the civil, structural, hydraulic design, and construction phasing. The primary geotechnical site conditions include:

- *presence of the very soft to soft, compressible and weak foundation conditions across the entire conveyance complex alignment*
- *occurrence of high groundwater, and engineering challenges that this would pose on constructibility and long-term performance of the project*
- *occurrence of long-term regional subsidence that must be factored into setting the conveyance complex levee and structure crown/top elevations*
- *potential geologic fault activity"*

In order to address the above points concerning the geotechnical feasibility of the MBSD, especially the evaluation of long-term regional subsidence rates and the potential for geologic fault activity, a thorough subsurface geological evaluation of the MBSD vicinity needs to be undertaken, as it is the only way to incorporate the potential impact of faulting.

Table 3-2 from the same report (CPRA, 2014b) indicated that additional technical work is required to evaluate faulting in the Mississippi River bed, as well as faulting within the MBSD site as a regional geologic consideration.

Table 3-2. Major areas of additional technical work

Project feature	Additional work
Mississippi River	• Navigation studies (for example, vessel and barge tow) • Shoaling estimates • Geomorphologic studies • Flow vectors, eddies, and scour • Geotechnical characterization
Mississippi River bed from thalweg to revetment	• Geotechnical characterization • Slope stability • Scour • Bed form stability • Faulting
Mississippi River bed revetment to batture (inlet channel)	• Thickness and construction of revetment • Subsurface conditions • Cutting and patching • Removal and stability • Construction in the dry versus in the wet • Full or partial prefabrication versus cast-in-place • Foundation and pile supports (test pile) • Skew, angle, top open, partial cover, and fully covered • Sediment capture efficiency • Geotechnical characterization (point bar)
Mississippi River batture to MR&T (first segment of inlet channel)	• Near-field effect on batture and levee face for scour • Large debris impact and management • Section 408 design criteria • Construction in the dry versus in the wet • Full or partial prefabrication versus cast-in-place • Foundation and pile supports (test pile) • Geotechnical characterization (point bar)

Table 3-2. Major areas of additional technical work

Project feature	Additional work
Pump station	• Geotechnical and geomorphic characterization (natural levee, distributary channel, and marsh deposits) • NOV/NFL design coordination with USACE • Foundation and pile supports (test pile) • Section 408 design criteria • Hydraulics
System hydrodynamics	• Physical model (hydraulics) • Flow three-dimensional modeling (design hydraulics) • Delft3D modeling (sediment) • Morphological characterization • Sea level rise • Hurricane surge, wind, and wave
Regional geologic considerations	• Regional subsidence • Geologic faulting and offsets

Notes: MR&T = Mississippi River and Tributary, NFL = Non-Federal Levee, NOV = New Orleans to Venice, USACE = U.S. Army Corps of Engineers

RECOMMENDATIONS

There are several indications of the existence of faults and of potential recent fault activity in the immediate vicinity of the Mid-Barataria Sediment Diversion in the published scientific literature (e.g., Greene, 1998; Armstrong et al., 2014). There are clear indications of the necessity for additional work to determine the potential impacts of faulting, as noted in the CPRA documentation for the Basis of Design reports. It is recommended that a thorough subsurface geological evaluation of the vicinity of MBSD be conducted to attempt to determine the location of geological faults, the recent history of fault movement and the effects of active faults on subsidence rates and variations in the thickness of highly compactible soils.

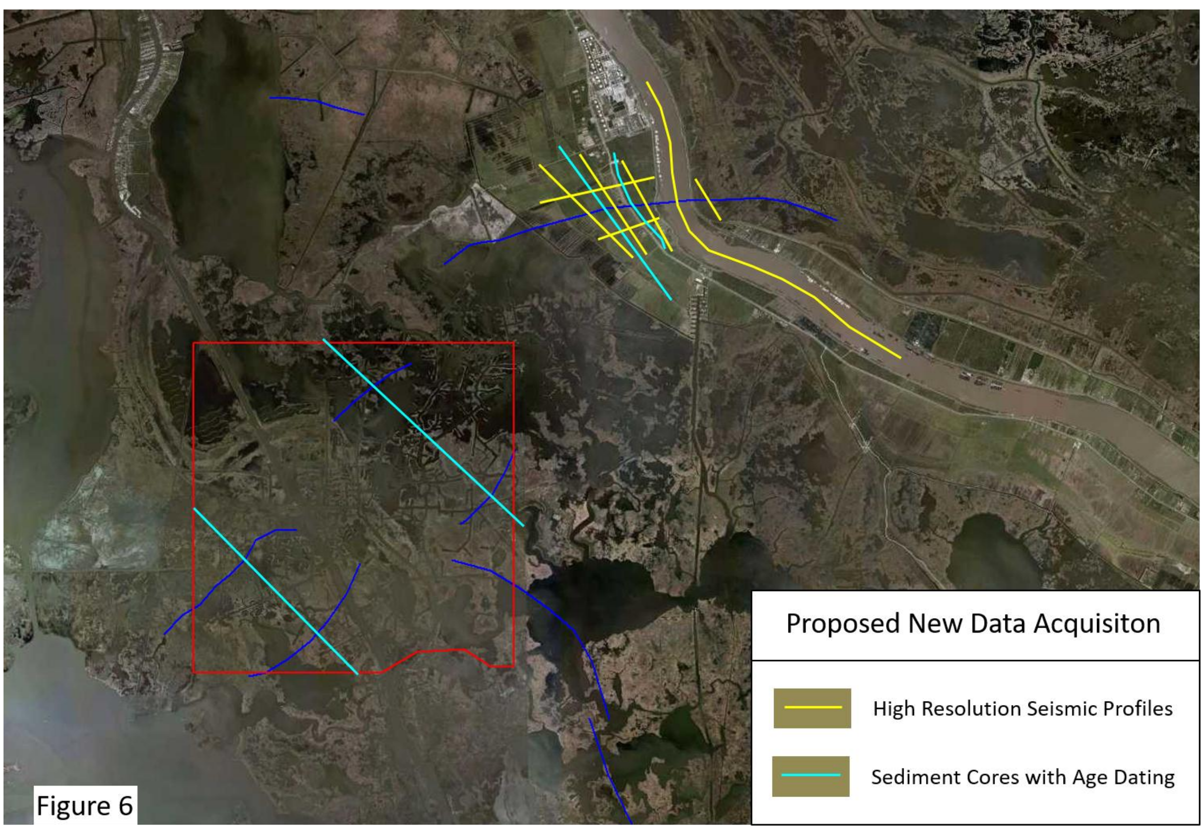


Figure 6

It is recommended that a subsurface geological evaluation should include the following elements:

1. A review the subsurface geology using oil and gas industry 3-D seismic data. This may be accomplished through a collaborative engagement with owners, licensees and interpreters of the 3-D seismic surveys in the area. Such a collaborative engagement may be facilitated with the assistance of the New Orleans Geological Society, the Louisiana Mid-Continent Oil and Gas Association, or the Louisiana Oil and Gas Association.
2. The acquisition of high resolution seismic data in the immediate vicinity of the diversion structure. This should necessarily include land-based acquisition along both banks of the river and marine acquisition in the river channel, as indicated in Figure 6.
3. The acquisition of sediment core profiles across potential faults. The arrangement of these core profiles should be of adequate density to allow for the interpretation of faults by the vertical offset and variations in thickness of the sedimentary layers. The evaluation of core profiles should include detailed stratigraphic analysis and age-dating of the sedimentary layers to allow for estimates of historical subsidence rates and rates of fault movement.
4. The addition of subsidence measurement capabilities similar to those of the Myrtle Grove Superstation at several additional locations in the vicinity of the diversion. These stations should be positioned with advance knowledge of the location of faults in the area to allow for the direct measurement of variations in subsidence velocities across the faults.
5. The integration of detailed variations in subsidence rate and estimates of fault slip rate into predictive subsurface geological models including models for the response to sediment loading associated with diversion operations.

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