Beryllium - 7 Analysis in the Caernarvon Freshwater Diversion Receiving Basin: January through April, 2017

Addendum to the Report:
Caernarvon Freshwater Diversion Pulse Opening January 4 to February 3, 2017: Observations and Data Collections

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Introduction


Background

The Caernarvon Freshwater Diversion was operated (or opened) on three separate occasions in the winter and spring of 2017. The previous report only captured one of the openings that spanned January and February, but the diversion was opened again March and April (Figure 1). The openings ranged from 1,000 to 6,000 cfs (cubic feet per second) as measured at the USGS hydrologic station located in the Caernarvon Diversion outfall canal. The first opening spanned 30 days (January 4 to February 2) with an average discharge of 2,968 cfs and median discharge was 2,270 cfs. The second opening spanned 31 days (March 3 to April 2) with an average discharge of 2,150 cfs and median discharge of 2,740 cfs. The third opening spanned eight days (April 4 to April 13) with an average discharge of 3,435 cfs and median discharge of 3,485 cfs.

![USGS 295124089542100 Caernarvon Outfall Channel at Caernarvon, LA](image)

**Figure 1:** Discharge through the Caernarvon Freshwater Diversion during three openings spanning January through April, 2017. Also shown is the collection day for the turbidity data and the period covered by the Beryllium - 7 data.

During the period of the three openings of the diversion, there approximately five sediment spikes in the Mississippi River (Figure 2). Fortuitously, it appears that the three openings coincided with four of the sediment spikes (two during the first opening) which would have transported sediment into the Caernarvon Freshwater Diversion receiving basin. The sediment distribution patterns during the January opening is described in the report referenced above. These patterns were elucidated based on turbidity sample collection performed during the first opening. As a reminder, the major flow lines in the
Caernarvon Freshwater Diversion receiving basin were down Bayou Mandeville and into Big Mar (Figure 3). Water and sediment flowing into Bayou Mandeville flowed into Lake Lery. Water flowing through Big Mar eventually reached the Delacroix Canal and then the majority flowed into Bayou Mandeville, while a small portion flowed west in the Delacroix Canal. Based on the turbidity data, it appeared that the majority of the sediment deposition occurred in Big Mar and Lake Lery. This was inferred from the reduction in turbidity as water moved downstream from the diversion.

![Image](USGS 07374000 Mississippi River at Baton Rouge, LA)

Figure 2: Turbidity in the Mississippi River at Baton Rouge during the period of the three Caernarvon Freshwater Diversion openings. Fortuitously, four of the five sediment spikes picture here were captured during the three openings. Also shown is the day of turbidity data collection and the depositional period covered by the Beryllium-7 data.
Figure 3: The two major flow lines for water and sediment from the diversion (top) and results of turbidity sampling in the Caernarvon Freshwater Diversion receiving basin on January 9, 2017 (bottom).

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The reduction in turbidity across Big Mar and down Bayou Mandeville indicated that sediment deposition is occurring in those areas. However, our turbidity sample collection was strictly from the
surface water to one foot deep. Therefore, sediment could have sunk in the water column, resulting in lower turbidity measurements, but not actually deposited on the water bottom. LPBF requested and obtained funding to conduct a Beryllium-7 survey (7Be) in the receiving basin. Beryllium-7 is a naturally occurring radionuclide produced in the upper atmosphere. It has a half-life of 53.1 days, is particle reactive, and is associated with vegetation, soils and particulate matter (Sommerfield et al. 1999). Therefore, 7Be is an effective tracer of short-term sedimentation, and 87.5% of observed signal can be attributed to activity within the previous 159 days (Allison et al. 2000). The soil samples for 7Be were collected on May 11, 2017 (methods described below) but were analyzed between May 31, 2017 and June 17, 2017. Therefore, given the half-life of 7Be, assuming detection through three half-lives or 159 days, this data will cover deposition from December 3, 2016 until the date of collection and therefore captured all openings.

Methods

Sample Collection

Cores for 7Be analysis were collected at 10 locations in the Caernarvon Freshwater Diversion receiving basin (Figure 4). Nine of the ten sample sites were from water bottom (in some areas very shallow water) and one sample was collected on land (Label 9, Figure 4). Cores (approximately 10 cm in length) were collected using an Eckman Dredge (Figure 5). A sediment sample was “grabbed” using the dredge and then a core was pushed into the soil in the dredge and removed. The cores were immediately capped on both ends, taped shut with electrical tape, labeled with a sample number and placed in a cooler filled with packing peanuts in order to reduce jostling during transport (Figure 5). Two cores were collected in one dredge “grab” for a total of 20 samples at the 10 locations. At the location on land, the dredge was not used and the core was collected by pushing the core into the soil. At each location the GPS location of the core collection was recorded.

Figure 4: Core collection locations for Beryllium-7 analysis.
Figure 5: Core collection process using the Eckman Dredge. Counterclockwise from top left; pushing the Eckman dredge into the soil to collect sample; pushing core into dredge to collect core sample; placing cap on top and bottom of core; taping the core caps onto core with electrical tape.

Sample Processing
The cores were returned to the Coastal and Environmental Hydrodynamics and Sediment Transport Research Laboratory at the University of New Orleans for processing. Since $^7$Be is a tracer for recent deposition, only the top 2 cm of each core were analyzed. The top 2 cm were cut from the top of the core, weighed, then placed in a drying oven and dried at 110 °C (230 °F). The samples were then weighed in order to calculate percent moisture content. The samples were then homogenized using a mortar and pestle and dried in a desiccator for twelve hours. Loss on ignition (LOI, percent organic matter) was performed by placing the samples in a combustion oven at 580 °C (1,076 °F) for three hours. The samples were then cooled in the desiccator and weighed in order to obtain percent organic matter. Lastly, the samples were bagged for transport to the USGS Coastal and Marine Science Center in St. Petersburg, Florida for $^7$Be analysis.

Beryllium 7 Analysis
Dried samples of the top 2 cm (15 – 50 g) were sealed in 125 mL airtight polypropylene containers. The sample weights and counting container geometries were matched to pre-determined calibration standards. The sealed samples were counted for 24 – 48 hours on a planar-style, low energy, high-purity germanium, gamma-ray spectrometer (Canberra Industries, Inc., http://www.canberra.com/). The standard suite of naturally-occurring and anthropogenic radioisotopes
measured at the USGS SPMCSC radioisotope lab along with the corresponding photopeak energies in kiloelectron volts (keV) for $^7$Be (477.6 keV). Sample count rates were corrected for detector efficiency determined with IAEA RGU-1 reference material, standard photopeak intensity, and self-absorption using a U-238 sealed source (Cutshall et al. 1983). $^7$Be activities (disintegration per minute (dpm)/g) were determined by measuring the number of counts (decays) at the 477 keV photopeak. These were then used to calculate core inventory (dpm/cm$^2$), which is the total amount of $^7$Be in a sedimentary column, determined by summing the product of the activity (dpm/g), dry bulk density, and interval core length for the proportion containing $^7$Be. Dry bulk density was calculated by using the following equation:

$$\rho = \frac{1 - W}{\rho_W + 1 - W} \rho_S$$

Where $\rho$ is dry bulk density, $W$ is the water content (percent moisture as a decimal), $\rho_W$ is the density of water (1.02 g/cm$^3$), and $\rho_S$ is the density of sediments, which was determined by $1\text{-LOI} \times 2.6 + \text{LOI}\times 1.2$, where 2.6 and 1.2 are assumed density of mineral and organic matter, respectively (Kolker et al. 2009).

**Analysis**

There were no statistical analysis performed on the $^7$Be. Rather, the results were mapped in ArcMap 10.5 (ESRI 2016), to compare to the patterns revealed by the turbidity study discussed above.

**Results**

**Bulk Sedimentary Properties**

The percent moisture of the ten sample locations ranged from 44% to 88% with a mean of 72% (± 15%) and a median of 75%. The lowest percent moisture was found at the site on land and the highest was found in the hurricane sheers west of Lake Lery and the southwest corner of Big Mar (Figure 6).

Percent organic matter ranged from 5% to 43% with a mean of 17% (± 12%) and a median of 14%. The highest percent organic matter was found in the hurricane sheers west of Lake Lery and the lowest was found in and around the delta, closest to the diversion outfall (Figure 7). This supports the depositional patterns, in that areas with higher deposition tend to have lower organic matter content and higher mineral sediment content. Bulk density ranged from 0.1 to 0.53 g/cm$^3$. The mean bulk density was 0.27 g/cm$^3$ (±0.15) with a median of 0.24 g/cm$^3$. As expected, bulk density was inversely correlated with percent organic matter, with higher organic matter associated with lower bulk density (Figure 8).
Figure 6: Percent moisture in the Caernarvon Freshwater Diversion receiving area.

Figure 7: Percent organic matter in the Caernarvon Freshwater Diversion receiving area.
Figure 8: Bulk density was inversely correlated with percent organic matter in the Caernarvon Freshwater Diversion receiving area.

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The highest $^7$Be inventory, 3.92 ± 0.34 dpm/cm$^2$, was sampled at the mouth of Bayou Mandeville where it empties into Lake Lery (Figure 9). The second highest inventory, 2.92 ± 0.4 dpm/cm$^2$ was found on the west side of the Caernarvon Delta (on the opposite side from the diversion outfall canal) near where a natural cut through the delta (named Bayou Bonjour by LPBF), exits into open water. The third highest inventory, 1.84 ± 0.55 dpm/cm$^2$, was found at the site on land, in the delta. One other high inventory, 1.42 ± 0.25 was also found on the west side of the delta but further north from the natural cut. In one of the hurricane sheers (developed during Hurricane Katrina), west of Lake Lery, there was no $^7$Be activity was detected. The remaining $^7$Be inventories were all below 1.0 dpm/cm$^2$. In general, there was low $^7$Be activity in the hurricane sheers west of Lake Lery and in the deeper, open water areas of Lake Lery and high activity in areas where canals or water ways (Bayou Mandeville) deposit into more open environments. Since the $^7$Be inventory was calculated from the activity readings and the bulk density, the activity results are also shown (Figure 10). The activity figure reveals slightly different patterns. Activity (dpm/g) does not take into account bulk density or the volume of the core. The activity data still had the location at the mouth of Bayou Mandeville and the southern location on the west side of the delta with the highest activity. However, the location in the southwest corner of Big Mar also had high activity but the inventory was low when bulk density is taken into account. There was also high activity on the west side of Lake Lery that also resulted in lower inventory based on low bulk density.
Figure 9: Beryllium - 7 inventory (dpm/cm²) in the Caernarvon Freshwater Diversion influence area. Sample cores were collected on May 11, 2017.

Figure 10: Beryllium - 7 activity (dpm/g) in the Caernarvon Freshwater Diversion influence area. Sample cores were collected on May 11, 2017.
**Discussion**

The patterns of deposition revealed by the $^7$Be analysis supports the patterns seen previously in the turbidity data collected during the opening in January, 2017 (Figure 11). The patterns of deposition also follow the major flow lines measured in the Caernarvon Freshwater Diversion receiving basin. The majority of the deposition occurred at the mouth of Bayou Mandeville and on the west side or backside (away from the diversion outfall canal) of the Caernarvon Delta that has developed since 2005. The $^7$Be data confirms that the reduction in turbidity observed during our previous study was due to deposition and not merely settling of sediment lower in the water column. Also, there was deposition detected on land in the delta, indicating that at some point the diversion was flowing at a high enough discharge to induce overland flow. Past study has surmised that flowing the diversion above 4,000 cfs induces overland flow (Snedden 2006, Snedden et al. 2007) and at various times during the three pulses that occurred in 2017, the flow was above this threshold, reaching 6,000 cfs on some occasions.

![Figure 11: Interpretation of discharge and sediment distributions from the Caernarvon Freshwater Diversion from the openings spanning January through April, 2017. Interpretation is based on ADCP, turbidity, and Beryllium-7 data, and aerial photography.](image)

The Caernarvon Freshwater Diversion was never intended to carry significant amounts of sediment to build land or nourish the basin. The diversion draws water from the surface of the Mississippi River where the concentrations are lowest and only the smallest, lightest sediments persist. Despite this, the diversion is transporting sediment into the basin, building land and creating mudflats. The positive side of this diversion is that there is nearly 100% retention of sediment in the system, and very little, if any is lost out into open water. Sediment that is deposited in Lake Lery and at the mouth of Bayou Mandeville may not be directly building land but it is available for burrow for marsh creation projects and can be re-suspended and deposited onto the marsh platform during fronts and storms, nourishing nearby marshes. Ideally, LPBF would like to see more of the water diverted west down Delacroix Canal and into the hurricane sheers that developed during Hurricane Katrina. While the $^7$Be data revealed that there was some deposition from the diversion operations in the winter of 2017 in the hurricane sheers, filling them in slowly, they could be filled in more quickly with some diversion outfall management and redirecting of the flowing waters.
While the purpose of this diversion is not to build land, it is important to study the sediment transport dynamics for the benefit of future or proposed sediment diversions (CPRA 2017). Given the scale of sediment transport for the Caernarvon Freshwater Diversion, we would expect that with sediment diversions, which will be larger and target sediment, will have a larger influence area, larger land-building potential, and a shorter time to see first signs of land-building. It was 14 years before land-building was observed at Caernarvon as Big Mar filled in enough to allow for the growth of emergent marsh vegetation. This investigation also shows the importance of silt and clay in land-building and sediment transport dynamics, since that is the majority of what is transported at this site (Snedden et al. 2007). This study and others, on freshwater diversions, can provide insight into how to better operate existing and proposed diversions for maximum benefit.

**Literature Cited**


Snedden, G. 2006. River, tidal, and wind interactions in a deltaic estuarine system. Louisiana State University, Baston Rouge, LA. Dissertation.
