Demonstration Pilot Project to Examine Whether Diffusers Will Improve the Ecological Condition of Dead-End Tidal Canals, Status Report, November 2013

Background

The Town of South Bethany (Figure 1) is a densely populated urban community initially developed in the 1950s. It consists of approximately 1,300 single family homes situated on 270 acres located in the southeastern part of Sussex County, Delaware, between the Atlantic Coast and the Little Assawoman Bay and the Assawoman Canal. South Bethany was developed before the 1990 stormwater management regulations and contains five (5) miles of dead-end canals. These canals are currently used mainly for boating and storm water management. In the past they were also used for swimming, fishing and crabbing. How-ever, due to increased pollution (excess nutrients, high Enterococcus levels and low dissolved oxygen) as a result of stormwater runoff these canals are rarely used for swimming, fishing and crabbing.

Figure 1. Town of South Bethany

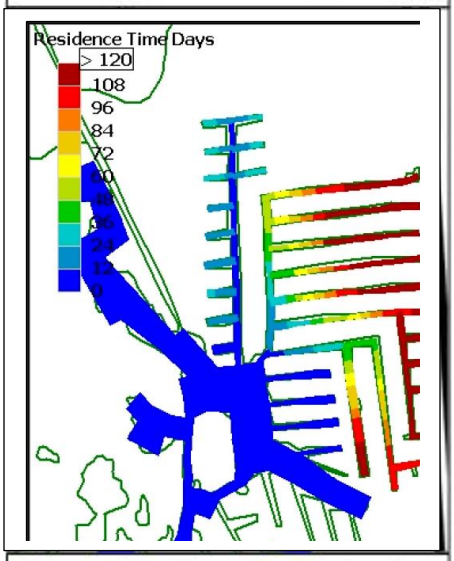


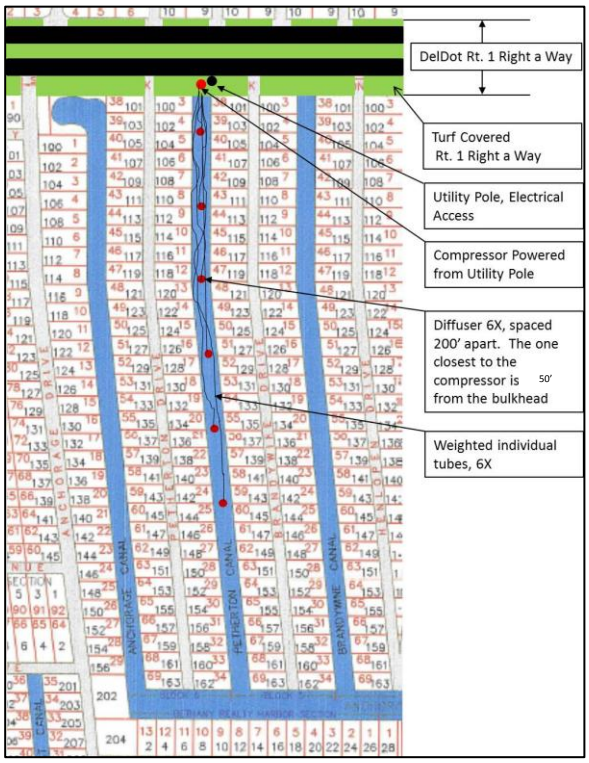
Figure 2. Residence Times in Canals

The canals perform the function of stormwater management ponds. Some have argued that since the canals are tidal that they in fact do not act as ponds. However this is not substantiated. The South Bethany Canals Flushing Study – Entrix 2005 – demonstrates that there is essentially no flushing in the ends of the canals (Figure 2, Residence Time in Canals). Residence Time is defined as the time it takes a concentration to reduce by 36.79%. The computer flushing model was run to simulate three months of tidal action. The areas in red did not reach the 36.79 % reduction in the three months. The areas in green reached the 36.79% reduction in one month. The areas in dark blue reached 36.79% reduction in about one day. The resulting finding is that the canals shown in red do indeed act as storm water management ponds since they have no significant exchange of water due to tidal action.

Based on the fact that the dead end canals act as stormwater management ponds, the Canal Water Quality Committee recommended to Town Council that diffusers, similar to aerators used in nearby stormwater management ponds, be placed in a test dead end canal as a means to increase circulation and dissolved oxygen in the test canal. Town Council supported the recommendation for a two year test program.

Description of the Diffuser Pilot Demonstration Project

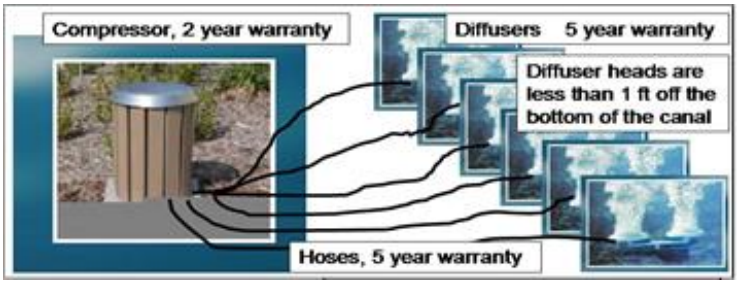
The primary objective of the two year pilot project is to determine if diffusers will provide a new method that works effectively in dead-end tidal canals, as they do in stagnant water management ponds, to increase dissolved oxygen and possibly reduce algae blooms. The secondary objective is to quantitatively measure the effectiveness of the improvement of the ecological conditions in support of a cost benefits analysis to justify installing diffusers into all impaired canals.



The Diffuser Demonstration is being conducted on three of the canals that have been determined to be among the most impaired from previous water quality monitoring programs. These are the Anchorage Canal, the Petherton Canal and the Brandywine Canal. The Petherton Canal is the test canal, the one with diffusers, and is located between the Anchorage and Brandywine Canals. The Brandywine Canal is the control canal. It was selected over the Anchorage Canal because it has the same drainage area (about 6 acres) as the Petherton Canal, while the Anchorage Canal has a drainage area of about 100 acres. The Anchorage Canal is a second reference canal since it is adjacent to the Brandywine Canal and it is the canal with the most historical data associated with it. Each canal has about two acres of surface area and each is about five feet deep. When the water is deep enough (12 to 15 feet) for a diffuser to operate at high efficiency, only one diffuser is needed per acre. When the depth is 4 to 11 feet the vendor suggests using 2 diffusers per acre. Since the canals have a very poor aspect ratio and they are very shallow, there are six (6) diffusers equally spaced along the most eastern 1,000 feet of the 1,600 foot Petherton Test Canal (about 4 diffuser per acre).

The diffuser system was professionally installed by Envirotech Environmental Consulting, Inc. (EECI) in the Petherton Canal on April 24, 2013. The system consists of the following components:

- AquaAir 6 – 1 hp, 115/120V, Single Phase Compressor;
- Six (6) Single Membrane or Dual Diffusers, Stainless Steel Case, Molded Base; and
- 3,900 feet of weighted tubing.



Each diffuser is independently supplied with compressed air though weighted tubes that lie along the bottom of the canal from one compressor that is located on shore at the east end of the canal.

Pictures of the Installation – April 24, 2013

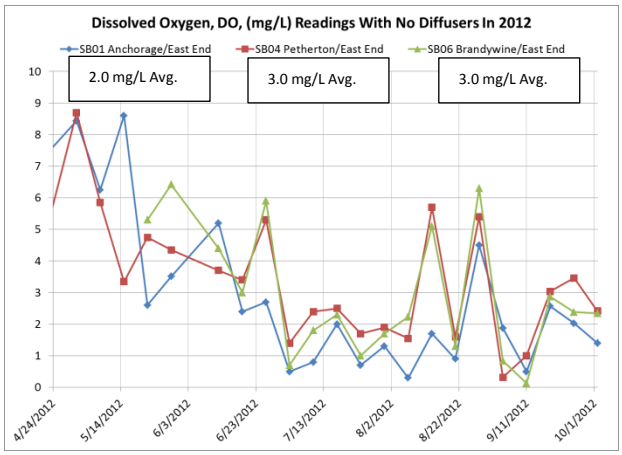
Water Quality Monitoring Results

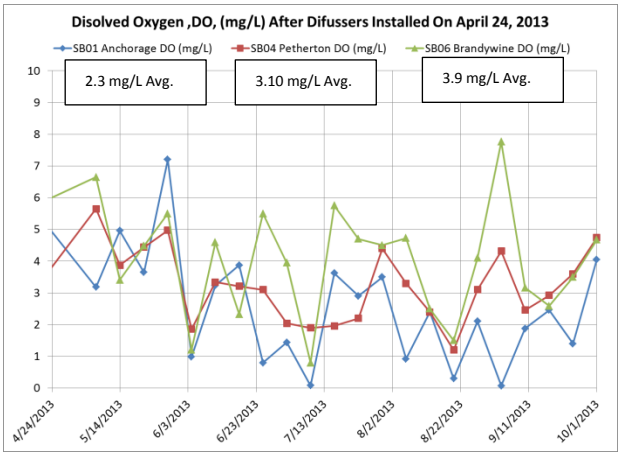
During May through September, 2013, water quality was monitored three different ways.

- Weekly water quality monitoring (Dissolved Oxygen (DO), salinity, temperature and secchi depth) was measured from shore at the most eastern end of each of the three canals; Anchorage, Petherton and Brandywine.
- Continuous data was monitored at about 150 feet from the east end of the Petherton Canal.
- Weekly water quality monitoring was conducted by boat. DO measurements were made at 15 locations along the 1,600 foot length of both the Petherton and Brandywine Canals at one foot deep and at three feet deep.

Results from monitoring from shore at canal ends

Below are the canal end measurements made during 2012 when there were no diffusers in the Petherton Canal compared to the 2013 measurements, made during the same months, when there were diffusers in the Petherton Canal.

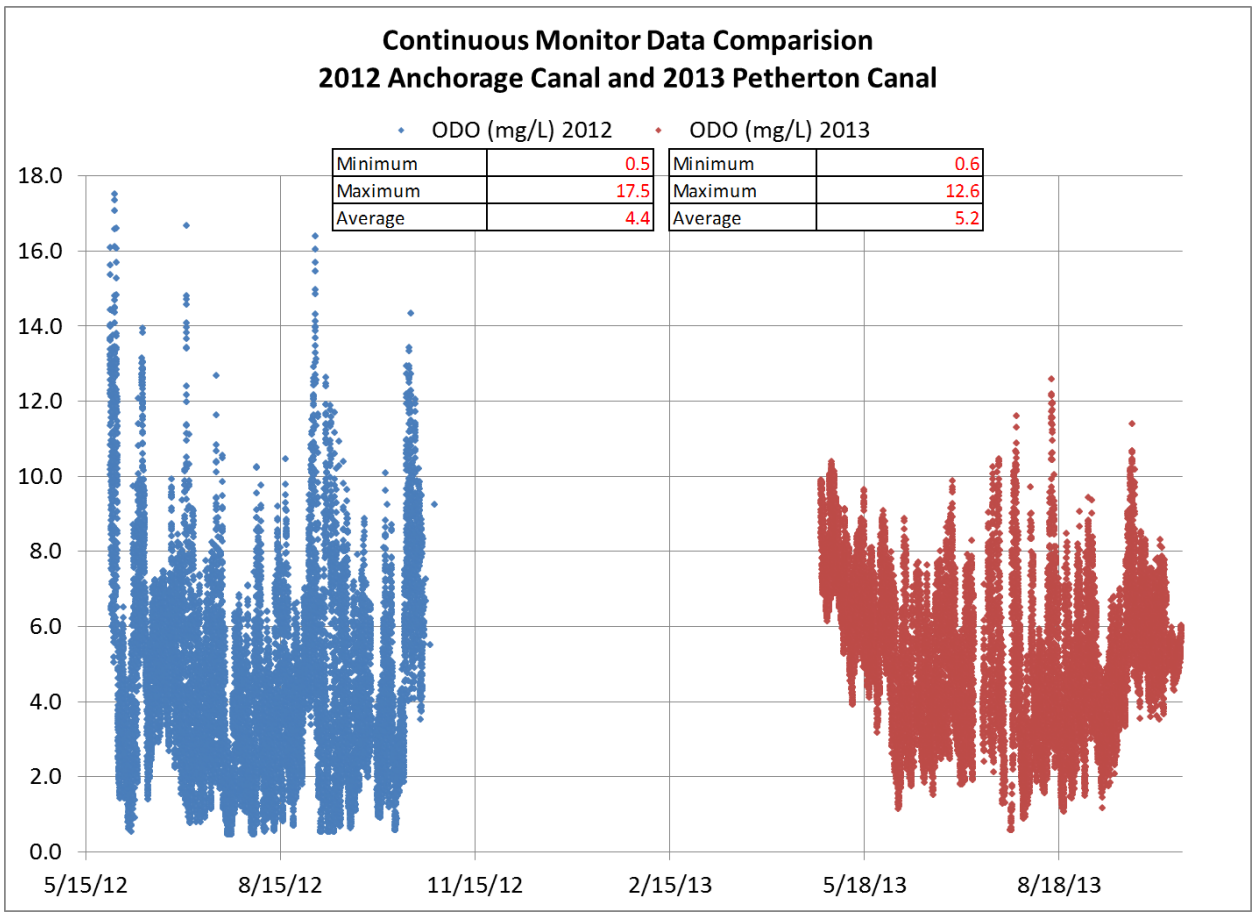




- The 2012 chart shows that the Petherton Canal seemed to follow closely the large fluctuations in DO levels from about 0.0 to about 6.0 mg/L for the period 5/21 to 10/1 that were seen in the Brandywine Canal. Both the Petherton and the Brandywine Canals had the same average DO level of 3.0 mg/L for the same time period. This compared to 2.0 mg/L for the Anchorage canal. This verifies that the Brandywine Canal was the best selection as the control canal.
- The 2013 chart shows that the after diffusers were installed the fluctuations in DO levels in the Petherton Canal were now reduced to about 1.0 to about 5.0 mg/L during the period 5/21 to 10/1. In the canals that did not have diffusers the fluctuations ranged from about 0.0 to 8.0 mg/L for the same period. This year the average DO levels for the same time period increased slightly in the Anchorage Canal and significantly in the Brandywine Canal. The Petherton Canal, with the diffusers, had about the same average as it had in 2012.

Results from the continuous monitor

Below are the continuous monitor measurements for 2012 and 2013. In 2012 the continuous monitor was in the Anchorage Canal (no diffusers) about 150 from the east end (dead end) located on the north bulkhead. In 2013 the continuous monitor was relocated to the Petherton Canal (with diffusers) about 150 feet from the east end (dead end) located on the south bulkhead.



(In the above chart ODO is the term used by the monitor. It means Optical Dissolved Oxygen.)

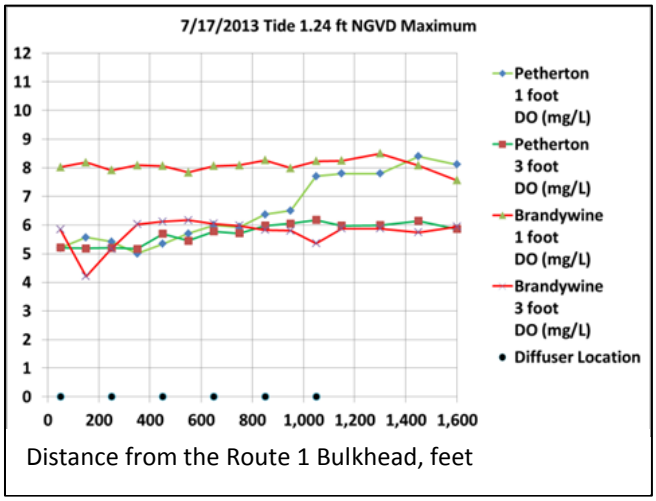
As can be seen from the charts above

- There was less fluctuation in DO in the canal that had the diffusers.
- The low DO measurements in the canal with diffusers were slightly higher.
- The highs were significantly lower in the canal with diffusers.
- The average was 0.8 mg/L higher in the canal with diffusers.

The above continuous monitor results may not be too significant since the 2012 canal end measurements showed that the Petherton Canal did not behave similarly to the Anchorage Canal. In fact in 2012 the Petherton Canal averaged 1.0 mg/L higher than the Anchorage Canal. There was no continuous monitor data available for the Brandywine Canal since the Town has only one continuous monitor.

Results from weekly monitoring by boat

Approximately, weekly dissolved Oxygen, DO, measurements were made by boat along the 1,600 foot length of the Petherton and Brandywine Canals at a depth of one foot and 3 feet at 15 locations along the center of the canals. These data are presented in 17 charts on the pages at the end of this report. The data are very confusing as they appear to show that the diffusers are removing oxygen from the water. Here is one of the most illustrative charts. The chart shows that;



- At 1200 to 1600 ft where there are no diffusers in either canal there is about 2.0 mg/L difference in DO between the one foot reading and the three foot reading. This is to be expected since there is no mixing.
- At 1200 to 1600 ft where there are no diffusers in either canal the readings at one foot are about the same in each canal. This same trend occurs at three feet. This is to be expected since the canal end data from 2012 had shown that the two canals were similar.
- In the Brandywine Canal, where there are no diffusers, the 2.0 mg/L difference in DO between the one foot reading and the three foot reading extends all the way back to 50 feet from the Route 1 bulkhead. This is to be expected since there is no mixing.
- In the Petherton Canal, where there are diffusers, the difference in readings between the one and three foot readings are eliminated. This is to be expected since the diffusers are designed to eliminate stratification by mixing.
- The surprising result is that where there are diffusers in the Petherton Canal the average DO is lower than in the Brandywine Canal by about 2.0mg/L.

The above is just one of 17 charts. Depending on the day the results can be quite different. There are other patterns in the data that are worth mentioning. The most consistent pattern seems to be that in the Petherton Canal the DO levels at one foot and at three feet are essentially the same. This indicates that the canal water is well-mixed by the diffusers. On some dates, the Brandywine Canal seemed well mixed, but sometimes stratified. Sometimes the DO level was similar between canals, but more often, the DO level was higher in Brandywine Canal, especially at the surface.

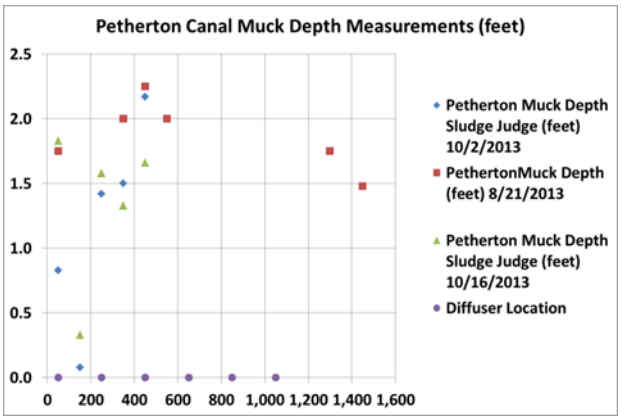
After it was observed that the canal with diffusers appeared to have less DO on average, it was decided to collect temperature data as well as salinity data. Plots of this data follow at the end of this report. These additional plots contain a lot of data and are difficult to follow. The additional data does not appear to assist in the explanation for the lower DO in the Petherton Canal. See the next page for possible explanations.

Measurements of Muck Depth

The reduction in DO level where the diffusers are located does not make intuitive sense. The diffusers are adding oxygen, but where is it going. One explanation is, since diffuser are used to reduce "muck" on the bottom in ponds, that the diffusers are stirring up the zero DO components on the bottom and that it is stimulating the aerobic digestion process thus reducing nutrient levels and, possibly, associated algal growth. Raising the DO level near the bottom would favor aerobic bacterial decay of organic matter, "muck," which is faster than anaerobic decay. So adding the oxygen via diffusers should reduce the muck over time.

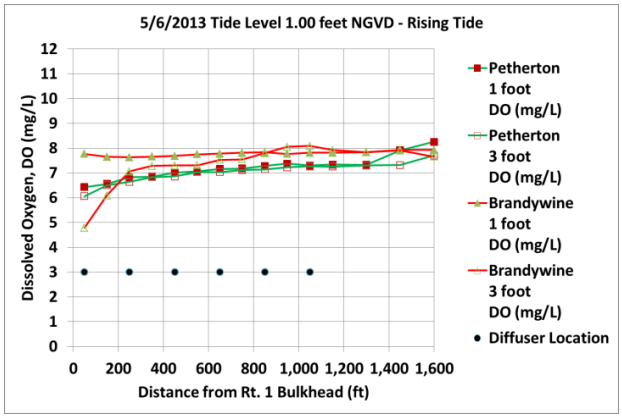
A second explanation for the apparent reduction in DO levels is that If canals are 4 to 5 feet deep, sampling at 1 foot and 3 feet covers only 60 to 75% of the depth profile, so it's conceivable that if Petherton Canal is well mixed, the DO level nearer the bottom might be similar to that at other depths, whereas Brandywine Canal might have had very low DO levels near the bottom that are not seen in the 3 foot sampling. Thus it would appear that the average DO level in the Petherton Canal is lower than in the Brandywine Canal. Since we try not to foul the probe on the bottom, we do not know the actual bottom reading.

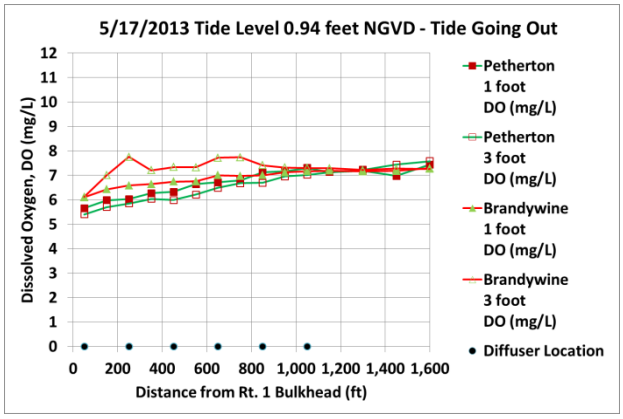
Because of the above, "muck" depth measurements were begun the end of August. These are difficult to do from a boat in the center of the canal. It is hard to measure in the same place each time. However data were taken as shown and more will be taken next year to attempt to determine if "muck" is indeed being reduced. For reference, in 2008 the Petherton and Brandywine Canal ends were dredged for about 400 feet from the east end bulkheads and the total length of the Anchorage Canal was dredged.

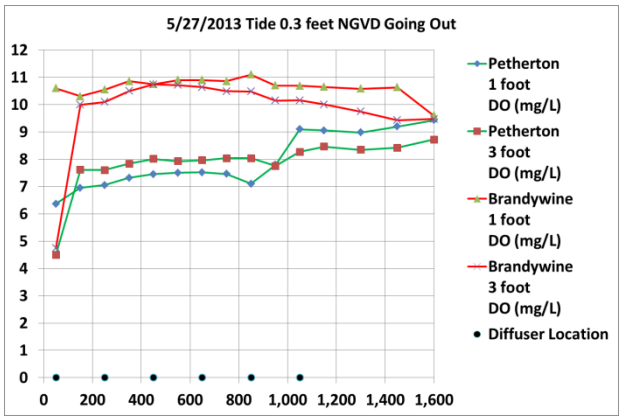


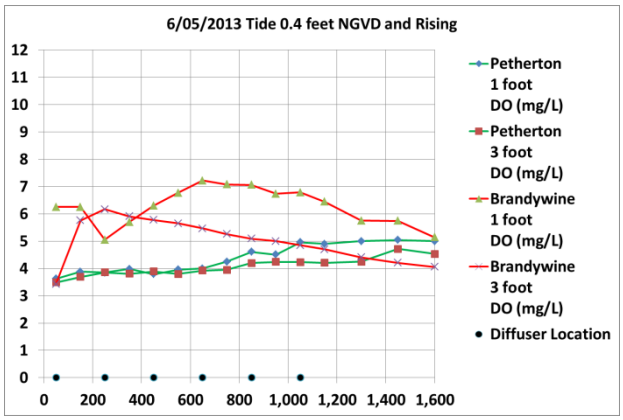
Summary - Conclusions

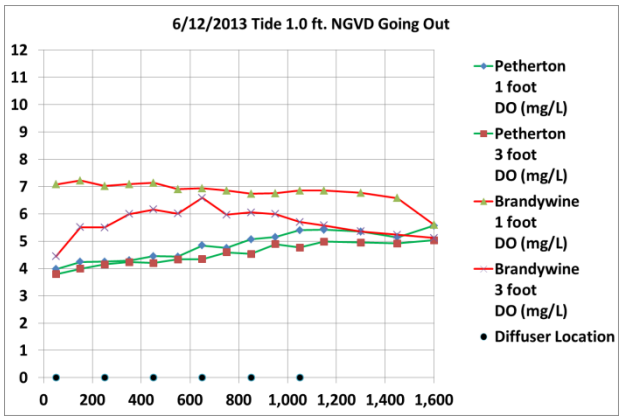
- The diffusers do eliminate stratification. (If there had been diffusers in the Russell Canal ends, the fish kill that occurred around September 9/10, 2013 probably would not have occurred.)
- Thus far the diffusers have not appeared to increase the DO level in the Petherton Canal. In reality they appear to have caused the DO to be reduced.
- The apparent reduction in DO level where the diffusers are located does not make intuitive sense. The diffusers are adding oxygen, but where is it going. One explanation is that the oxygen is being used to reduce "muck" on the bottom. A second explanation is that the 3 foot deep measurements are not recording the lowest DO in either canal, thus a true average DO is not being determined.
- Because of this "muck" reduction issue, some "muck" depth measurements were attempted. More muck depth measurements will be made for comparison next year.
- Next year DO measurements will be taken closer to the bottom of the canals in order to obtain a truer DO average for both the Petherton and Brandywine canals.
- Time will tell. That is why the project is scheduled for two years.

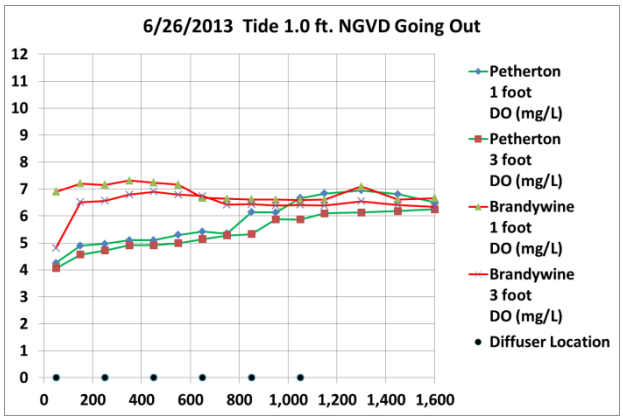

5/6/2013 Tide Level 1.00 feet NGVD - Rising Tide
Dissolved Oxygen, DO (mg/L)
Distance from Rt. 1 Bulkhead (ft)
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine 3 foot DO (mg/L)
Diffuser Location

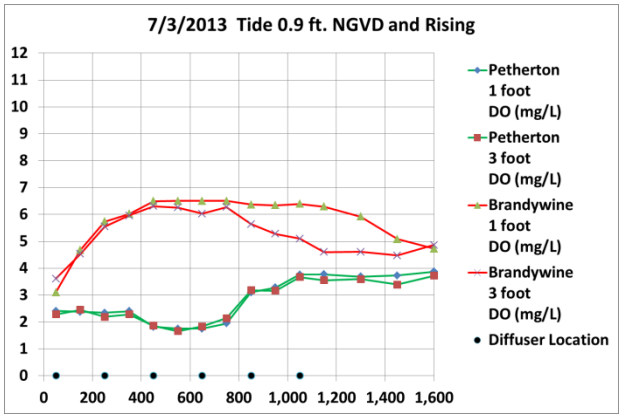

5/17/2013 Tide Level 0.94 feet NGVD - Tide Going Out
Dissolved Oxygen, DO (mg/L)
Distance from Rt. 1 Bulkhead (ft)
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine 3 foot DO (mg/L)
Diffuser Location

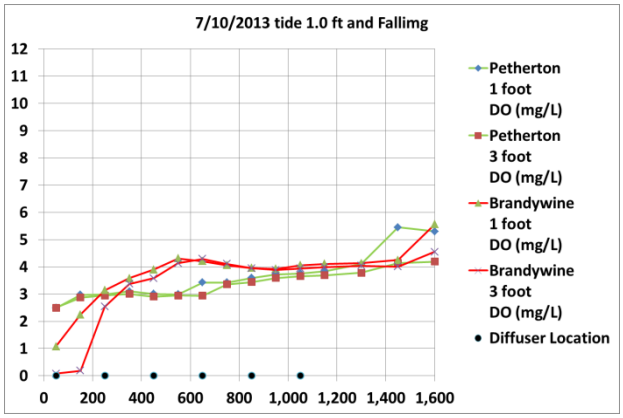

5/27/2013 Tide 0.3 feet NGVD Going Out
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine 3 foot DO (mg/L)
Diffuser Location

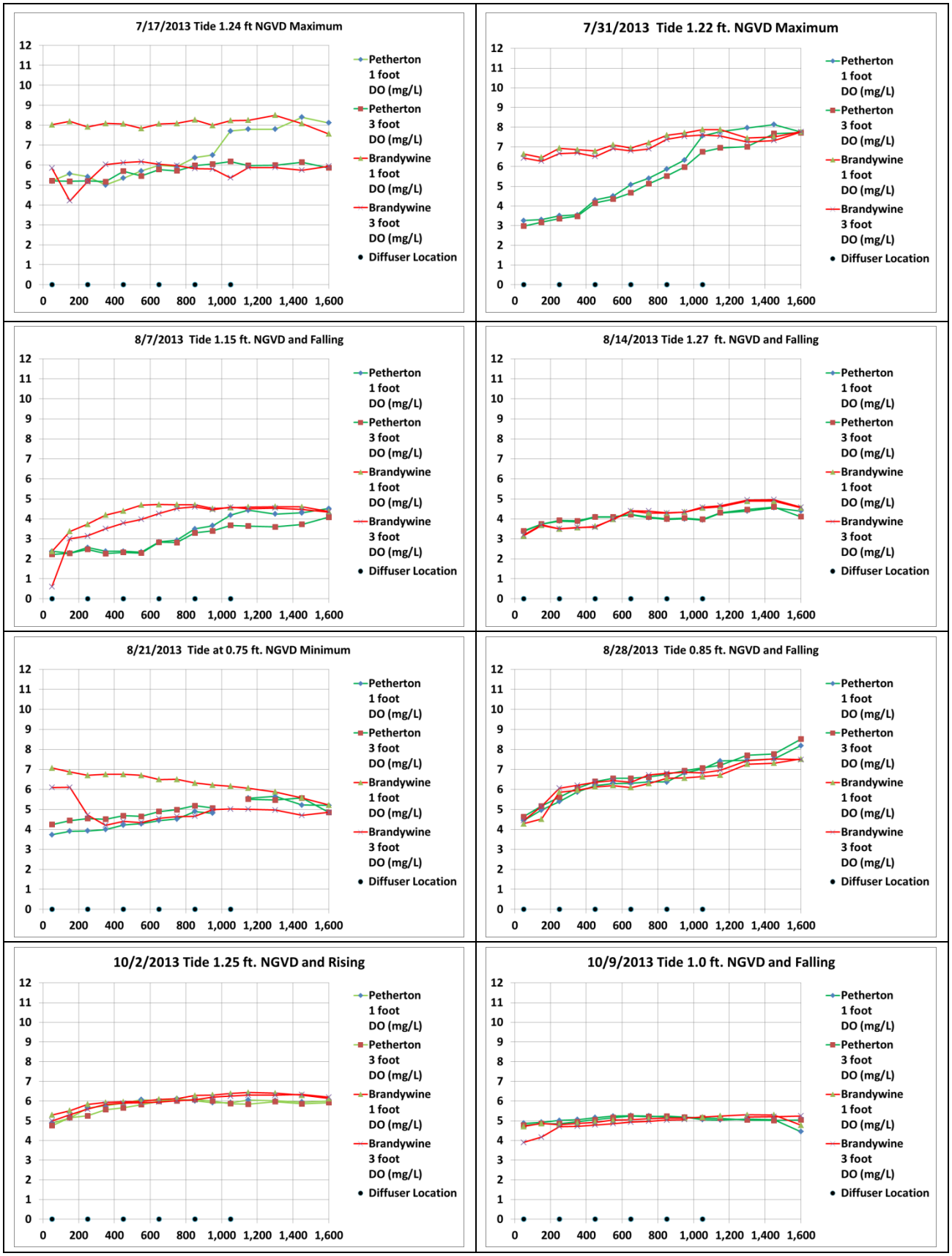

6/05/2013 Tide 0.4 feet NGVD and Rising
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine 3 foot DO (mg/L)
Diffuser Location

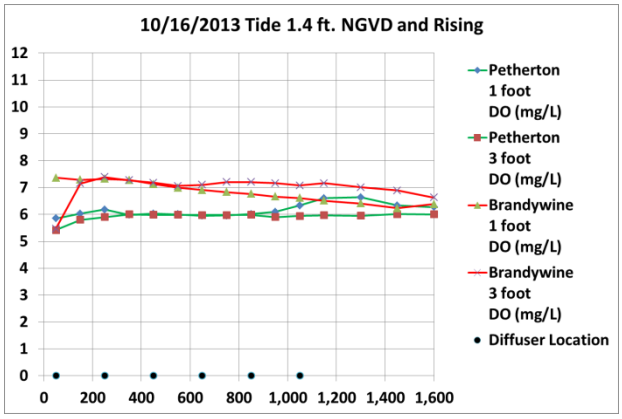

6/12/2013 Tide 1.0 ft. NGVD Going Out
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine 3 foot DO (mg/L)
Diffuser Location

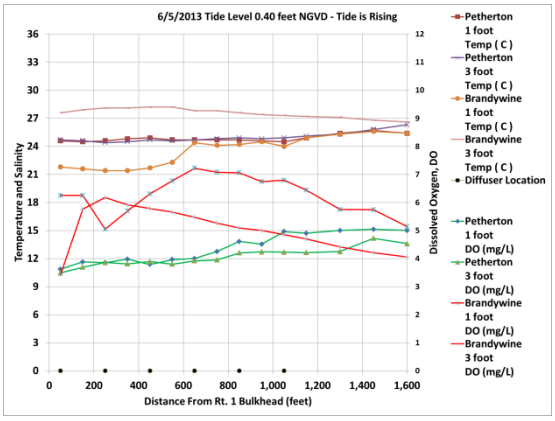

6/26/2013 Tide 1.0 ft. NGVD Going Out
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine 3 foot DO (mg/L)
Diffuser Location

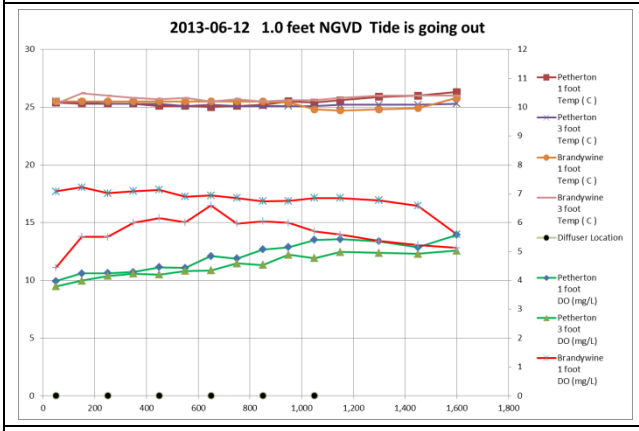

7/3/2013 Tide 0.9 ft. NGVD and Rising
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine 3 foot DO (mg/L)
Diffuser Location

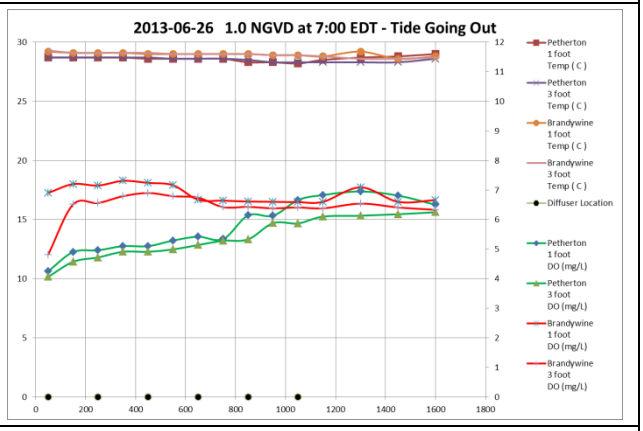

7/10/2013 tide 1.0 ft and Fallimg
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine 3 foot DO (mg/L)
Diffuser Location

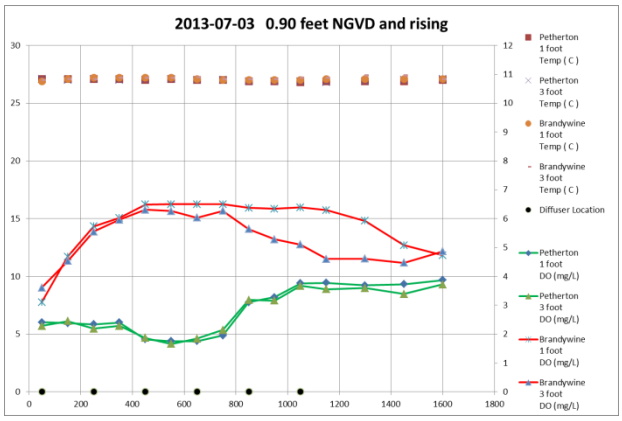

7/17/2013 Tide 1.24 ft NGVD Maximum
7/31/2013 Tide 1.22 ft. NGVD Maximum
8/7/2013 Tide 1.15 ft. NGVD and Falling
8/14/2013 Tide 1.27 ft. NGVD and Falling
8/21/2013 Tide at 0.75 ft. NGVD Minimum
8/28/2013 Tide 0.85 ft. NGVD and Falling
10/2/2013 Tide 1.25 ft. NGVD and Rising
10/9/2013 Tide 1.0 ft. NGVD and Falling
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine 3 foot DO (mg/L)
Diffuser Location
0 1 2 3 4 5 6 7 8 9 10 11 12
0 200 400 600 800 1,000 1,200 1,400 1,600

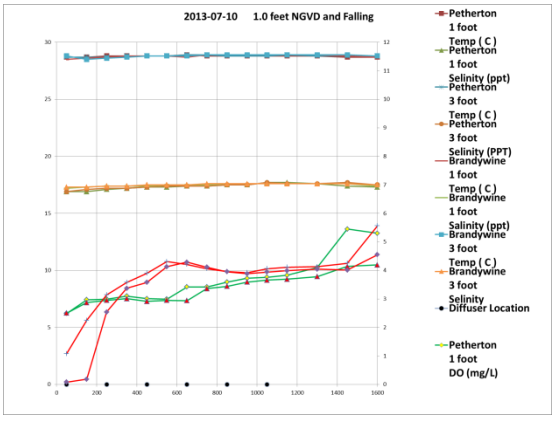

10/16/2013 Tide 1.4 ft. NGVD and Rising
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine 3 foot DO (mg/L)
Diffuser Location

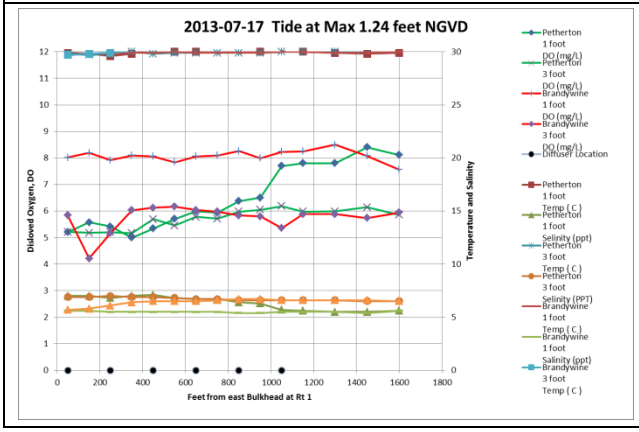

6/5/2013 Tide Level 0.40 feet NGVD - Tide is Rising
Temperature and Salinity
Dissolved Oxygen, DO
Distance From Rt. 1 Bulkhead (feet)
Petherton 1 foot Temp (C)
Petherton 3 foot Temp (C)
Brandywine 1 foot Temp (C)
Brandywine 3 foot Temp (C)
Diffuser Location
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine 3 foot DO (mg/L)

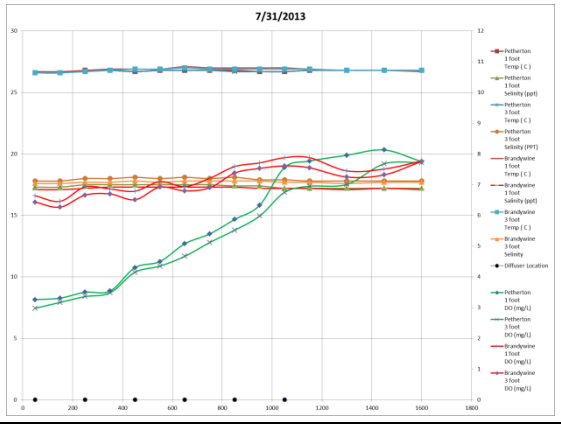

2013-06-12 1.0 feet NGVD Tide is going out
Petherton 1 foot Temp (C)
Petherton 3 foot Temp (C)
Brandywine 1 foot Temp (C)
Brandywine 3 foot Temp (C)
Diffuser Location
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)

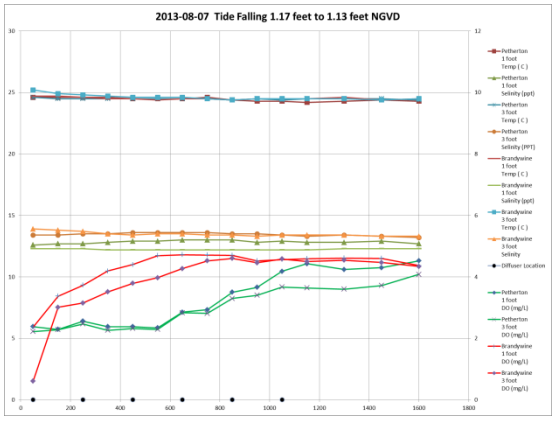

2013-06-26 1.0 NGVD at 7:00 EDT - Tide Going Out
Petherton 1 foot Temp (C)
Petherton 3 foot Temp (C)
Brandywine 1 foot Temp (C)
Brandywine 3 foot Temp (C)
Diffuser Location
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine 3 foot DO (mg/L)

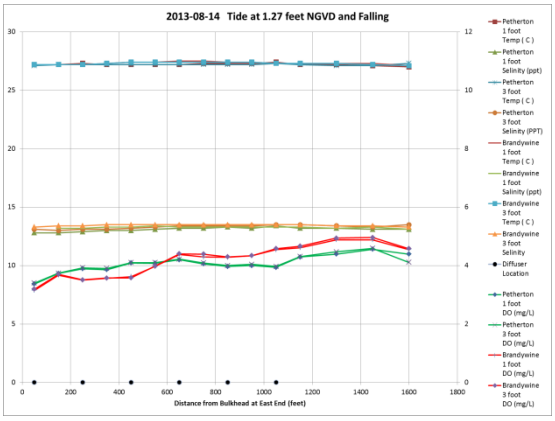

2013-07-03 0.90 feet NGVD and rising
Petherton 1 foot Temp (C)
Petherton 3 foot Temp (C)
Brandywine 1 foot Temp (C)
Brandywine 3 foot Temp (C)
Diffuser Location
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine 3 foot DO (mg/L)

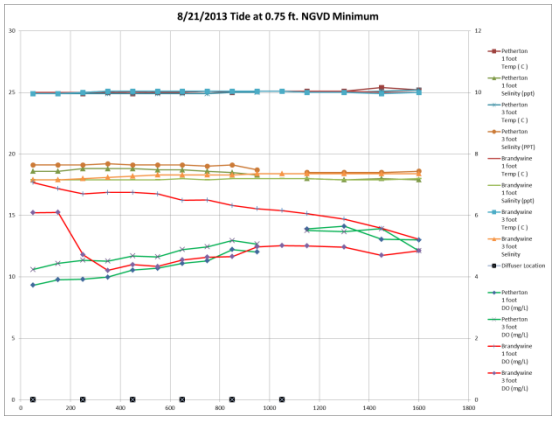

2013-07-10 1.0 feet NGVD and Falling
Petherton 1 foot Temp (C)
Petherton 1 foot Selinity (ppt)
Petherton 3 foot Temp (C)
Petherton 3 foot Selinity (PPT)
Brandywine 1 foot Temp (C)
Brandywine 1 foot Salinity (ppt)
Brandywine 3 foot Temp (C)
Brandywine 3 foot Selinity
Diffuser Location
Petherton 1 foot DO (mg/L)

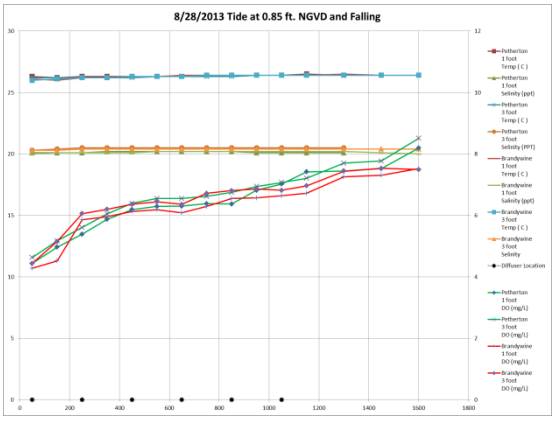

2013-07-17 Tide at Max 1.24 feet NGVD
Dislowed Oxygen, DO
Temperature and Salinity
Feet from east Bulkhead at Rt 1
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine 3 foot DO (mg/L)
Diffuser Location
Petherton 1 foot Temp (C)
Petherton 1 foot Selinity (ppt)
Petherton 3 foot Temp (C)
Petherton 3 foot Selinity (PPT)
Brandywine 1 foot Temp (C)
Brandywine 1 foot Salinity (ppt)
Brandywine 3 foot Temp (C)

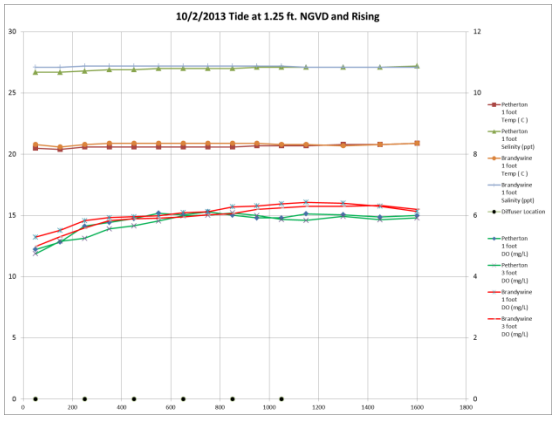

7/31/2013

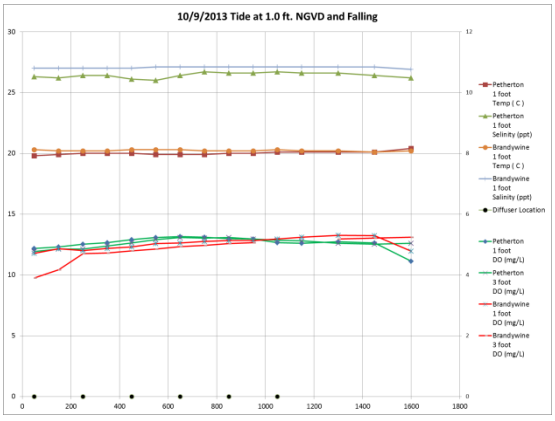

2013-08-07 Tide Falling 1.17 feet to 1.13 feet NGVD

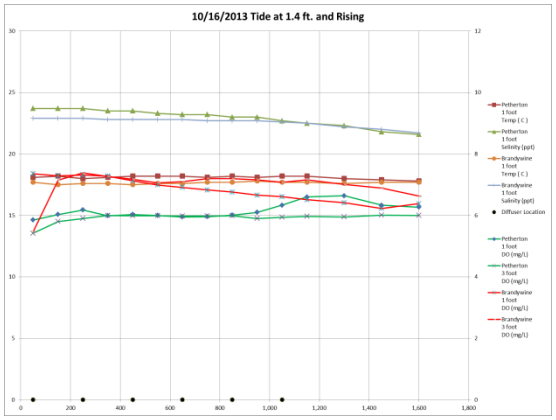

2013-08-14 Tide at 1.27 feet NGVD and Falling
Distance from Bulkhead at East End (feet)


8/21/2013 Tide at 0.75 ft. NGVD Minimum


8/28/2013 Tide at 0.85 ft. NGVD and Falling


10/2/2013 Tide at 1.25 ft. NGVD and Rising


10/9/2013 Tide at 1.0 ft. NGVD and Falling


10/16/2013 Tide at 1.4 ft. and Rising