Evaluation of Anoxic Zone Mixers at the Red Hook WPCP

(Contract # PW-047)

FINAL REPORT

NEW YORK CITY
DEPARTMENT OF ENVIRONMENTAL PROTECTION
Process Planning Section
Division of Operations Support
Bureau of Wastewater Treatment

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EXECUTIVE SUMMARY

The objective of this study was to compare the performance of the PHI 9/18 Mixing System to the Davis EMU Model TRS 48.22 Uniprop submersible mixers as installed and operated in two parallel anoxic zones located at the Red Hook WPCP. The submersible mixers have been in operation for approximately 10 years while the PHI 9/18 MIXING SYSTEM was in operation for approximately 9 months at the Red Hook WPCP. The comparison of the two types of mixers was based on the following factors:

- Ability to sustain uniform distribution of SS throughout the volume of the anoxic zones.
- Maintenance of low DO concentrations to conform to anoxic zone criteria of less than 0.3 mg/L.
- Capital and Operating costs

The Davis EMU Model TRS 48.22 Uniprop submersible mixers have a two blade propeller of 480 mm, (1.57ft) diameter rotating at 226 rpm. The mixer is supported on a mounting skid anchored at the side of the tank. PHI 9/18 Mixing System sequentially injects compressed air beneath round, flat circles called forming plates. The compressed air forms large single, oval shaped bubbles that rise to the top of the tank. There are no moving parts within the tank. During the study the PHI 9/18 Mixing System was operated at an injection time of 0.5 secs. per firing, with a frequency of 6 times per minute and a pressure of 45 PSI at a flow rate of 25 ACFM.
The evaluation of each mixer was conducted by City College of New York staff in cooperation with personnel from the Red Hook WPCP and the Process Planning Section of the Bureau of Wastewater Treatment. All sampling and analyses were performed by City College in conformance to Standard Methods. Specifically, SS concentration profiles were developed across the horizontal section of the anoxic zones at elevations of 3, 12, and 20 feet below the surface of the water. DO was measured using the YSI 556 multi parameter probe.

Capital and preventive maintenance costs were provided by the vendors. However, operating experience for the Davis EMU Model TRS 48.22 Uniprop submersible mixers were based on the records documented at the Red Hook WPCP. There are currently no PHI mixer installations in anoxic zones.

Based on the data collected by City College, the input of the vendors, and the full-scale experience at Red Hook, the following conclusions were made:

- Both the mixers achieved uniform distribution of SS throughout the bulk volume of the anoxic zones. However, when the PHI 9/18 Mixing System was turned down to 1 HP on May 5, 2006 and the MLSS were at 3100 mg/L, the profiles of May 5, 2006 showed SS stratification at the lower depths of the tank and some solids accumulation at the bottom of the tank.

- Both mixers were able to maintain the low DO concentrations necessary for promoting denitrification.

- Initial capital cost is higher for the Davis EMU mixers than the PHI 9/18 Mixing System. Additionally, due to lower preventive maintenance and energy costs, the PHI 9/18 Mixing System has a lower capitalized cost.

- Over a 10 year period, the savings in capitalized costs using the PHI 9/18 Mixing System would be lower based on vendor's own recommendations.

- Experience at the Red Hook WPCP suggests that the Davis EMU Uni-Prop mixers are prone to frequent breakdowns.

1. OBJECTIVE OF THE STUDY

The objective of the study was to evaluate the performance of the PHI 9/18 Mixing System compared to the Davis EMU Model – TRS 48.22 Uniprop submersible mixers as installed and operated in two anoxic zones. The two zones were located at the beginning of pass B in aerations tanks # 3 and # 4, respectively of the Red Hook Water Pollution Control Plant, (WPCP) as shown in **Figure 1**. Each zone was 43.3 ft long, 25 ft wide with a side water depth of 22.5 feet. Primary settling tank effluent enters through a sluice gate located on the side wall at the start of pass B and immediately mixes with returned activated sludge flow from pass A. The combined mixture flows through the anoxic zone into the oxic zone of pass B, separated by a baffle as shown in **Figure 2.**

The performance of the two types of mixers was evaluated based on their abilities to:

- Sustain the SS uniformly distributed throughout the volume of the anoxic zone.
- Maintain acceptable low DO concentrations in the anoxic zone

Additional parameters considered were initial cost of the two types of mixers, power usage, preventive maintenance cost, and suggested maintenance within a 10 year operating period.

2. MIXERS EVALUATED AT THE RED HOOK WPCP

The application of the two types of mixers considered in this study was limited to anoxic zones. Anoxic zones are designed to promote denitrification by maintaining DO concentrations less than 0.3 mg/L, uniform distribution of SS within the volume of the anoxic zone and thorough mixing of chemicals added such as an external source of organic carbon, e.g., methanol.

The two types of Mixing Systems evaluated were the PHI 9/18 Mixing System, a system manufactured by Pulsed Hydraulics, Inc., headquartered in Bellevue, WA and Model – TRS 48.22 Uniprop submersible mixer manufactured by Davis - EMU, headquartered in Germany.

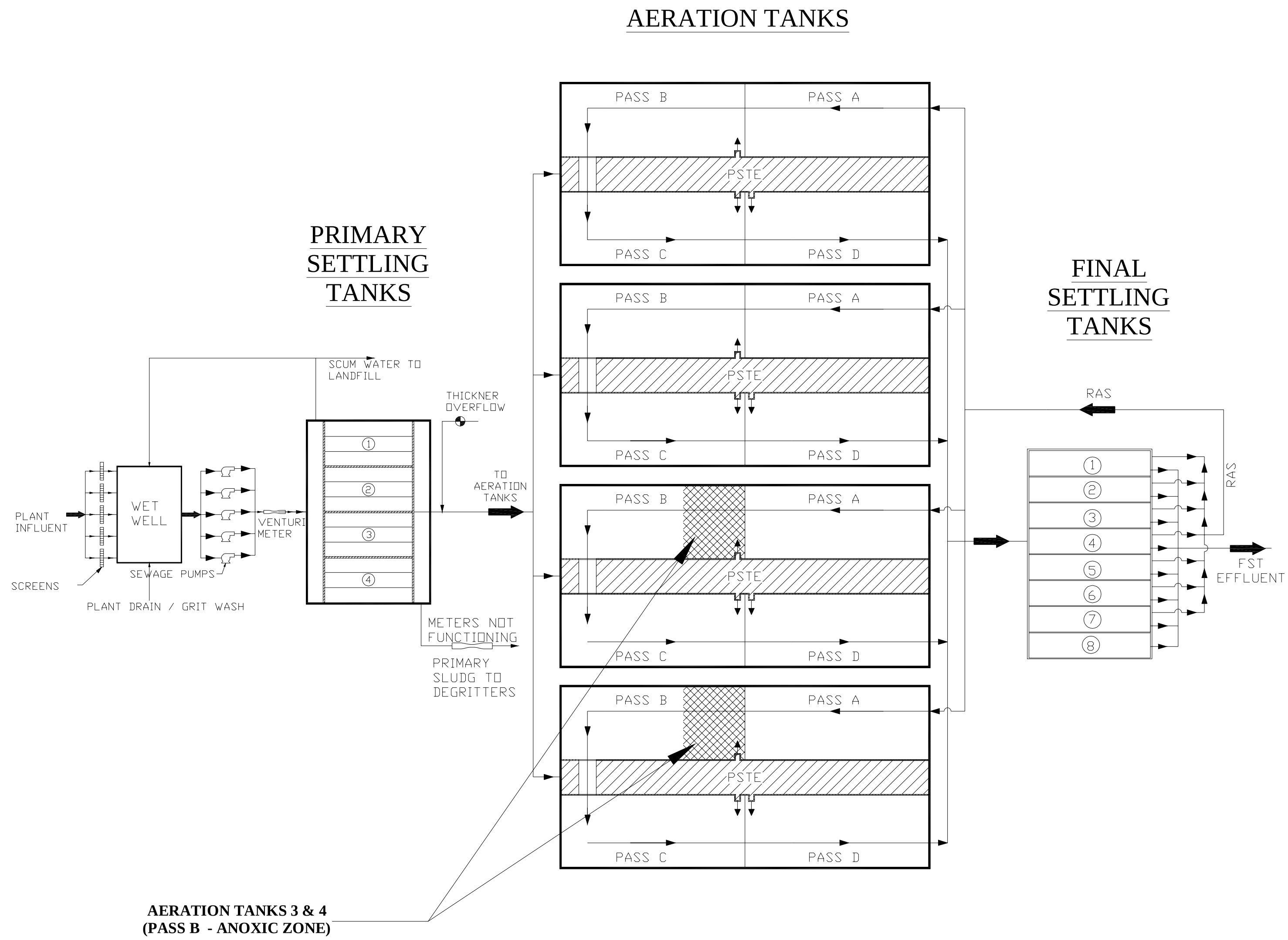


Figure 1. Layout of the Red Hook WPCP

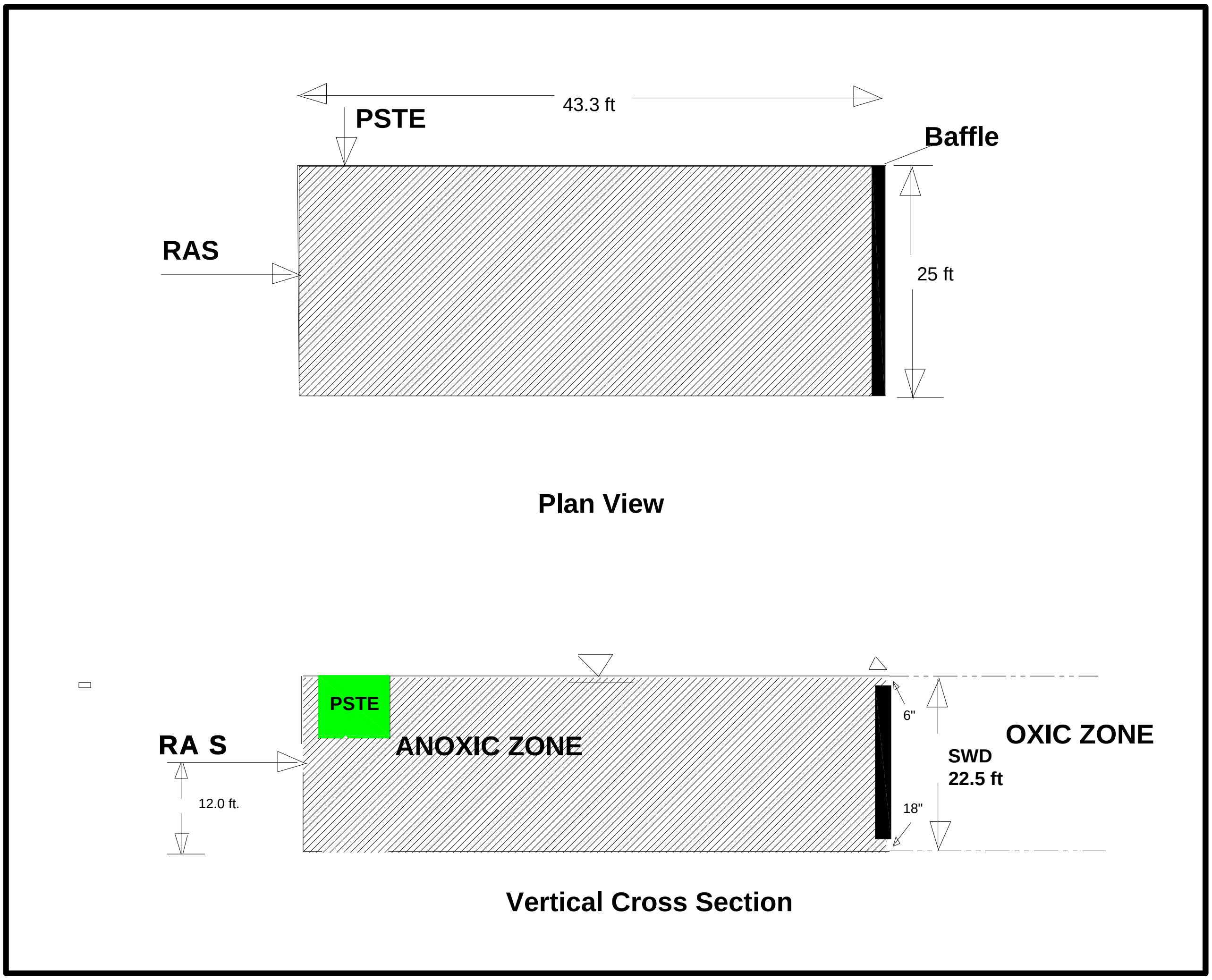


Figure 2. **Plan and Vertical Cross-sectional View of the Anoxic Zones in Pass B in Aeration Tanks 3 & 4, Red Hook WPCP**

2.1. PHI 9/18 Mixing System: A Pneumatic Mixing System

The PHI 9/18 Mixing System injects compressed air sequentially between round, flat 304 stainless steel circles called forming plates. As air is released, it forces SS away from the center of the plate. The air quickly reforms into a large oval shaped bubble mass above the plate and the displaced SS rush back and are caught up in the suction created by the fast rising bubble. As the bubble reaches the surface, the SS that have risen are forced to the sides and eventually back down the sides to the bottom of the tank. Since the injection of air is sequential, both a horizontal and a vertical circular motion is established and the SS in the tank are blended into a uniform mix. The mixing action is primarily controlled by the injection time, frequency and pressure or flow rate of air. The mixing horsepower or the flow rate is varied by increasing or decreasing the injection pressure with the help of a regulator. Programmable logic controllers (PLCs) are used to optimize the mixing action and keep the dissolved oxygen within the prescribed limits. During the study the PHI 9/18 Mixing System was operated at an injection time of 0.5 secs. per firing, a frequency of 6 times per minute and a pressure of 45 PSI for the first three sampling dates while the frequency was reduced to once per minute for the fourth sampling period on May of 5th, 2006.

Figure 3 depicts the rise of the “hydro-Pulse” putting the liquid and solids in its path into motion upward. The PHI 9/18 Mixing System has three main components: forming plates secured to the bottom of the tank to form bubble-masses shown in **Figure 4**, a control system to regulate the air-pulse delivered to the forming plates, and an air compressor to supply air for pulsing. In addition, there is air piping to deliver the air from the compressor to the regulator valve and from the valve to the forming plates. Piping from the control system to the forming plates is stainless steel although 1” plastic schedule 80 PVC pipe was used for the demonstration system at Red Hook.

The PHI 9/18 Mixing System controller sends a 24VDC electrical signal to actuate the solenoid valves inside the electro-pneumatic interface (EPI) which in turn sends a pneumatic signal to the main injection valve. These injection valves supply the air that creates the pulse under the forming plates. The pulse rate and injection time can be changed any time during the operation of the system. The injection pressure is set at the pressure regulators and can also be adjusted at any time. During normal operation, the pressure is set and then not changed unless there are significant changes in the solids level within the tank. **Figure 5** shows one of the NEMA-4 control boxes which houses the EPI and the secondary enclosure to house the injection valves, pressure regulator and heater.

Figure 6 is a photograph of the installation in progress of the forming plates of the PHI 9/18 Mixing System in the anoxic zone (pass B) of aeration tank # 4. PHI Inc. installed a demonstration mixing system, consisting of nine twin forming plates arranged at the tank bottom to uniformly disburse solids throughout the tank and minimize dead zones. Pulses to each forming plate array were individually controlled.. **Figure 7** is the schematic of the layout of the forming plates and **Figure 8** is a plan and sectional view of the layout of the forming plates. **Figure 9** is a set of pictures of the air piping system from the compressor to the forming plates via the regulator. **Table 1** shows the essential elements that make up the PHI 9/18 Mixing System.

The mixers were operated continuously since installed on August 25, 2005. The vendor, PHI Inc., claims the following mixing characteristics:

- PHI 9/18 Mixing System forming plates are mounted on the very bottom of the tank where it can lift solids that have settled there.

- Mixing with a PHI 9/18 Mixing System in a tank is horizontal and vertical, from the bottom to the top, rather than sideways as is typical with a mechanical mixer. PHI mixing guarantees homogeneity of solids distribution throughout the vertical column of tank contents.

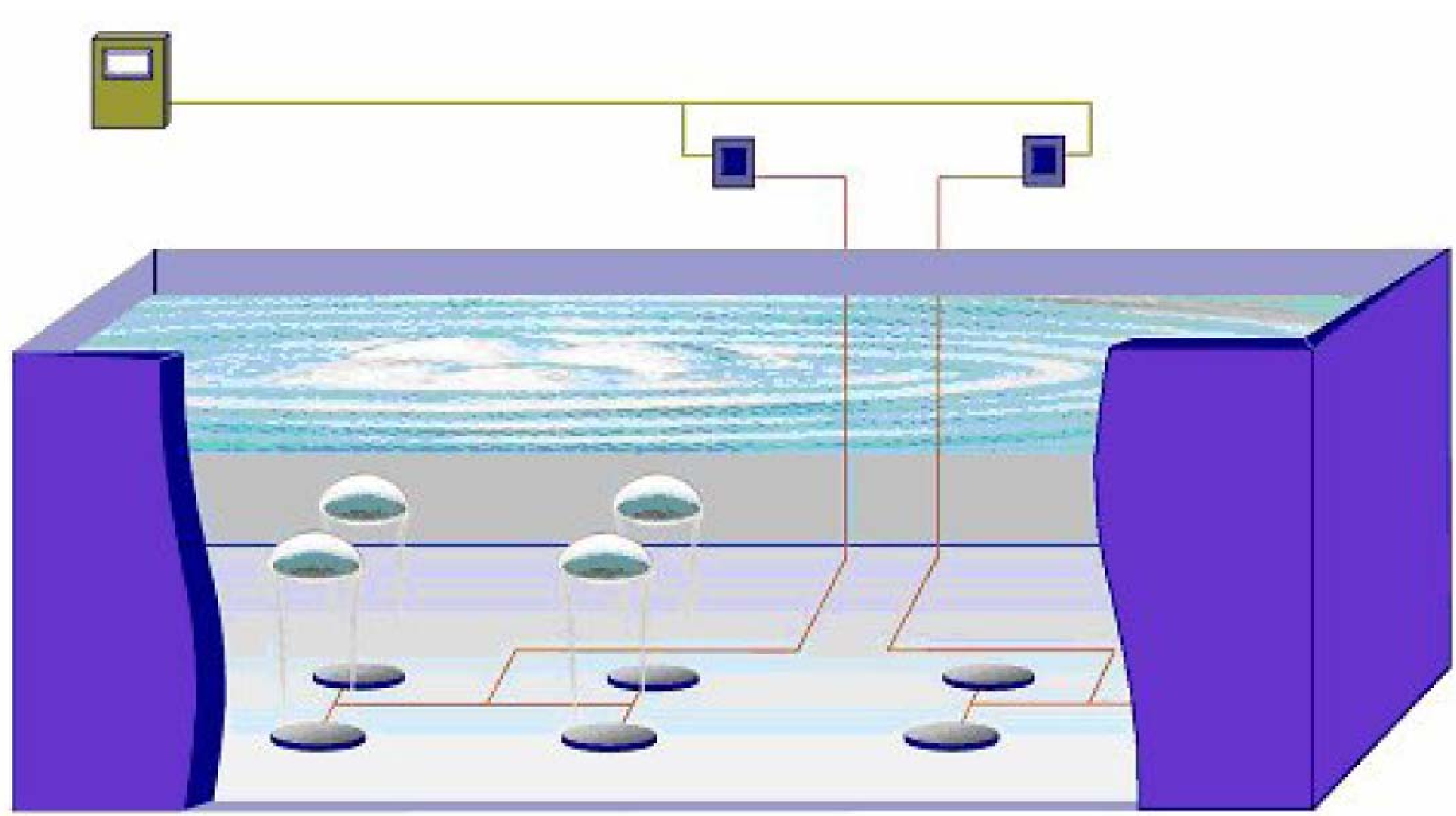


Figure 3.   The “Hydro-Pulse” Mixing Action

Figure 4. **12 inch diameter 304 Stainless Steel Forming Plates used by the PHI 9/18 Mixing System**

Figure 5. PHI 9/18 Mixing System : Control system to manage individual pulsing sequence

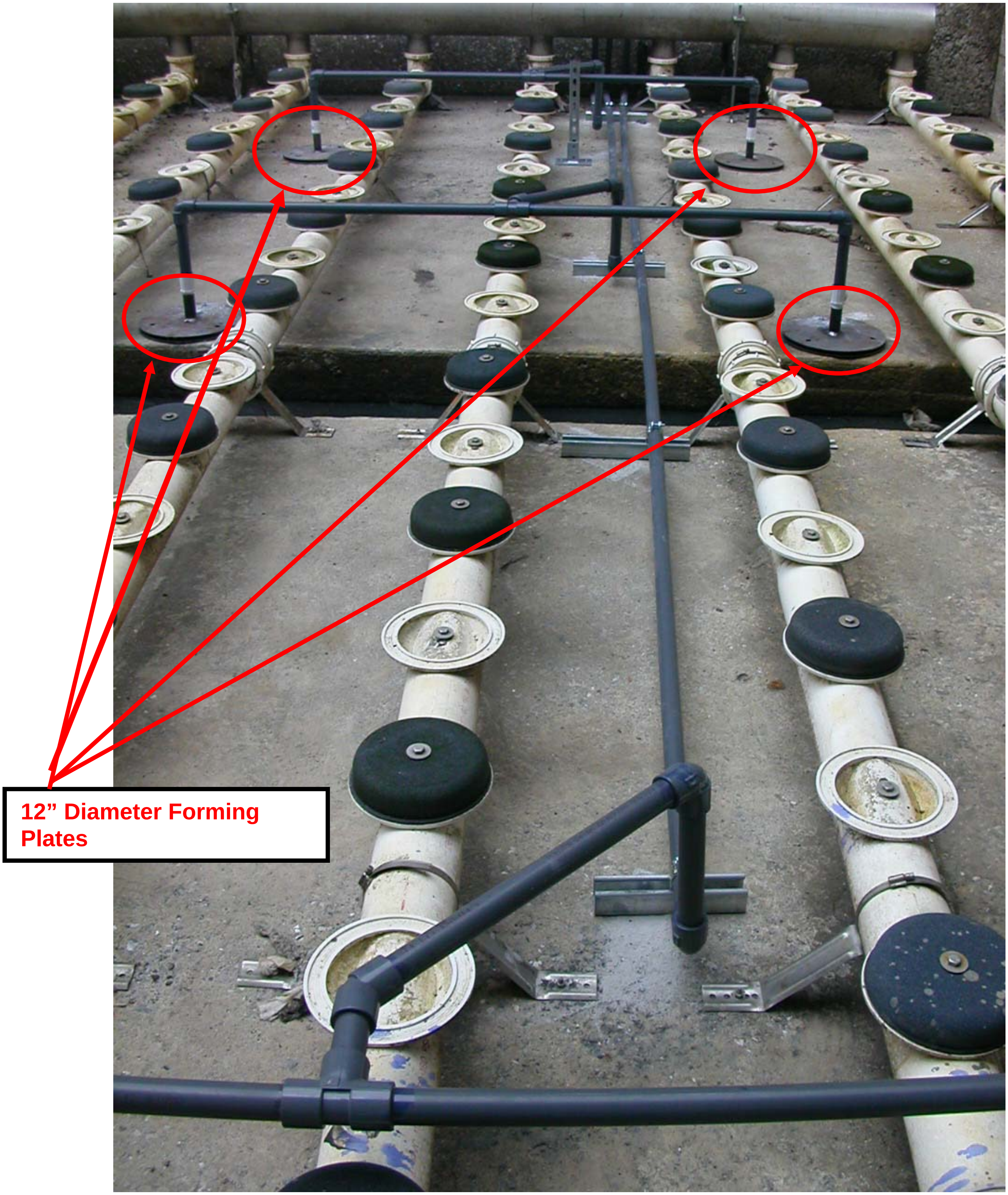


Figure 6 **PHI 9/18 Mixing System being Installed in Aeration Tank # 4, Red Hook WPCP**

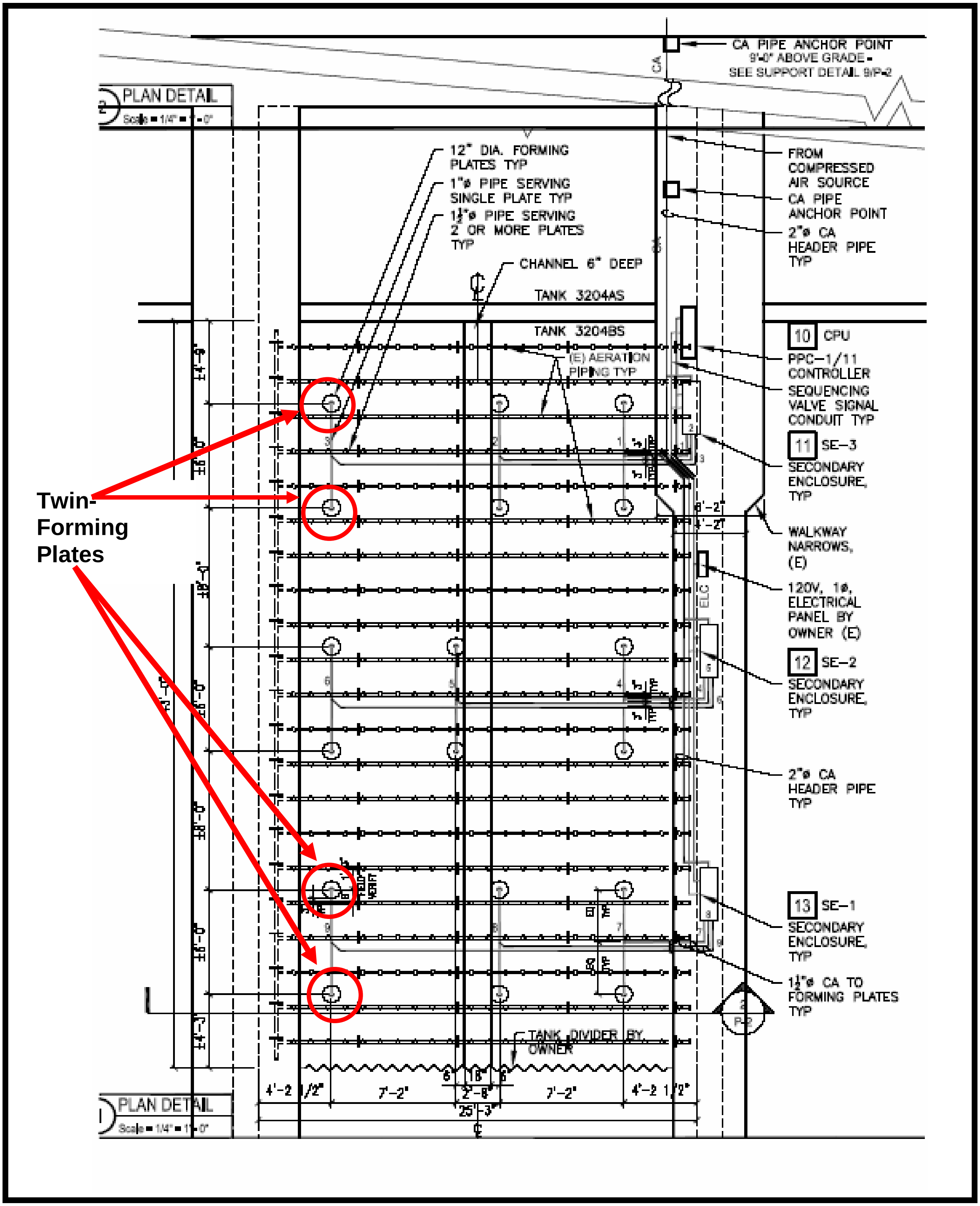


Figure 7: Layout of the nine twin - forming plate arrays for the PHI 9/18 Mixing System in the Anoxic Zone of Pass B: Aeration Tank # 4, Red Hook WPCP

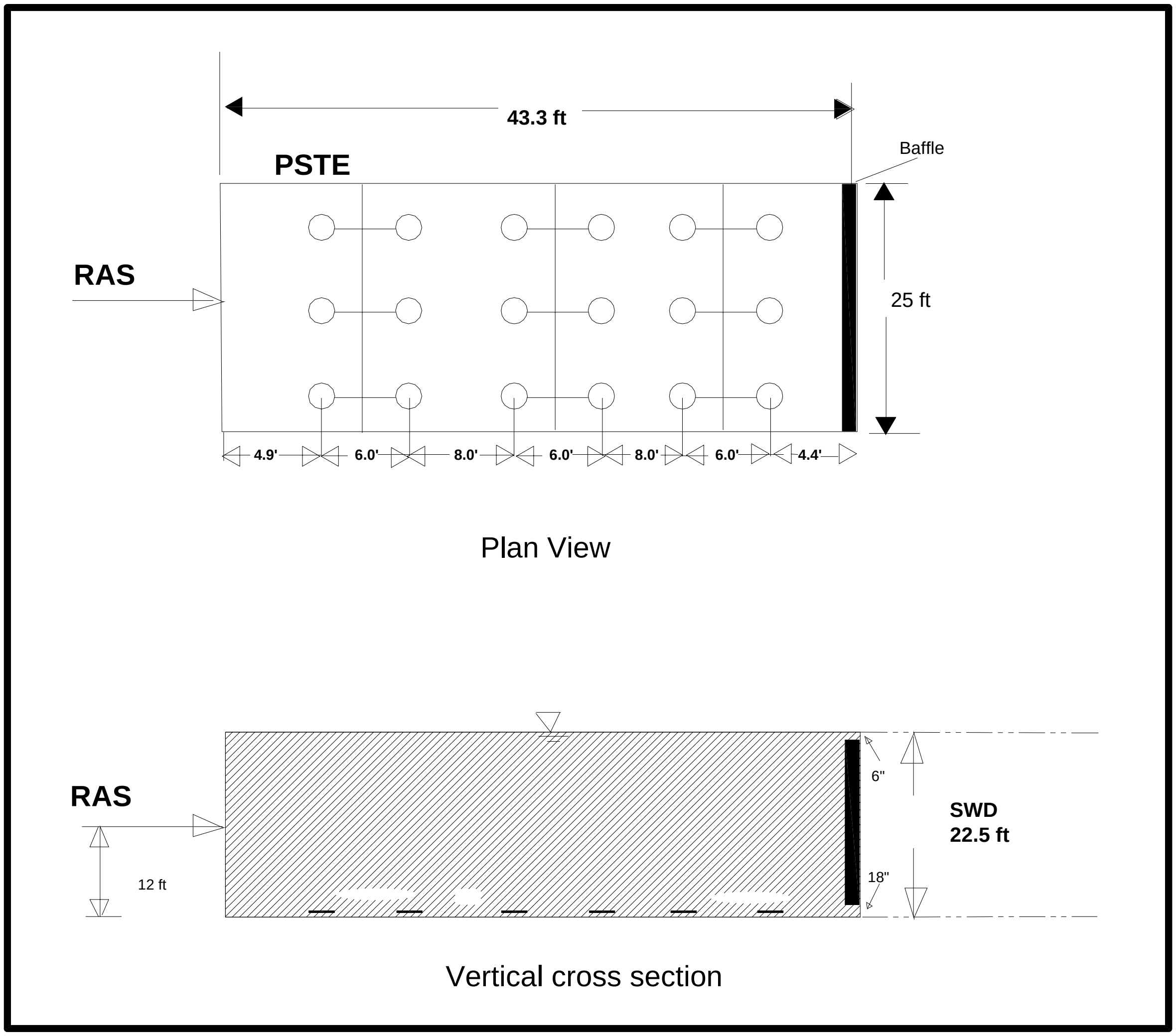


Figure 8. Plan and Sectional View of the Anoxic Zone in Aeration Tank # 4 with the Location of the Forming Plates of the PHI 9/18 Mixing System

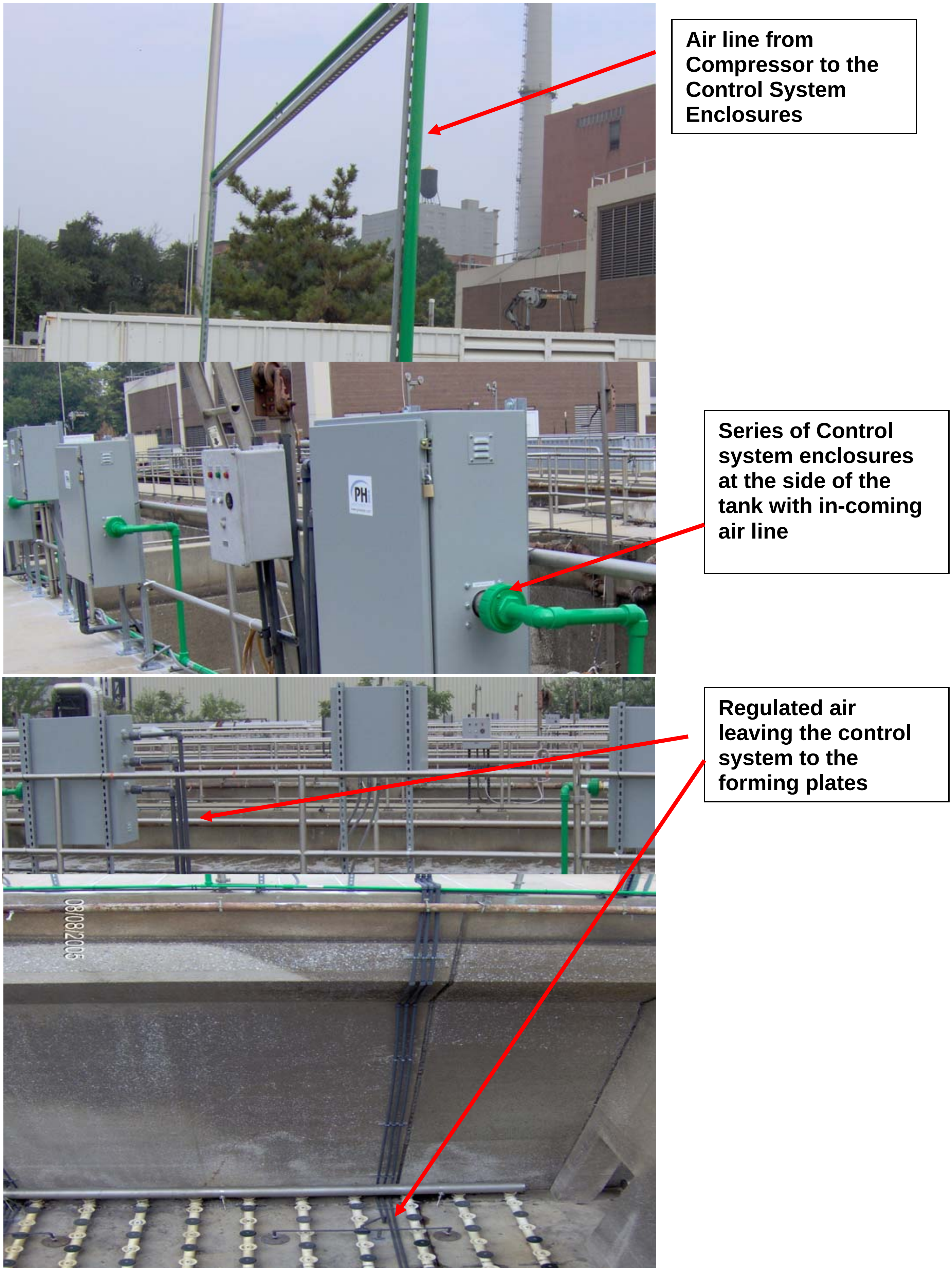


Figure 9. Air Piping layout photographs at the Red Hook WPCP for the PHI 9/18 Mixing System

Table 1. PHI 9/18 Mixing System: Details

Size of Forming Plate	12”
Size of Air delivery Pipe: Compressor to Regulator/Valve: Valve to Accumulator Plate:	 2” 1”
Air Compressor Capacity	30 hp
Smart Relay Program	IDEC FL1C-H12RCC
Air Regulator	Watts R 119-16 JK
Heater	Hoffman AH 1001-A
Air Holding Tank capacity	240 gallons
Air Dryer	Kaeser KAD - 115
Air Pressure range: Typical	30-80 psi: 45 psi
Power Requirements: Enclosure: Compressor:	 15 Amps/115 V 6KW/460V

2.2 DAVIS EMU : Model – TRS 48.22 Uniprop Submersible Mixer

EMU produces a series of submersible mixers used in a number of industrial operations and municipal wastewater treatment operations which include their use in anoxic zones. **Figure 10** shows the essential constructional elements of the Davis EMU Model – TRS 48.22 Uniprop submersible mixer used at the Red Hook WPCP. The mixer has a two blade propeller of 480 mm, (1.57ft) diameter rotating at 226 rpm. The mixer is supported on a mounting skid anchored at the side of the tank. Thus the mixer can be located at any depth or hoisted to the surface for preventive maintenance or refurbishment as needed. The mixer motor is a squirrel cage, induction, shell-type design, housed in an air filled water tight chamber. The stator winding is insulated with moisture resistant class F insulation. The motor draws not more than 4.5 KW at nominal voltage. Motor speed shall be nominally 1140 RPM. The control box for switching the motor on is mounted on the handrail adjacent to the mixer assembly. A comparison of the PHI 9/18 Mixing System and the Davis EMU Model – TRS 48.22 Uniprop submersible mixers is shown in **Table 2**. A noticeable advantage of the PHI System is the absence of moving parts in the tank which simplifies maintenance requirements.

Two uniprop submersible mixers have been installed in the anoxic zone of aeration tank # 3 as shown in **Figure 11**. One of the mixers is located near the beginning of the anoxic zone along the wall across from the influent primary settling tank effluent entrance. The second mixer is located on the opposite wall further downstream and closer to the baffle. The mixers were installed approximately ten years ago and both mixers were continuously operating during this study period. The vendor, Davis EMU, describes the mixing pattern developed as:

> "A turbulent free jet is created with a propeller as the mixing organ. The propeller imparts a rotation on this free jet. Vertical currents are also present in addition to the main horizontal flow. The free jet is limited by the bottom and the walls of the basin and follows every basin geometry."

3. EVALUATION OF MIXING INDUCED BY THE PHI 9/18 MIXING SYSTEM AND DAVIS EMU TRS 48.22 UNIPROP SUBMERSIBLE MIXERS

The level of mixing achieved in the two anoxic zones were evaluated on the basis of the profiles of SS and DO concentrations measured.

At the time of the study, all four aeration tanks were in continuous operation. The objectives of operation of the Red Hook WPCP included equal diversion of the plant flow among the four aeration tanks with subsequent splitting of the flow equally among passes B,C and D of each tank. Concurrently the returned activated sludge (RAS) was to be introduced at the beginning of pass A at a rate of 2.7 MGD per aeration tank. An additional shortcoming in terms of a more thorough analyses of the data collected was the lack of metering of any of the previously stated flows. However, the profiles of SS and DO concentration are sufficient in themselves to document whether adequate mixing was achieved.

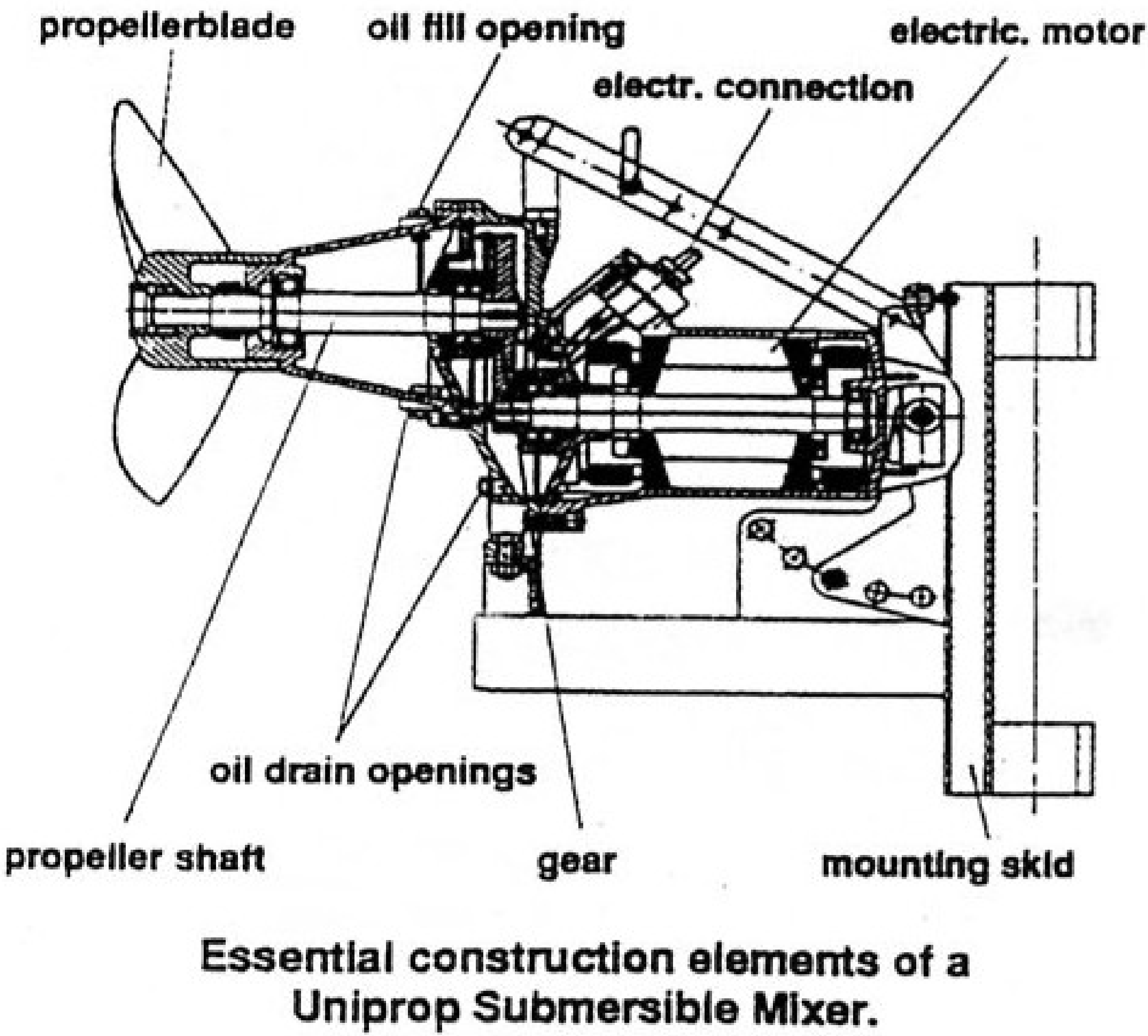


Figure 10. Construction Elements of a Uniprop Submersible Mixer

Table 2. Comparison of PHI 9/18 Mixing System and Davis EMU Model TRS 48.22 installed at the Red Hook WPCP

	PHI 9/18 Mixing System	EMU DAVIS
Location of gear box and motor	None	submerged
Electrical cables in the basin	None	yes
Type of gears	None	Cylindrical Helical type
Mechanical seal	None	Submerged mechanical seal
Propeller type	N/A	2 blade Propeller
Forming Plate Size/ Diameter Mixer Blade	305 mm (12")	480 mm
Speed of mixer blade	N/A	276 rpm
Brake Horse Power	6.0	6.0
Plate/Propeller material	Stainless Steel	Steel with PVC Coating
Type of Oil	N/A	SAE 90: 1.75 L in gear box & 1.5 L in seal chamber
Controller	9/18 PLC based	Control box with on/off switch
Interface Unit	Electro-pneumatic	Electro-Mechanical
Injection valves	Air	N/A
Air Piping	2" from Compressor to valve,& 1" to plates	N/A
Power Requirements: Enclosure: Compressor:	15 Amps/115 V 6KW / 460V	4.5KW/660 V

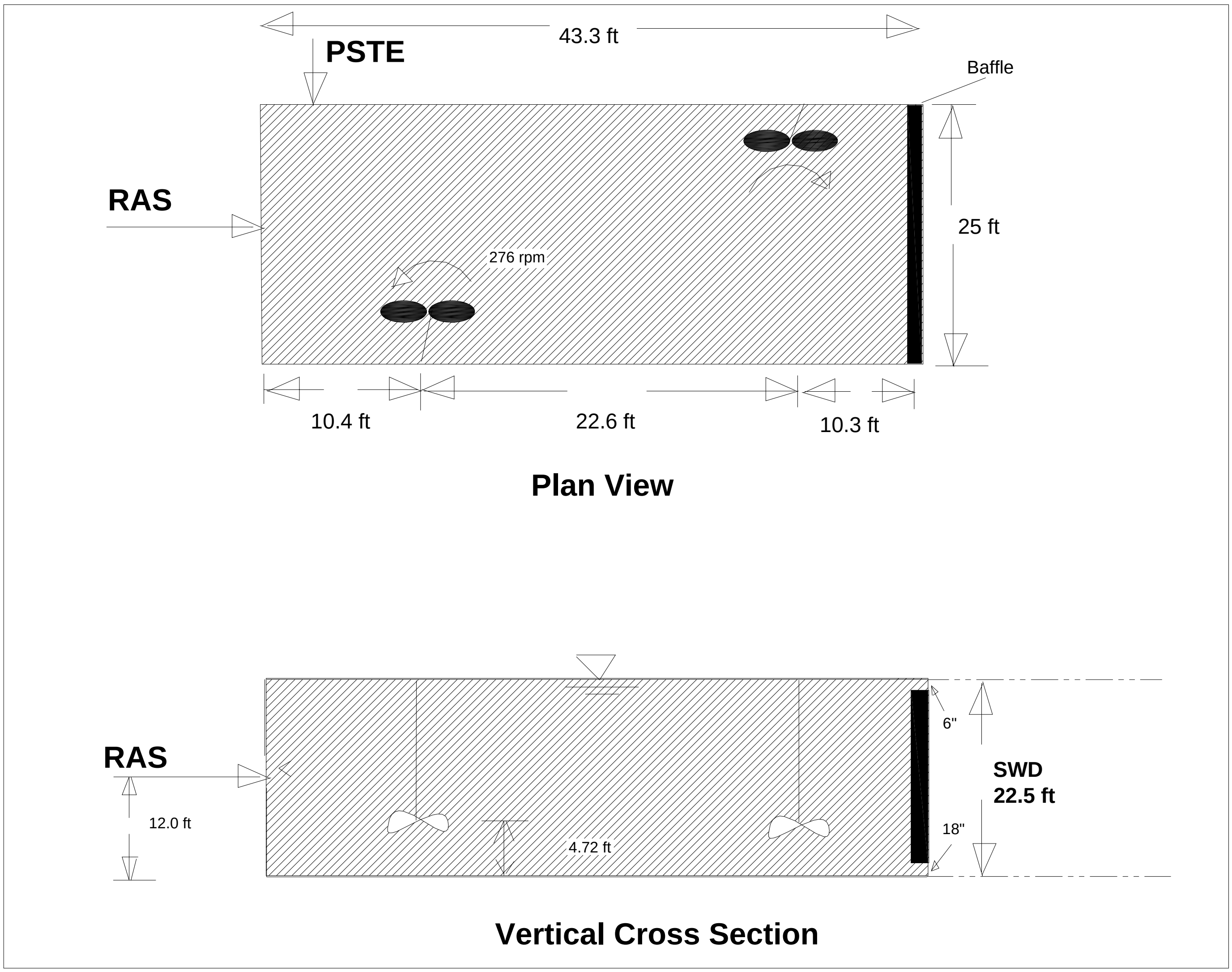


Figure 11. Location of the Davis EMU TRS 48.22 Uniprop Submersible Mixers in Aeration Tank # 3 at the Red Hook WPCP

3.1 Evaluation of Mixing Using SS Concentration Profiles

The concentration of SS in the anoxic zone represents an indirect measure of the mass of bacteria active in denitrification. Therefore it is important for any mixing device to be able to sustain a uniform distribution of SS throughout the volume of the anoxic zone to facilitate denitrification. To confirm whether such an uniform distribution of SS was achieved, sampling locations were pre-selected across the horizontal cross-section of the anoxic zone at three different elevations, namely 3, 11, and 20 feet below the water surface in the tank. **Figure 12** shows the locations used to sample both of the anoxic zones in the two aeration tanks.

At each location, the concentration of SS was measured using a portable Royce SS probe, model 711A. At the same time, mixed liquor samples were collected at selected stations and analyzed for SS using “Standard Methods” method 2540D. The concentrations of SS in the collected samples were used in part to verify the values obtained from the Royce SS probe.

To establish base line conditions before installation of the PHI system in aeration tank # 4, two preliminary profiles of the pass B anoxic zones in AT-3 & 4 were carried out on June 29, 2005 & July 14, 2005. The second profile was necessitated because of excessive foam on June 29, 2005. **Table 3** shows the data and the corresponding contour profiles of SS for each depth is presented In **Figures 13 through 16**. The concentration of SS in the bulk volume of the anoxic zone appears to be in the range of 1200 to 1700 mg/L for the two days in both tanks.

3.1.1. AERATION TANK # 4: ANOXIC ZONE WITH PHI 9/18 MIXING SYSTEM

The anoxic zone in aeration tank 4, was sampled on three different dates and the data collected is presented in **Table 4**. This data was then plotted and separate contour concentration lines at each elevation were developed and shown in **Figures 17**, **18**, **and 19**. In all the figures, the PHI 9/18 Mixing System is shown only at the 20 feet depth profiles and to approximate scale.

In **Figure 17**, the concentration of the SS in the bulk volume is in the 1200 to 1300 mg/L range, and appears to be uniformly mixed with the exception of some gradients at the influent end of the anoxic zone at the 20 ft. elevation.

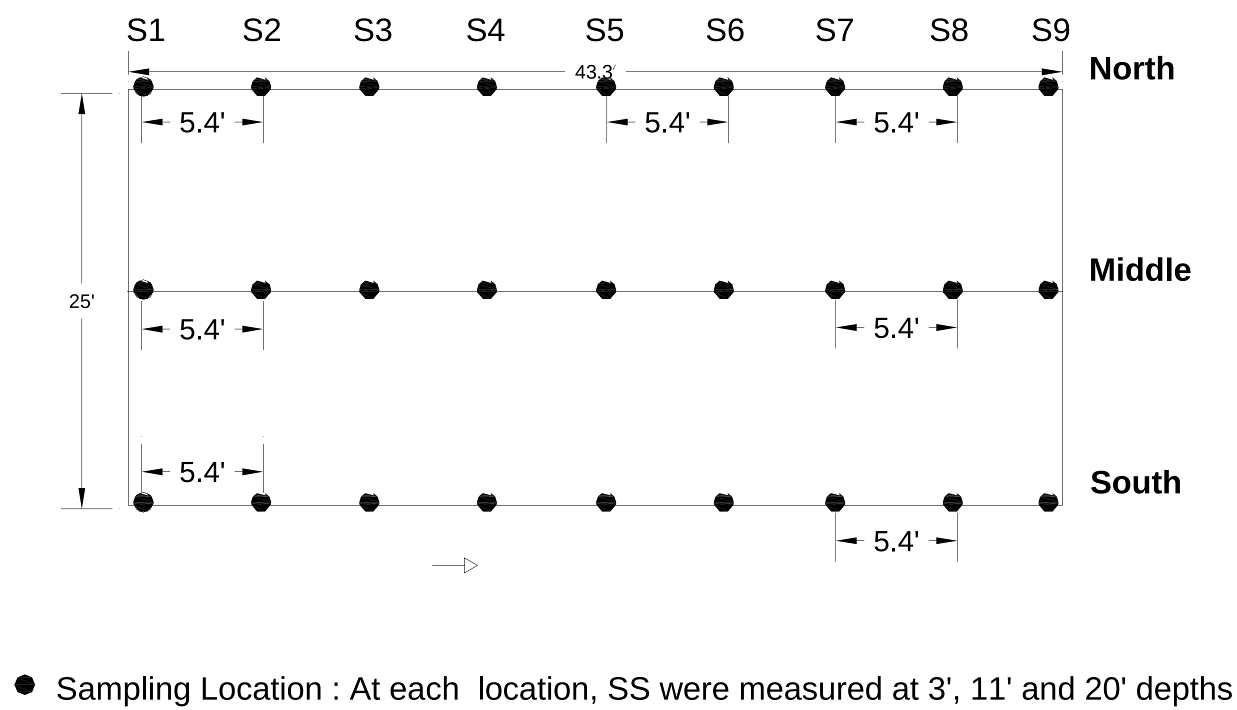


Figure 12. Sampling Locations for Measuring the SS Profiles in the anoxic zone of pass B of Aeration Tanks # 3 and # 4: Red Hook WPCP.

Table 3: Solids Profile in Aeration Tanks 3 & 4 prior to installation of the PHI 9/18 System, Red Hook WPCP:

Solids profile in Aeration Tank # 3 (DAVIS-EMU), Red Hook WPCP

6/29/05		3 ft depth			11 ft depth			20 ft depth		
		Royce Readings, mg/L			Royce Readings, mg/L			Royce Readings, mg/L		
Station	Distance, f	North	Mid Sec.	South	North	Mid Sec.	South	North	Mid Sec.	South
S1	0	1350	1700	1610	1550	1500	1660	1660	1450	1800
S2	7.5	1800	1560	1500	1580	1440	1600	1600	1600	1850
S3	12.5	1820	1750	1550	1600	1550	1600	1600	1650	1750
S4	19.5	1790	1840	1700	1630	1700	1570	1570	1550	1750
S5	22.5	1650	1810	1750	1500	1600	1550	1550	1530	1700
S6	27.5	1530	1700	1750	1400	1660	1550	1550	1560	1700
S7	32.5	1650	1600	1650	1500	1500	1570	1570	1580	1630
S8	37.5	1580	1500	1610	1400	1690	1500	1500	1550	1600
S9	42.5	1500	1700	1680	1400	1550	1650	1650	1500	1650

7/14/05		3 ft depth			11 ft depth			20 ft depth		
		Royce Readings, mg/L			Royce Readings, mg/L			Royce Readings, mg/L		
Station	Distance, ft	North	Mid Sec.	South	North	Mid Sec.	South	North	Mid Sec.	South
S1	0	1930	1750	1950	1850	1720	1920	1820	1730	2200
S2	7.5	1930	1840	1870	1860	1620	1820	1810	1800	2200
S3	12.5	1940	1800	1780	1900	1750	1920	1850	1750	1950
S4	19.5	1920	1980	1800	1750	1900	1870	1740	1700	1800
S5	22.5	1610	1960	1870	1700	1750	1850	1800	1630	1900
S6	27.5	1800	1880	1850	1600	1850	1710	1700	1750	1850
S7	32.5	1770	1750	1850	1700	1650	1700	1800	1700	1830
S8	37.5	1850	1750	1780	1800	1880	1800	1700	1650	1800
S9	42.5	1700	1760	2000	1700	1900	1930	1780	1800	1970

Solids profile in Aeration Tank # 4 (DAVIS-EMU), Red Hook WPCP prior to installation of the PHI 9/18 Mixing System

6/29/05		3 ft depth			11 ft depth			20 ft depth		
		Royce Readings, mg/L			Royce Readings, mg/L			Royce Readings, mg/L		
Station	Distance, ft	North	Mid Sec.	South	North	Mid Sec.	South	North	Mid Sec.	South
S1	0	1370	1100	1680	1430	1420	1770	1480	1310	1900
S2	6.67	1590	1400	1650	1510	1400	1640	1500	1370	1740
S3	11.67	1620	1280	1680	1560	1400	1590	1500	1300	1600
S4	18.67	1710	1680	1700	1640	1530	1480	1520	1380	1620
S5	21.67	1620	1640	1690	1600	1580	1520	1390	1300	1560
S6	26.67	1410	1550	1740	1350	1420	1560	1470	1250	1490
S7	31.67	1390	1450	1660	1300	1400	1510	1270	1260	1590
S8	36.67	1400	1420	1590	1290	1450	1480	1310	1400	1550
S9	41.67	1410	1520	1610	1240	1320	1500	1260	1400	1550

7/14/05		3 ft depth			11 ft depth			20 ft depth		
		Royce Readings, mg/L			Royce Readings, mg/L			Royce Readings, mg/L		
Station	Distance, ft	North	Mid Sec.	South	North	Mid Sec.	South	North	Mid Sec.	South
S1	0	1200	1280	1180	1230	1100	1170	1200	1240	1190
S2	6.67	1300	1250	1220	1270	1350	1180	1250	1320	1340
S3	11.67	1320	1280	1180	1240	1300	1170	1220	1260	1270
S4	18.67	1300	1490	1300	1260	1330	1120	1200	1310	1260
S5	21.67	1310	1450	1360	1230	1400	1240	1230	1300	1260
S6	26.67	1260	1300	1380	1220	1300	1260	1270	1400	1250
S7	31.67	1210	1230	1220	1260	1350	1270	1300	1300	1230
S8	36.67	1180	1150	1320	1270	1350	1240	1280	1220	1250
S9	41.67	1220	1050	1290	1250	1380	1270	1270	1250	1250

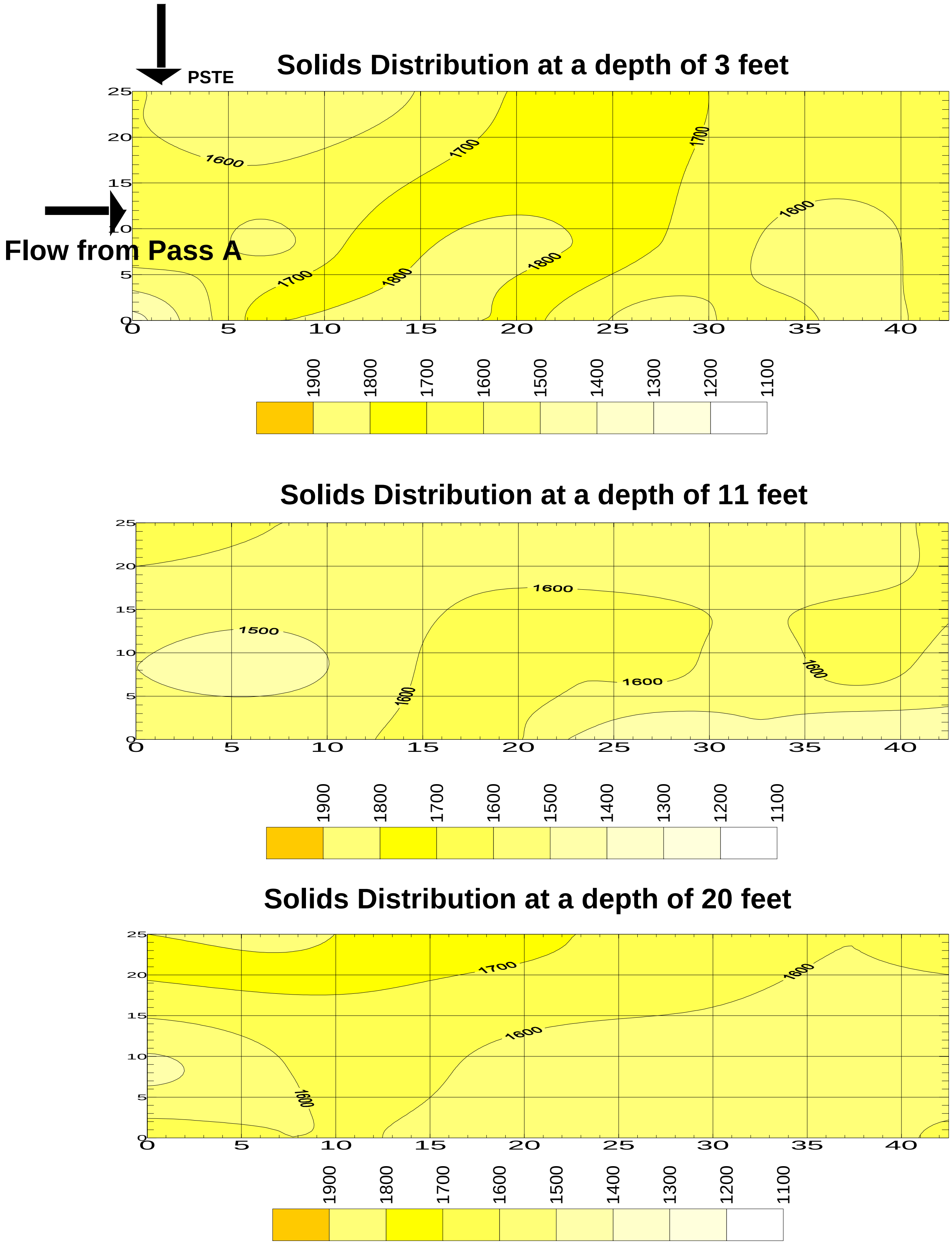


Figure 13: **Red Hook WPCP: Aeration Tank # 3: Existing EMU Davis Mixer Evaluation Pass B Anoxic Zone, June 29, 2005**

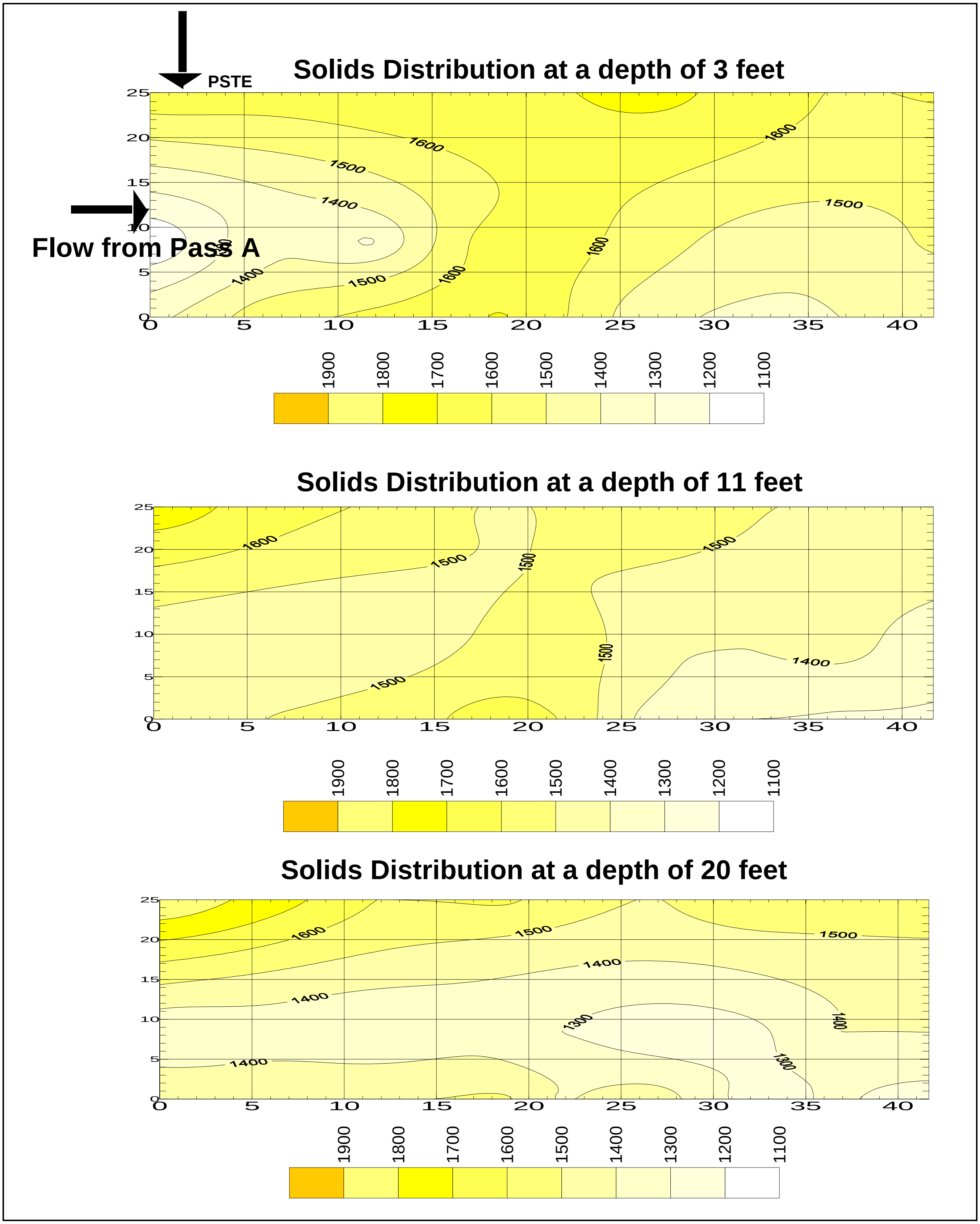


Figure 14: **Red Hook WPCP: Aeration Tank # 4: Existing EMU Davis Mixer Evaluation Pass B Anoxic Zone, June 29, 2005 prior to installation of the PHI 9/18 Mixing System**

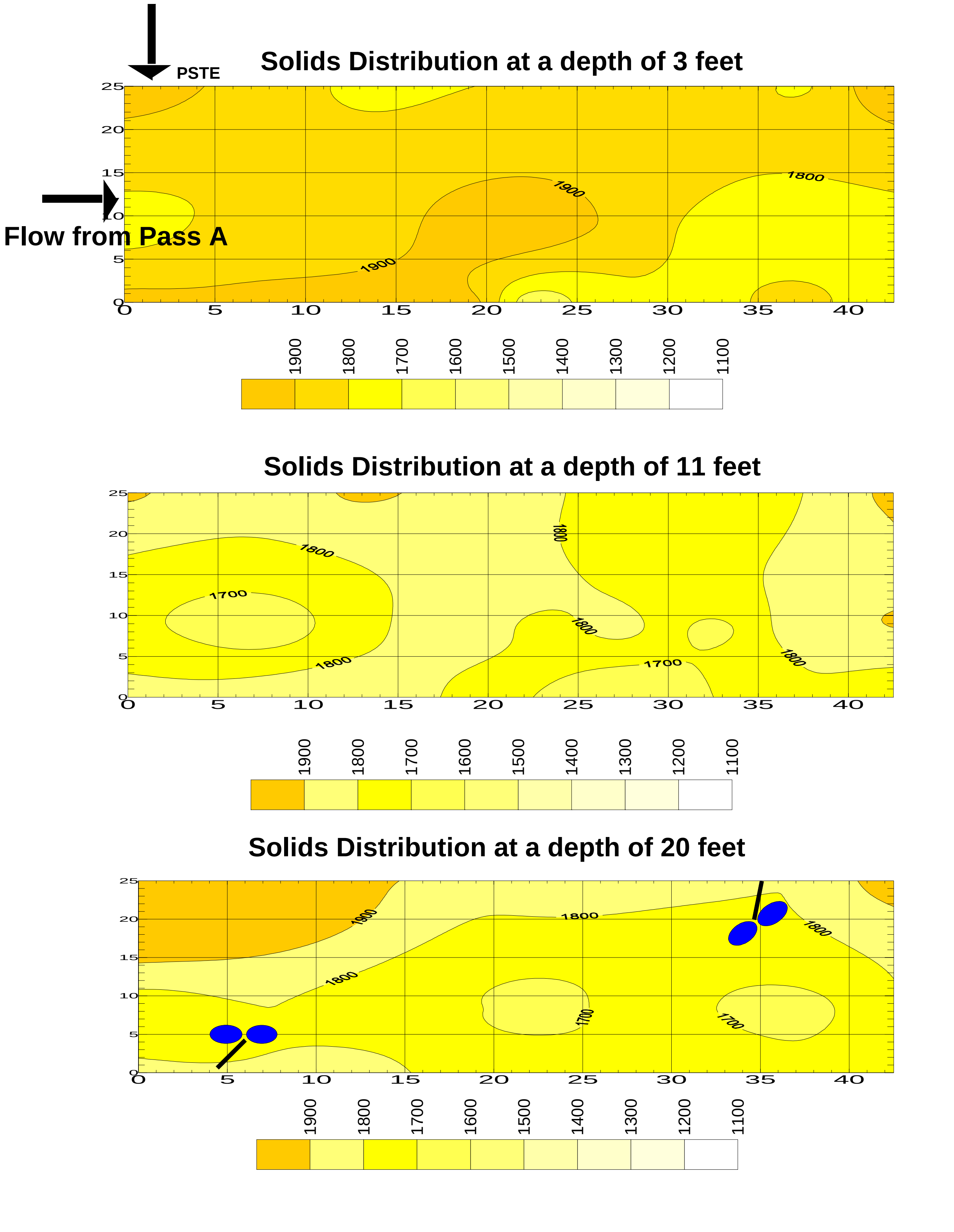


Figure 15: Solids Profile AT-3: Pass B Anoxic Zone - Red Hook WPCP: Davis EMU Mixer Evaluation, July 14, 2005

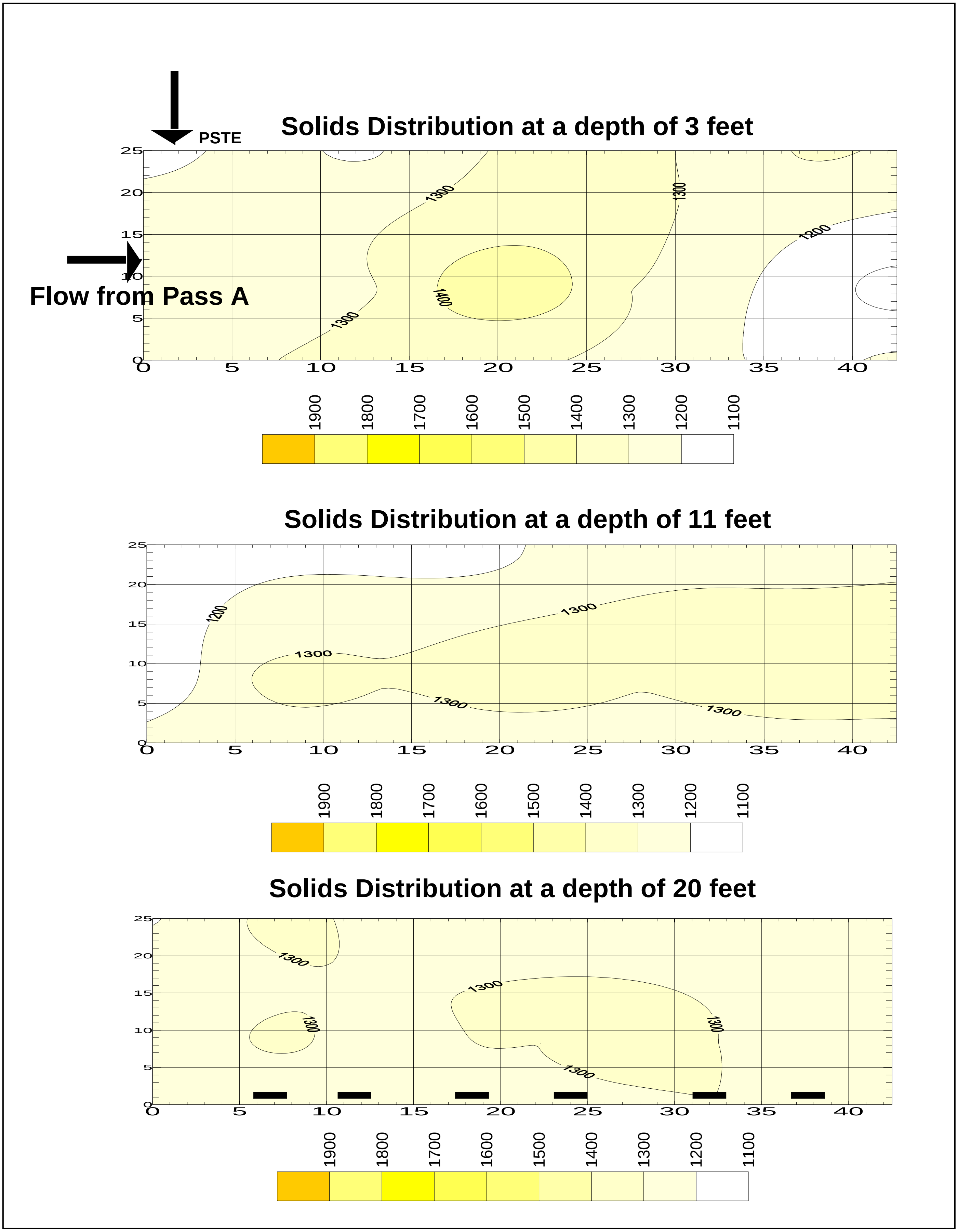


Figure 16: Solids Profile AT-4: Pass B Anoxic Zone - Red Hook WPCP: Existing EMU Davis Mixer Evaluation prior to PHI 9/18 Mixing System Installation- July 14, 2005

Table 4. Solids profile in Aeration Tank 4 (PHI 9/18 MIXING SYSTEM), Red Hook WPCP

9/16/05		3 ft depth			11 ft depth			20 ft depth		
		Royce Readings, mg/L			Royce Readings, mg/L			Royce Readings, mg/L		
Station	Distance, ft	North	Mid Sec.	South	North	Mid Sec.	South	North	Mid Sec.	South
S1	0	1110	1220	1220	1000	1100	1250	1180	1100	1840
S2	6.67	1120	1180	1250	1050	1090	1300	1200	1050	1350
S3	11.67	1200	1220	1320	1140	1110	1250	1050	1250	1400
S4	18.67	1170	1240	1300	1140	1160	1200	1500	1140	1250
S5	21.67	1180	1320	1250	1050	1180	1200	1500	1240	1300
S6	26.67	1240	1300	1320	1200	1180	1220	1100	1340	1120
S7	31.67	1250	1340	1300	1200	1050	1250	1200	1320	1280
S8	36.67	1200	1310	1300	1200	1000	1200	1350	1200	1120
S9	41.67	1200	1420	1300	1300	1100	1150	1350	1180	1250

2/23/06		3 ft depth			11 ft depth			20 ft depth		
Station	Distance, ft	Royce Readings, mg/L			Royce Readings, mg/L			Royce Readings, mg/L		
		North	Mid Sec.	South	North	Mid Sec.	South	North	Mid Sec.	South
S1	0	2322	1432	2490	2362	1660	2578	2882	2531	3387
S2	6.67	2130	927	2346	2482	1777	2482	3259	2018	3035
S3	11.67	2210	2030	2546	2362	2013	2570	3019	2093	2826
S4	18.67	2226	2022	2554	2226	2022	2554	2810	2109	2874
S5	21.67	2218	2022	2562	2442	2072	2578	3011	2001	2874
S6	26.67	2578	2114	2538	2498	2089	2458	3011	2001	2826
S7	31.67	2642	2106	2586	2546	2114	2546	3027	2043	2786
S8	36.67	2618	2106	2482	2530	2022	2522	3027	2287	2826
S9	41.67	2674	2249	2554	2690	2106	2634	2914	2018	2874

5/5/06		3 ft depth			11 ft depth			20 ft depth		
Station	Distance, ft	Royce Readings, mg/L			Royce Readings, mg/L			Royce Readings, mg/L		
		North	Mid Sec.	South	North	Mid Sec.	South	North	Mid Sec.	South
S1	0	2300	2900	2420	2600	2680	2570	3300	3440	4440
S2	6.67	2300	3050	1850	2850	2400	2500	3200	2970	2430
S3	11.67	2150	3030	2880	2800	2720	2650	3350	3500	2650
S4	18.67	2600	3060	2970	2750	2940	2760	3400	2750	2800
S5	21.67	2700	2970	2950	2650	2750	2770	3350	3800	2850
S6	26.67	2700	3010	3070	2900	3050	2580	2800	3400	2500
S7	31.67	2600	2530	3030	2700	2700	2490	3100	3300	2700
S8	36.67	2600	2010	2850	2400	3050	2630	3000	2970	3100
S9	41.67	2750	2080	2660	2500	2980	2470	3150	3050	2850

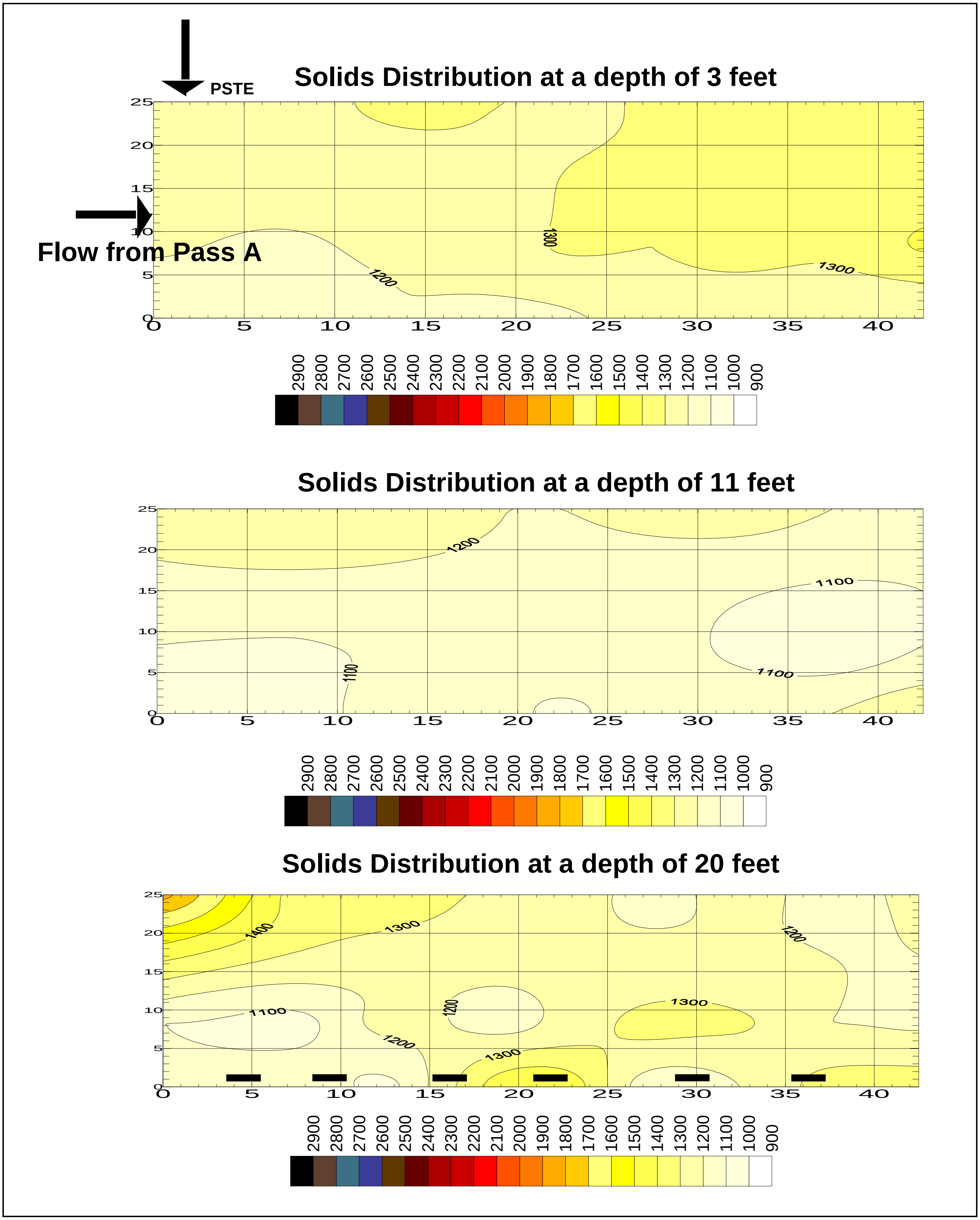


Figure 17: Solids Profile AT-4: Pass B Anoxic Zone - Red Hook WPCP: PHI 9/18 Mixing System Evaluation, September 16, 2005

Figure 18 shows the solids profile carried out on 2/23/2006. The SS concentration is between 2200 and 2700 mg/L in the tank which is significantly higher than on the previous occasions. At the 3 ft. depth, substantial gradients ranging between 1500 mg/L and 2300 mg/L can be noticed especially at the influent end. Similarly, at the 20 ft. depth, gradients appear along the longitudinal wall and towards the influent end although the bulk of the volume in the middle of the zone seems to be well-mixed.

The contour profiles for the SS data collected on 5/5/2006 are shown in **Figure 19**. During this sampling period, all four aeration tanks were carrying a significantly higher SS concentration. Hence, the profile in aeration tank 4 reflects that higher level of SS with concentrations in the range of 2600 mg/L to 3100 mg/L. Consequently, substantial gradients became evident at the 3 ft. and 20 ft. depths with much higher concentrations towards the influent end at the 20 ft. depth. The SS seems to be fairly well mixed at the 11 ft. elevation. It appears that at the higher concentration of SS, there was a tendency for the solids to settle and accumulate, especially at the front end of the zone as revealed by additional sludge blanket readings measured with the help of a sludge judge. **Figure 20** shows the presence of sludge accumulation in the front end of the tank reaching as much as three feet with concentrations of 10,000 mg/L.

The PHI 9/18 Mixing System appears to achieve uniform mixing as long as the solids concentration are in the range of 1200-1700 mg/L. With higher concentrations of SS in the bulk volume there appears to be gradients developing towards the influent end and at the lower elevations of the anoxic zone.

The profiling conducted on 5/5/2006 was carried out at the express request of PHI, Inc. as the company was interested in turning down the PHI 9/18 Mixing System to the lowest possible pulsing rate and observe the efficiency of mixing. Hence, the profiling effort was confined to aeration tank 4 only on this day.

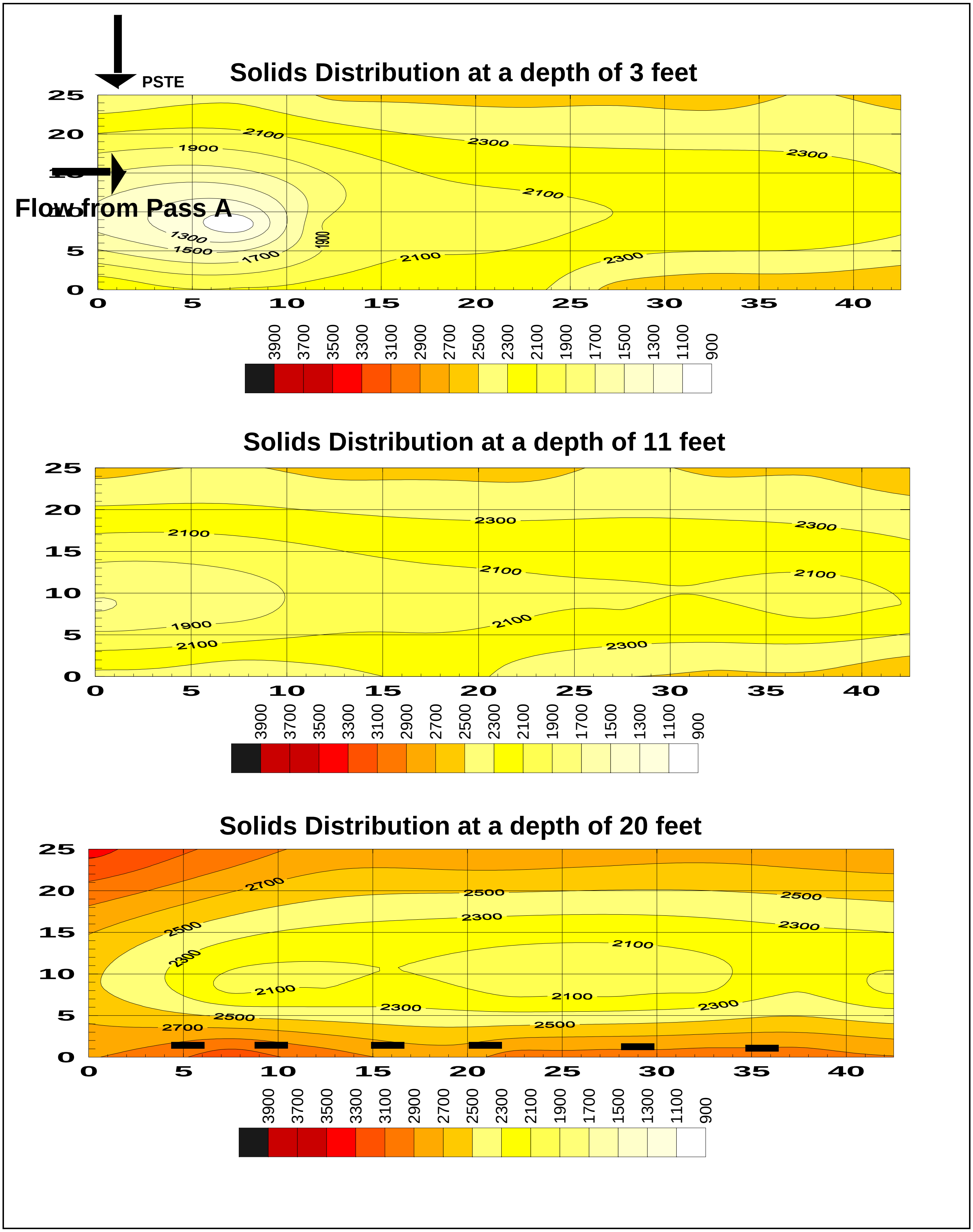


Figure 18: **Solids Profile AT-4: Pass B Anoxic Zone - Red Hook WPCP: PHI 9/18 Mixing System Evaluation, February 23, 2006**

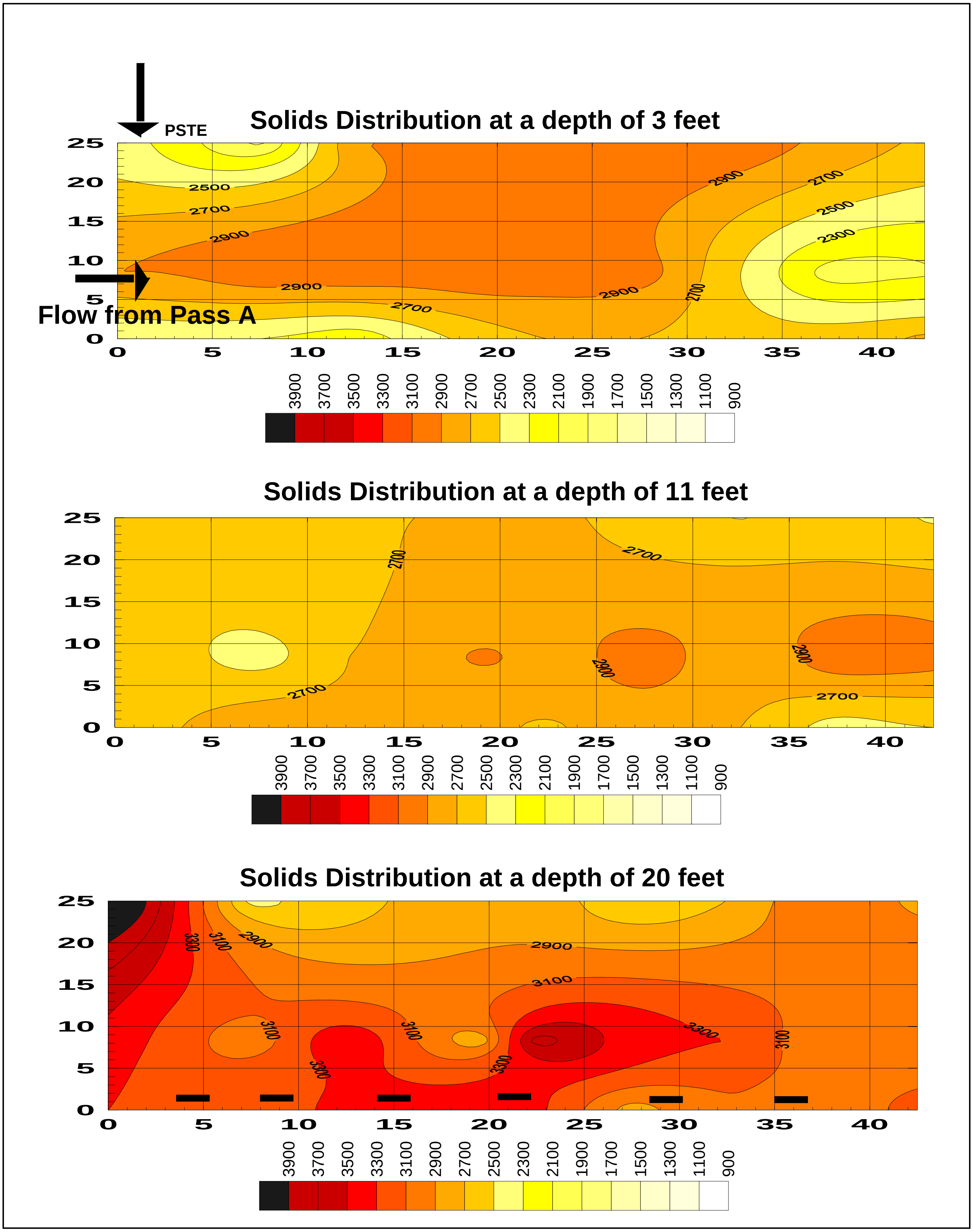
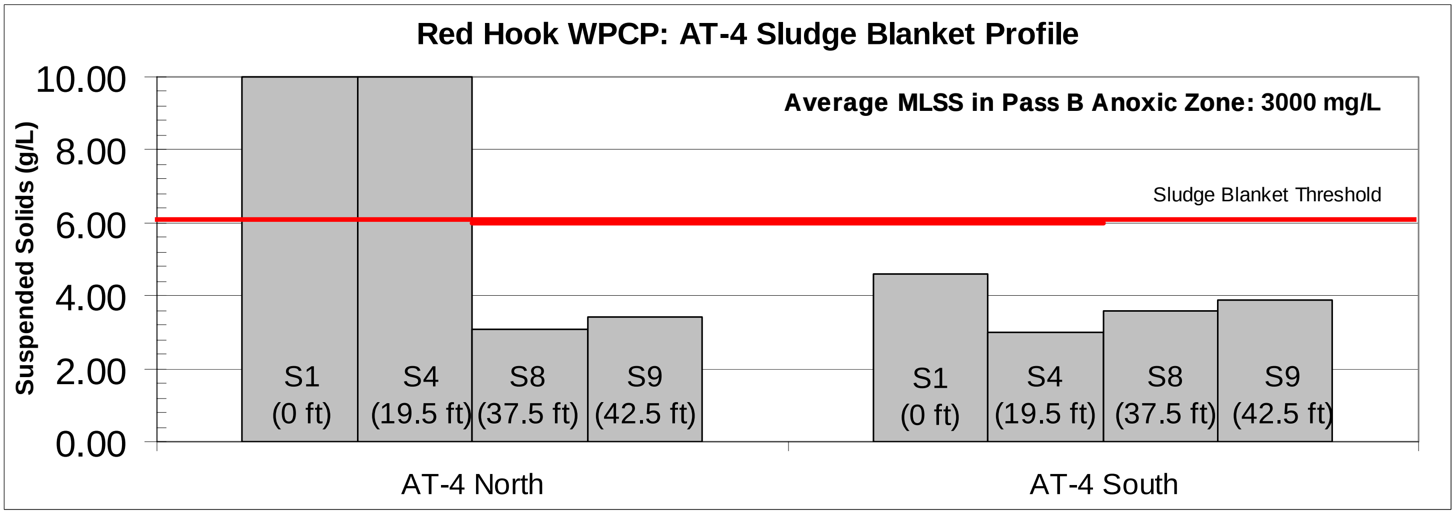
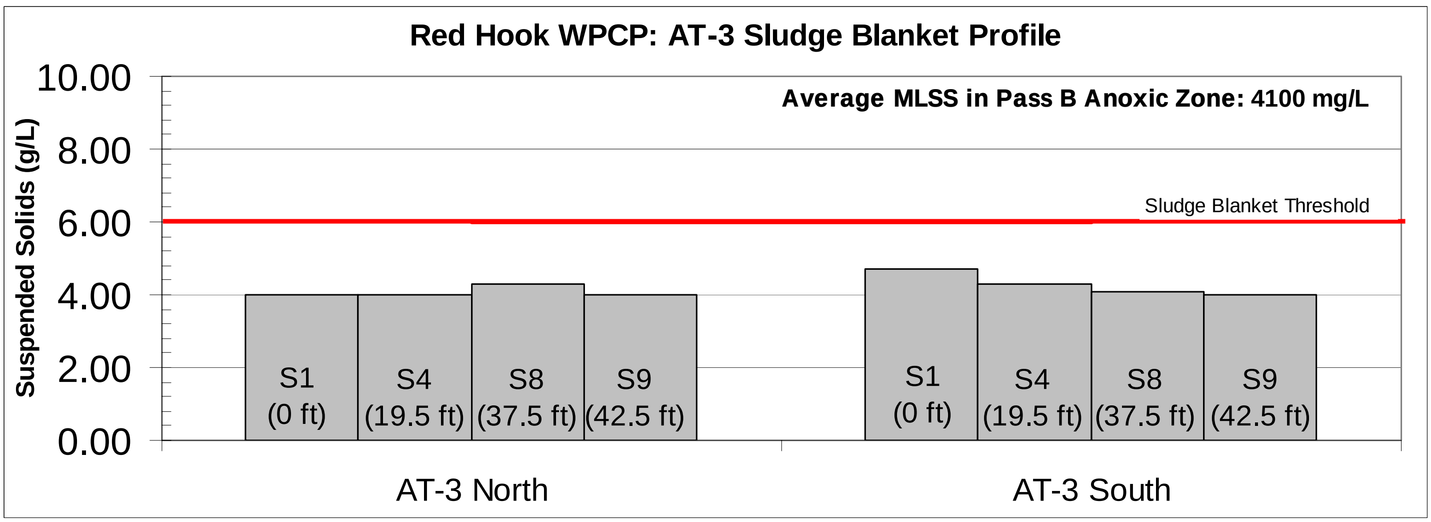


Figure 19: Solids Profile AT-4: Pass B Anoxic Zone - Red Hook WPCP: PHI 9/18 Mixing System Evaluation, May 05, 2006





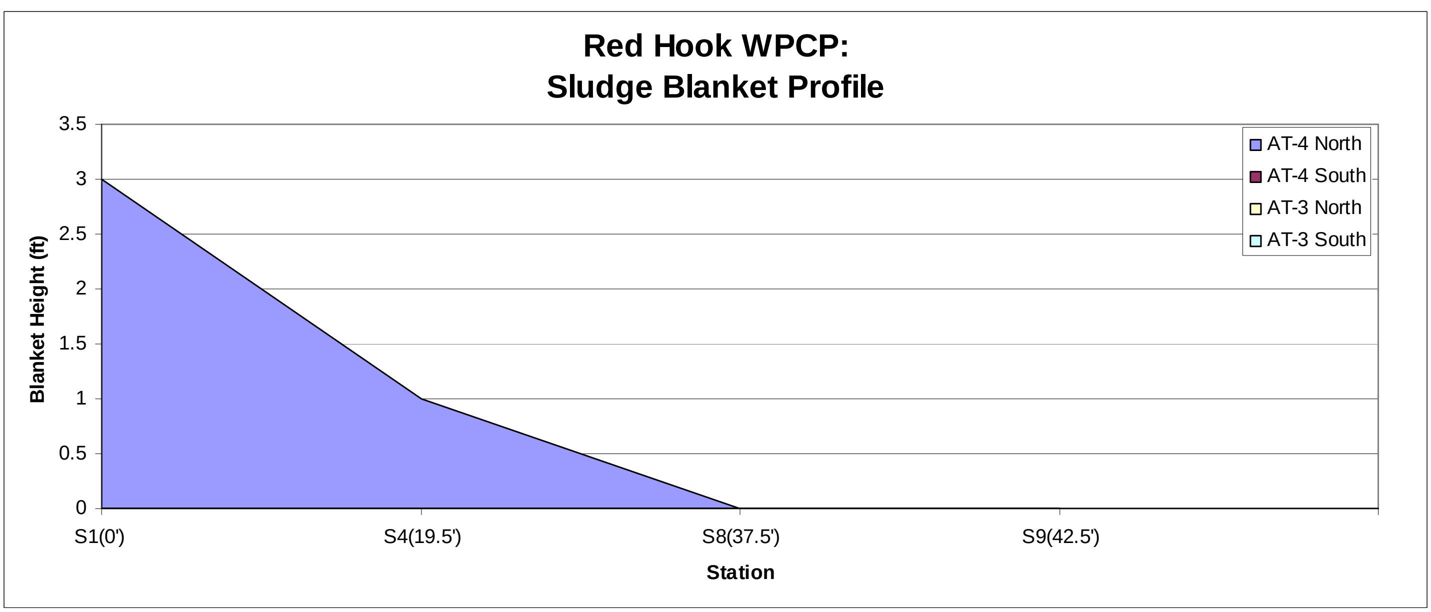


Figure 20: Sludge Blanket Profile AT-3 & 4: Pass B Anoxic Zone - Red Hook WPCP: 2/23/06

3.1.2. AERATION TANK # 3: ANOXIC ZONE WITH TWO DAVIS EMU MODEL 48.22 UNIPROP SUBMERSIBLE MIXERS

The anoxic zone in aeration tank # 3, is mixed using two uniprop submersible mixers, was sampled on two different dates and the data collected is presented in **Table 5**. These data were plotted and separate contour concentration lines at each elevation were developed and shown in **Figures 21 and 22**. In both figures the submersible mixers are only shown at a depth of 20 ft. at the spatial locations installed.

The profile carried out on 09/16/2006 is shown in **Figure 21**. The concentration of SS in the bulk volume is slightly higher in the range of 2000 - 2200 when compared to **Figures 13 & 15** but substantially higher than the 1200 to 1300 mg/L of SS in Aeration tank 4 for the same day. The contents of the anoxic zone seem to be fairly well mixed at all three elevations in spite of the higher load. The plant flow at the time of sampling was 28 MGD.

The second sampling event occurred on 02/23/2006 and is shown in **Figure 22**. There were significantly higher solids in the aeration tanks compared to the previous occasions with the SS in the bulk volume in the range of 3200 to 3500 mg/L. The mixing in the anoxic zone was fairly uniform in spite of the higher solids loading except at the 20 ft. elevation where gradients appeared along the longitudinal walls of the zone and towards the influent end of the zone.

3.2. EVALUATION OF MIXING USING DO CONCENTRATION PROFILES

An important characteristic desired of any type of mixer is to minimize surface water disruption or turbulence in order to minimize oxygen transfer from the atmosphere into the anoxic zone. The presence of DO induces a significant demand for organic carbon whether the carbon is inherent in the wastewater or added in the form of methanol or acetate. Thus DO concentration profiles in the anoxic zone are a further indication of the adequacy of the mixers to satisfy this additional criteria of performance.

The DO concentrations throughout the volume of each anoxic zone were measured using a YSI 556 DO probe. **Table 6** summarizes the DO concentrations which were consistently in the range where denitrification takes place. **Figure 23** allows a visual comparison of DO in the two tanks prior to the installation of the PHI 9/18 Mixing System in AT-4. **Figures 24 & 25** depict the DO profiles with the EMU Davis and PHI 9/18 Mixing System in AT-3 & AT-4, respectively. It appears that both mixers are able to address their primary objective of uniform distribution of SS while maintaining low DO concentration values. Higher DO values at the end of the anoxic zone in AT-3 could be a function of the mixing movement by the mixer nearer the baffle and subsequent back-mixing.

Table 5. Red Hook WPCP: Aeration Tank # 3 (Uniprop Mixer): Solids Profile in the Anoxic Zone of Pass B

9/16/05		3 ft depth			11 ft depth			20 ft depth		
		Royce Readings, mg/L			Royce Readings, mg/L			Royce Readings, mg/L		
		North	Mid Sec.	South	North	Mid Sec.	South	North	Mid Sec.	South
S1	0	2180	2310	2150	2150	2180	2010	2100	2250	2450
S2	7.5	2160	2260	2210	2000	2000	2300	2010	2220	2200
S3	12.5	2250	2460	2010	2150	2180	2000	2050	2280	2150
S4	19.5	2100	2470	2010	1800	2350	2210	2000	2140	2150
S5	22.5	2100	2450	2050	2150	2100	2200	2050	2180	2050
S6	27.5	2100	2380	2000	1950	2150	2050	2000	2050	2010
S7	32.5	2050	2250	2000	2000	2000	2130	2100	2200	2050
S8	37.5	2000	2200	2060	1900	1950	1900	2100	2050	1950
S9	42.5	1950	2180	1950	1900	2370	1950	2060	2220	2150

AT-3 Solids

2/23/06		3 ft depth			11 ft depth			20 ft depth		
		Royce Readings, mg/L			Royce Readings, mg/L			Royce Readings, mg/L		
Station	Distance, ft	North	Mid Sec.	South	North	Mid Sec.	South	North	Mid Sec.	South
S1	0	3600	3620	4340	4050	3400	4500	4380	3650	5040
S2	7.5	4320	3630	4210	4320	3620	4590	4560	3600	5090
S3	12.5	4350	3700	4310	4200	3640	4320	4430	3670	4630
S4	19.5	4330	3830	4380	4260	3600	4510	4470	3630	4600
S5	22.5	4260	3830	4380	4300	3720	4320	4440	3570	4500
S6	27.5	4050	3700	4310	4190	3680	4270	4310	3600	4650
S7	32.5	4160	3700	4280	4100	3540	4320	4350	3580	4530
S8	37.5	4070	3550	4310	4210	3620	4210	4530	3560	4620
S9	42.5	4100	3620	4200	4360	3590	4350	4610	3580	4430

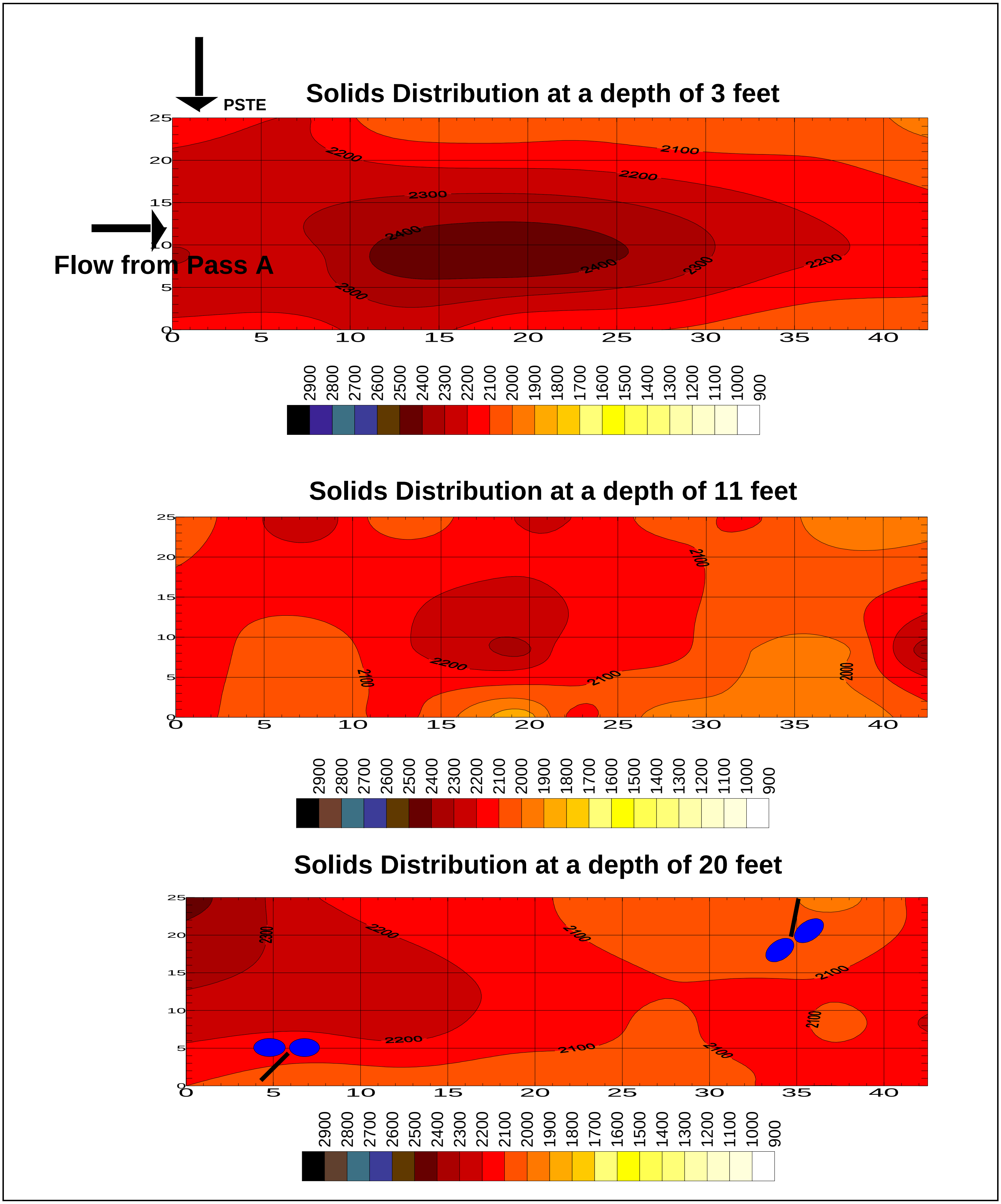


Figure 21: **Solids Profile AT-3: Pass B Anoxic Zone - Red Hook WPCP: Davis EMU Mixer Evaluation, September 16, 2005**

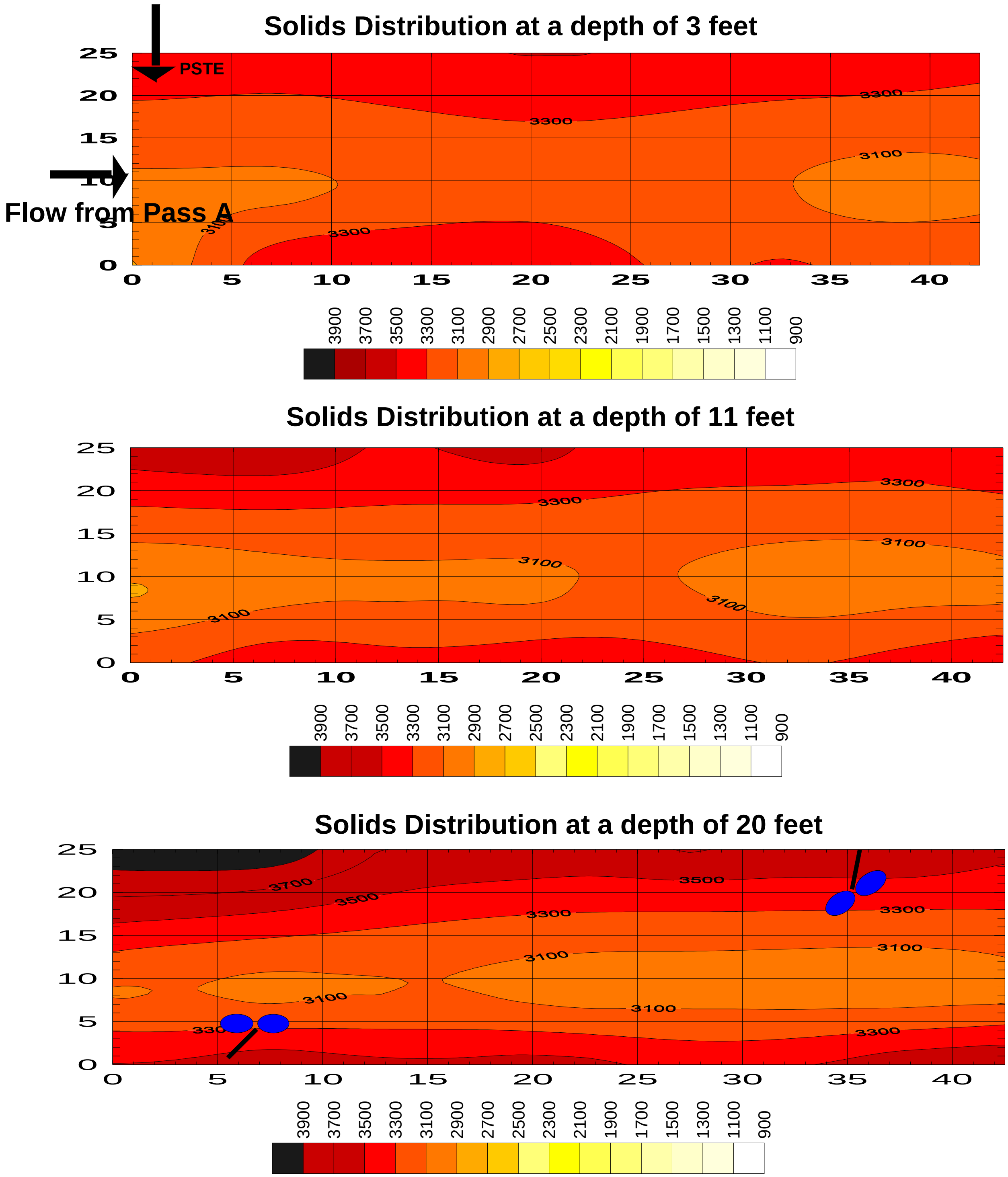


Figure 22: Solids Profile AT-3: Pass B Anoxic Zone - Red Hook WPCP: Davis EMU Mixer Evaluation, February 23, 2005

Table 6. Red Hook WPCP:DO Readings in the Anoxic Zone of Pass B in Aeration Tanks 3 & 4 (7/14/05. 9/16/05 & 2/23/06)

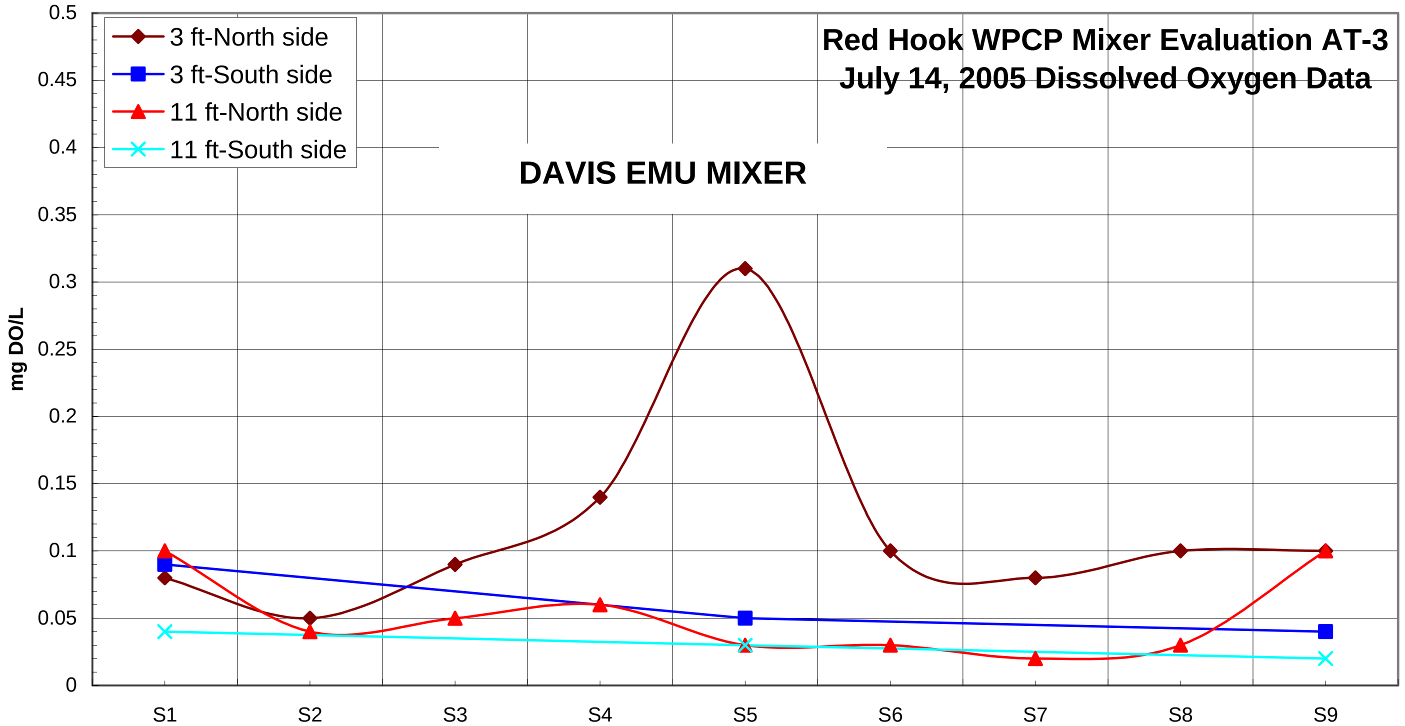
7/14/2005		AT-3 Mixer Type: Davis EMU				AT-4 Mixer Type: Davis EMU			
Station	Distance (ft)	North Side (mg/L)		South Side (mg/L)		North Side (mg/L)		South Side (mg/L)	
		3ft	11 ft	3ft	11 ft	3ft	11 ft	3ft	11 ft
S1	0	0.08	0.1	2.09	0.04	0.1	0.05	0.05	0.05
S2	7.5	0.05	0.04			0.07	0.06	0.05	0.04
S3	12.5	0.09	0.05			0.07	0.04	0.05	0.04
S4	19.5	0.14	0.06			0.04	0.05	0.04	0.04
S5	22.5	0.31	0.03	0.05	0.03	0.06	0.05	0.04	0.04
S6	27.5	0.1	0.03			0.04	0.04	0.06	0.04
S7	32.5	0.08	0.02			0.03	0.03	0.12	0.05
S8	37.5	0.1	0.03			0.03	0.03	0.13	0.05
S9	42.5	0.1	0.1	0.04	0.02	0.04	0.03	0.05	0.05

9/16/2005		AT-3 Mixer Type: Davis EMU				AT-4 Mixer Type: PHI System			
Station	Distance (ft)	North Side (mg/L)		South Side (mg/L)		North Side (mg/L)		South Side (mg/L)	
		3ft	11 ft	3ft	11 ft	3ft	11 ft	3ft	11 ft
S1	0	0.38	0.28	0.62	0.64	0.16	0.08	0.08	0.08
S2	7.5	0.71	0.48	0.6	0.5	0.06	0.05	0.08	0.06
S3	12.5	0.88	0.7	0.11	0.21	0.06	0.05	0.06	0.06
S4	19.5	0.9	0.48	0.12	0.17	0.13	0.05	0.11	0.06
S5	22.5	1.1	0.06	0.16	0.18	0.13	0.05	0.1	0.07
S6	27.5	1.04	0.08	0.18	0.1	0.13	0.05	0.08	0.05
S7	32.5	0.07	0.04	0.18	0.22	0.06	0.05	0.25	0.06
S8	37.5	0.06	0.02	0.17	0.19	0.06	0.05	0.13	0.07
S9	42.5	2.74	2.18	0.05	0.11	0.74	0.62	0.34	0.07

2/23/2006		AT-3 Mixer Type: Davis EMU				AT-4 Mixer Type: PHI System			
Station	Distance (ft)	North Side (mg/L)		South Side (mg/L)		North Side (mg/L)		South Side (mg/L)	
		3ft	11 ft	3ft	11 ft	3ft	11 ft	3ft	11 ft
S1	0	0.25	0.02	0.03	0.04	0.51	0.12	0.02	0.03
S2	7.5	0.01	0.01	0.01	0.02	0.29	0.03	0.1	0.68
S3	12.5	0.03	0.02	0.01	0.03	0.1	0.02	0.3	0.07
S4	19.5	0.07	Mixer	0.02	0.01	0.02	0.01	0.41	0.04
S5	22.5	0.14	0.07	0.03	Mixer	0.01	0.01	0.27	0.04
S6	27.5	0.06	0.02	0.01	0.04	0.33	0.01	0.4	0.06
S7	32.5	0.04	0.02	0.01	0.01	0.25	0.01	0.38	0.06
S8	37.5	0.03	0.02	0.01	0.01	0.06	0.01	0.37	0.08
S9	42.5	1.21	1.03	0.03	0.02	0.01	0.01	0.11	0.04

Note: Measurements carried out on 07/14/2005 are base line readings with both tanks having the Davis EMU units.

BASE LINE READINGS



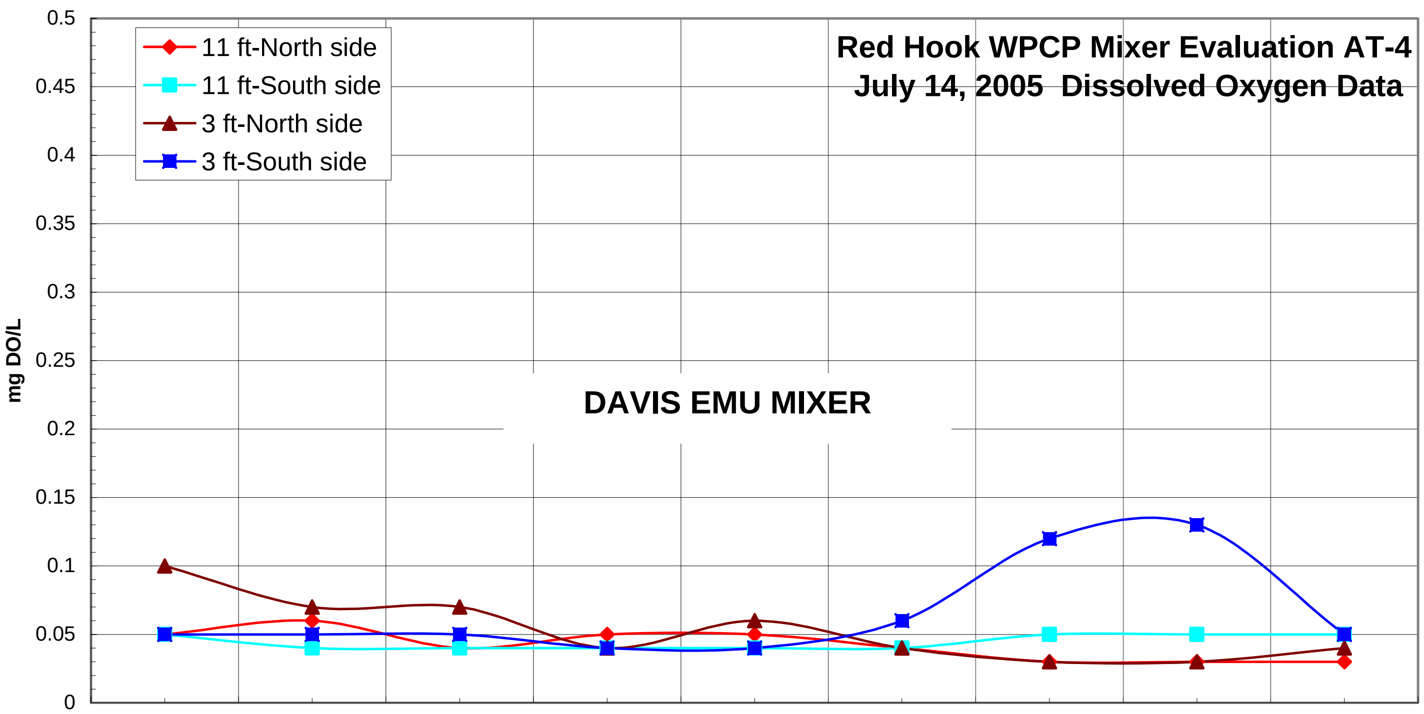
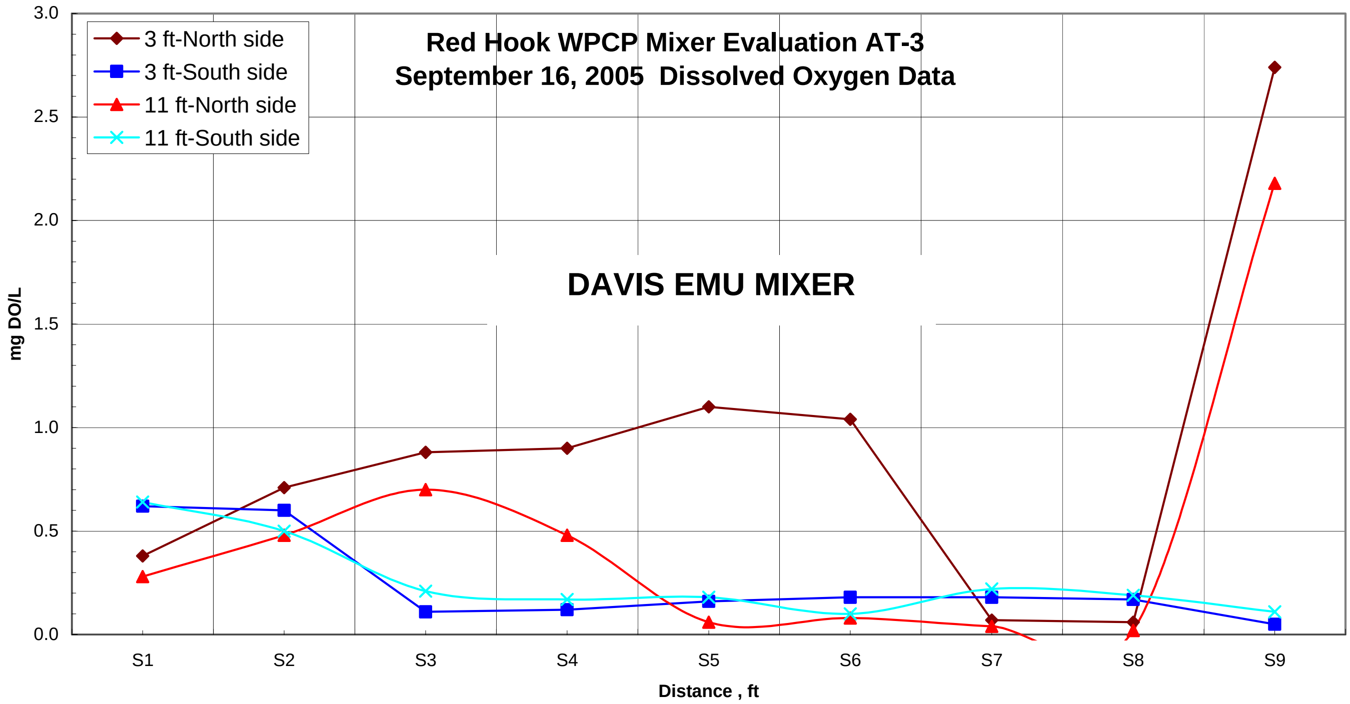


Figure 23. **DO profile in the anoxic zones of Pass B in Aeration Tanks 3 & 4 at the Red Hook WPCP, July 14, 2005 prior to installation of the Pulsair Systems, Inc. 9/18 Mixing System as represented by PHI**



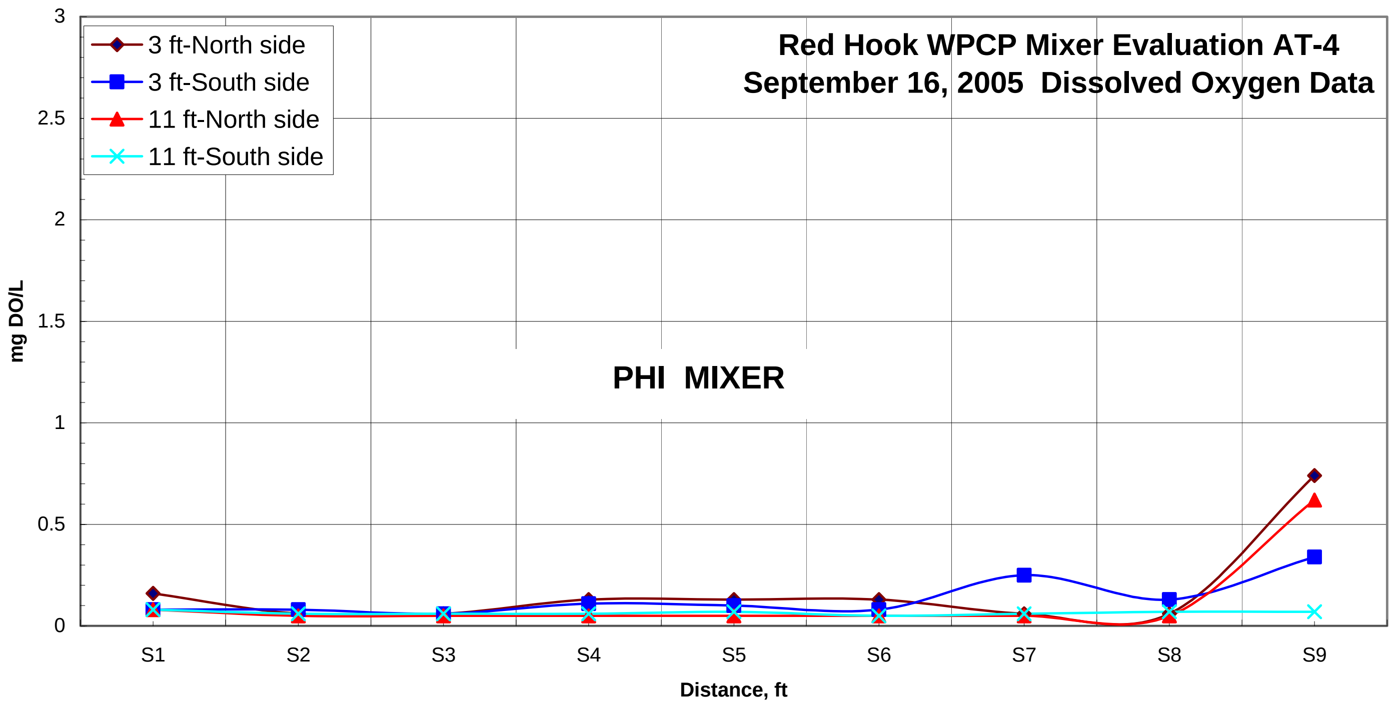


Figure 24. DO profile in the anoxic zones of Pass B in Aeration Tanks 3 & 4 at the Red Hook WPCP, September 16, 2005

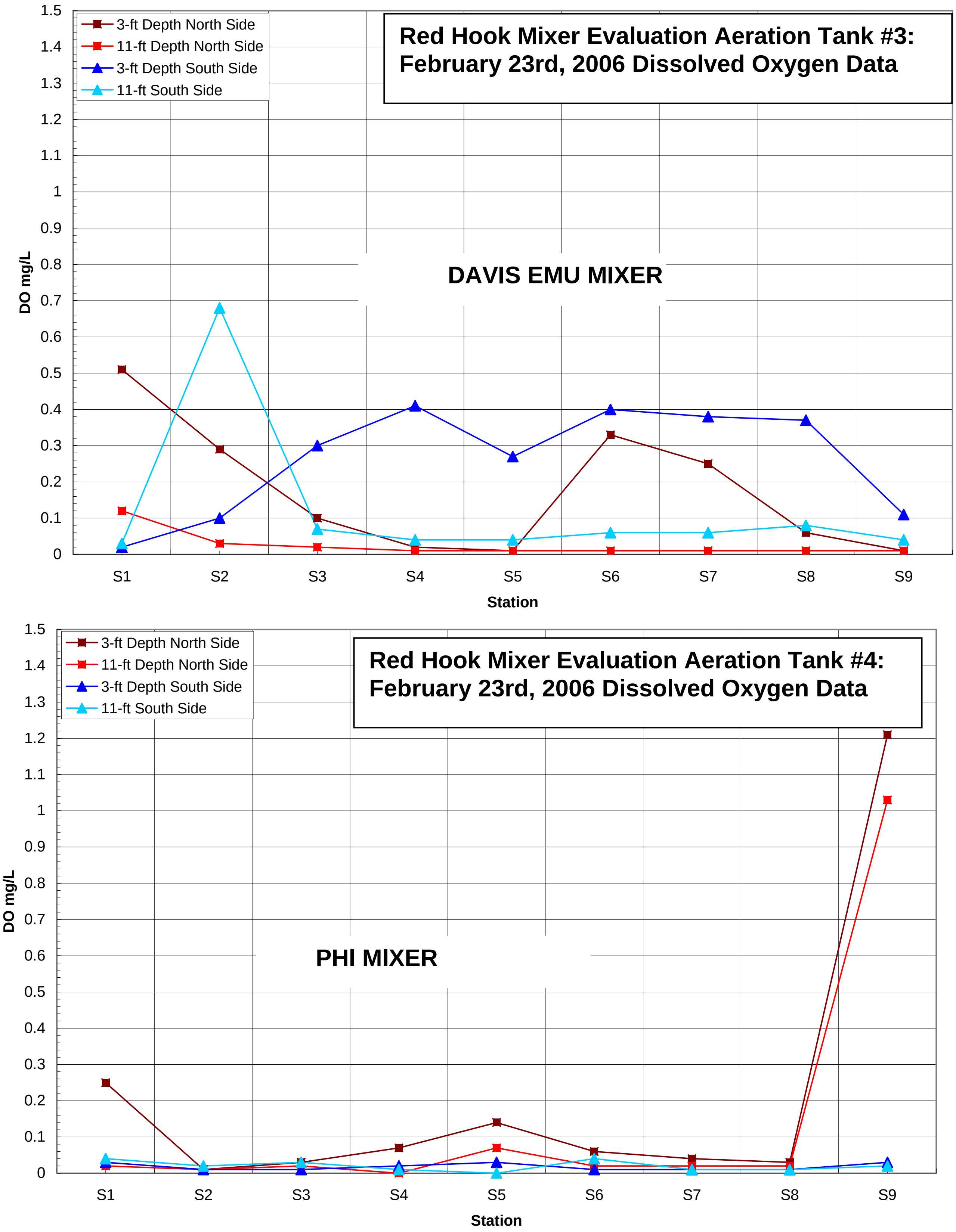


Figure 25. **DO profile in the anoxic zones of Pass B in Aeration Tanks 3 & 4 at the Red Hook WPCP, February 23, 2006**

4. COMPARISON OF THE TWO TYPES OF MIXERS: MECHANICAL AND OPERATIONAL CONSIDERATIONS

The process performance of the two anoxic zones in terms of the profiles of SS and DO suggest that both mixers perform adequately under typical operating conditions. The PHI 9/18 Mixing System was operated with a horsepower of one on 5/5/06 when substantial gradients at the lower elevation was observed. However, due to operational issues at the plant, the MLSS being carried that day was in the 3200-3500 mg/L range which is much higher than normal.

Additional factors were considered for comparison purposes. **Table 7** outlines the cost comparison between the two mixers. Unlike mechanical mixers, there are no moving parts within the tank in a PHI 9/18 Mixing System. The stainless steel piping and forming plates will have little or no deterioration over time. The compressor, air filters and valves are all located outside the tank and easily accessible for routine inspection and for service when needed. This is in contrast to the submersible mixers that need to be hoisted to the surface for inspection and service. **Table 7** shows that the initial cost of the PHI 9/18 Mixing System and its installation is less than that of the Uniprop submersible mixer and the power requirement for the PHI System was approximately two thirds less than the EMU Davis mixer as shown in **Table 7** during the test period. As a result of the lower initial cost, simplified maintenance procedures and lower energy costs, there could be significant savings in using the PHI 9/18 Mixing System.

4.1 FULL SCALE EXPERIENCE WITH THE TWO TYPES OF MIXERS

As of date, there are a few installations of the PHI 9/18 Mixing System as shown in **Table 8** with more installations to follow in the future. In addition PHI 9/18 Mixing System have been used in the oil, wine and paper industry for mixing purposes.

The Davis EMU submersible mixers have been in use at the Red Hook WPCP for the past 10 years. Plant personnel have expressed concerns with the operation in terms of frequency of failure of the mixers or their ancillary equipment and preventive maintenance. Maintenance was subcontracted to SEVERN TRENT SERVICES which for a period shown in **Table 9** repaired 22 mixers at an average cost of $ 5,162 per mixer.

Table 7. **RED HOOK WPCP: Cost Comparison of the two types of mixers: PHI 9/18 System and Davis EMU Uni – Prop Model 48.22**

	PHI 9/18 mixing system	**EMU DAVIS EMU Uniprop Mixers**
Capital Cost (per anoxic zone)	**$29,000** [1]	**$32,200** [2]
Brake Horse Power (per anoxic zone)	**6**	**12**
Energy Cost (per anoxic zone /year (based on continuous operation @ $0.039/KW-H currently applicable to the Red Hook WPCP)	**$1,537** (based on 4.5 KW shaft power)	**$3,075** (based on 4.5*2 KW shaft power)
Recommended Preventive Maintenance Cost/anoxic zone/year (Inspection and Routine Maintenance)	**$1,650**	**$1,000** (based on oil Change twice a year)
Long Term Maintenance Cost (10 years) [3]	`-	**$3,000**
Capitalized Cost per anoxic zone (Based on 10 years and at 6% interest)	**$52,459**	**$66,108**

1. As per Dick Koopmans, PHI Inc., Systems, June 13, 2006.
2. As per Wheeler Newman, EMU, February 15, 2005
3. Recommended Schedule from Vendors

Table 8: List of Installations of the PHI 9/18 Mixing System, Inc. Installations

INSTALLATION LOCATION	APPLICATION	COMMENTS
Greensboro, NC WWTP	Diluting Sodium Hypochlorite **since 2002**	• Tank -12' in diameter and 16' tall- 12,500 gallons capacity • Unit is currently in operation • Pulsair Installation
Greensboro, NC WWTP	BNR Anoxic Tank **since 2002**	• 60-75' in length × 20' wide × 20' Deep • Unit is currently in operation • Pulsair Installation
Rain Water Retention Tank , Lake Loramie, OH	Storage of Storm water runoff **Since June 2006**	• 196' Diameter tank, 12' Deep • PHI, Inc. Installation
Marysville WWTP, OH	12 MGD Plant **commencing construction**	• Installations in the anaeraobic, anoxic and oxic zones will be carried out by PHI, Inc .
Lower Scioto valley WWTP, OH	Mixing in circular anoxic zones – **construction to commence in 2007**	• Installations in 8 anoxic zones and a scum tank will be carried out by PHI, Inc
Sussex County, New York	**Construction will start in May 2007**	• Installations in 2 pre anoxic and 2 anoxic zones will be carried out by PHI, Inc.

Table 9. Experience with Davis EMU Mixers at the Red Hook WPCP

- Repair Cost/mixer : $5,162
  (Based on partial historical data from December 2004 & June, August & December 2005: 22 Mixers had to be repaired during this period)

5. CONCLUSIONS

- Both the mixers achieved uniform distribution of SS throughout the bulk volume of the anoxic zones. However, when the PHI 9/18 system was turned down to 1 HP on May 5, 2006 and the MLSS were at 3100 mg/L, the profiles of May 5, 2006 showed SS stratification at the lower depths of the tank and some solids accumulation at the bottom of the tank.

- Both mixers were able to maintain the low DO concentrations necessary for promoting denitrification.

- Initial capital cost is higher for the Davis EMU mixers than the PHI 9/18 Mixing System. Additionally, due to lower preventive maintenance and energy costs, the PHI 9/18 Mixing System has a lower capitalized cost.

- Experience at the Red Hook WPCP and other facilities in the City of New York suggest that the Davis EMU Uni-Prop mixers are prone to frequent breakdowns.