

5.0 RECOMMENDATIONS

Recommendations going forward

Overall, the 2007 ReOx demonstration project confirmed that the Speece Cone technology can effectively add DO to the harbor and reduce instream DO deficits during critical summer conditions. The demonstration also confirmed the soundness of the prototype design. We recommend the following actions:

- Develop a modular land-based ReOx station design specific to Savannah Harbor conditions, taking into account the “lessons learned” from the 2007 demonstration project.
- Identify, characterize, and acquire suitable shore locations for construction of two land-based dual cone ReOx stations.
- Construct the foundations and permanent shore-based infrastructure and service access for each ReOx station in advance and make the stations ready for operation of the ReOx equipment in concert with harbor deepening.
- Monitor the effects to water quality in an adaptive management approach so that system modifications may be made to increase transfer efficiency until the systems are optimized.
- Develop operation and maintenance plans and activities for a permanent installation. Consider backup systems as a part of the system design and installation.
- At the suggestion of the agencies, employ the use of conservative overall oxygen transfer efficiency (OOTE) of 70 to 80 percent for design purposes. Once permanent installations are implemented, then actual OOTE may be determined and apply an adaptive management approach to overall system operation.
- In the sampling and analysis program for permanent systems. in-stream monitoring should include alternative methods for oxygen transfer efficiency monitoring, near-field mixing zone monitoring, and frequent and detailed transect monitoring. Development of the monitoring program should include considerations such as continuous monitoring, regular instream cross sectional measurements taken manually, and dye studies.

6.0 REFERENCES

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Velz, C.J., 1970. Replacement Seawater Flow, Quantitative Determination in Applied Stream Sanitation. Wiley-Interscience, pp. 364 – 366.

- (1) Improving Water Quality Through Lake Oxygenation at Camanche Reservoir
- (2) Oxygenation Performance of Laboratory-Scale Speece Cone Hypolimnetic Aerator: Preliminary Assessment
- (3) A Decade on the Bottom: Performance of a Speece Cone in Neman Lake

TABLES

Table 2.1.
Cone Discharge
Theoretical DO Concs vs. Measured DO Concs

Time	CONE 1						CONE 2					
	Water Flow C1 (gpm)	Pres C1 (PSI)	Temp C1 (F)	C1 DO Conc Calculated (mg/L)	C1 DO Conc Measured (mg/L)	C1 Percent Error	Water Flow C2 (gpm)	Pres C2 (PSI)	Temp C2 (F)	C2 DO Conc Calculated (mg/L)	C2 DO Conc Measured (mg/L)	C2 Percent Error
8/27/07 13:00	8143	72.8	87.3	137.2	121.9	11.1	7702	73.8	87.5	138.8	122.3	11.9
8/28/07 12:00	7519	73	86.7	138.2	122.6	11.3	7203	73.4	87.4	139.1	121.2	12.9
8/29/07 8:30	7619	73	85.8	139.8	134.0	4.1	6924	74.1	87.3	139.9	130.3	6.8
8/30/07 10:00	7861	75	86.1	142.2	123.4	13.2	6983	76.7	87.1	136.8	149.7	9.5
8/30/07 11:00	8459	74.8	86.3	135.6	186.3	37.4	7022	75.8	86.9	136.4	173.8	27.4
8/30/07 15:00	8618	76.6	87.1	130.9	163.0	24.5	7482	75.2	87.4	141.0	133.0	5.7
8/30/07 16:30	8444	76.2	87	133.9	115.3	13.9	7235	75.8	87.5	140.1	96.2	31.3
9/4/07 13:30	7805	73.4	83.3	143.7	113.5	21.0	7448	71.9	83.2	139.9	126.2	9.8
9/4/07 16:30	8113	74.1	83.1	139.2	93.9	32.6	7093	71.2	84	139.3	105.3	24.4
9/9/07 11:30	7947	71	82.4	140.4	141.0	0.4	7244	70.9	83	138.9	121.0	12.9
9/9/07 12:00	8273	70.8	82.6	136.7	150.0	9.7	7414	70.4	83	138.1	117.0	15.3
9/11/07 18:30	7921	70.7	83.5	137.7	158.0	14.8	6812	69.4	84.3	135.0	131.0	3.0
9/12/07 11:30	8429	70.3	82.2	131.7	177.0	34.4	7167	67.9	83.4	133.8	153.0	14.3
9/15/07 9:30	7908	70.1	82.5	138.9	166.0	19.5	6817	64	84	128.2	181.0	41.2
	C1 Average			137.58	140.42		C2 Average			137.52	132.93	
	C1 Average Percent Error					17.7	C2 Average Percent Error					16.2

Notes:

C1 - Cone 1

C2 - Cone 2

gpm - gallons per minute

PSI - pounds per square inch

mg/L - milligrams per liter

F - degrees Fahrenheit

Pres - Pressure

Temp - Temperature

Conc - Concentration

DO - Dissolved oxygen

Prepared by: TRK 01/28/2009

Checked by: MET 02/03/2009

Table 2.2
Average Deep and Intake Barge Sonde Theoretical Increase in DO Concentration Calculation

Date	Flow	10% Flow	Q _s	Q _T	Q _T	C _{DO}	Total Oxygen to River	Salinity Barge Deep	Cone 1 Intake Salinity	Average water columns Salinity
	(cfs)	(cfs)	(cfs)	(cfs)	(MGD)	(mg/L)	(lbs)	(ppt)	(ppt)	(ppt)
8/5/2007	5540	6094	2286	8380	5416	0.04	1969	11.29	6.99	9.14
8/6/2007	5590	6149	2534	8683	5612	0.18	8324	12.36	7.19	9.78
8/7/2007	5470	6017	2736	8753	5657	0.65	30878	12.98	7.96	10.47
8/8/2007	5280	5808	3013	8821	5701	0.59	28213	14.46	8.42	11.44
8/9/2007	5220	5742	3295	9037	5841	0.58	28128	15.18	9.255	12.22
8/10/2007	5290	5819	3166	8985	5807	0.57	27837	14.29	9.32	11.80
8/11/2007	5280	5808	2937	8745	5652	0.59	27879	12.99	9.51	11.25
8/12/2007	5230	5753	ND	5753	3718	ND	27839	ND	10.58	ND
8/13/2007	5140	5654	ND	5654	3654	ND	27509	ND	10.05	ND
8/14/2007	5060	5566	3105	8671	5604	0.56	26277	14.12	9.87	12.00
8/15/2007	5120	5632	2848	8480	5481	0.57	26211	13.28	9.22	11.25
8/16/2007	5200	5720	2511	8231	5320	0.31	13570	13.79	6.65	10.22
8/17/2007	5100	5610	2454	8064	5212	0.76	32902	13.43	6.96	10.19
8/18/2007	4980	5478	2780	8258	5337	0.63	28038	14.05	8.51	11.28
8/19/2007	4990	5489	3881	9370	6056	0.53	26632	17.24	10.51	13.88
8/20/2007	4960	5456	4885	10341	6683	0.47	26142	19.64	12.01	15.82
8/21/2007	4900	5390	5061	10451	6755	0.50	27921	19.98	12.47	16.22
8/22/2007	4870	5357	5373	10730	6935	0.49	28199	20.31	13.24	16.77
8/23/2007	4860	5346	6020	11366	7346	0.48	29116	21.83	13.66	17.74
8/24/2007	4880	5368	6845	12213	7894	0.44	29247	22.80	14.755	18.78
8/25/2007	4870	5357	6611	11968	7735	0.46	29385	22.30	14.71	18.50
8/26/2007	4910	5401	5000	10401	6722	0.51	28802	19.13	13.08	16.10
8/27/2007	5090	5599	4373	9972	6445	0.55	29826	17.19	12.19	14.69
8/28/2007	5230	5753	3911	9664	6246	0.50	26245	15.81	11.3	13.56
8/29/2007	5290	5819	3893	9712	6277	0.50	26350	14.78	12.075	13.43
8/30/2007	5280	5808	3751	9559	6178	0.51	26207	14.14	12.155	13.15
8/31/2007	5330	5863	2915	8778	5674	0.51	24184	13.44	8.81	11.13
9/1/2007	5380	5918	3057	8975	5801	0.56	27121	13.65	9.17	11.41
9/2/2007	5450	5995	2707	8702	5624	0.56	26399	13.46	7.38	10.42
9/3/2007	5540	6094	ND	6094	3939	ND	ND	11.76	ND	ND
9/4/2007	5540	6094	2425	8519	5506	0.58	26836	11.33	7.74	9.54
9/5/2007	5580	6138	3211	9349	6042	0.53	26842	14.35	8.66	11.51
9/6/2007	5190	5709	2976	8685	5613	0.54	25097	14.00	8.955	11.48
9/7/2007	5250	5775	3148	8923	5767	0.55	26530	14.19	9.45	11.82
9/8/2007	5130	5643	3193	8836	5711	0.58	27511	13.98	10.225	12.10
9/9/2007	4890	5379	3095	8474	5477	0.58	26405	14.06	10.41	12.23
9/10/2007	4770	5247	2777	8024	5186	0.61	26287	13.02	10.17	11.59
9/11/2007	4730	5203	2574	7777	5027	0.62	25987	12.55	9.63	11.09
9/12/2007	4750	5225	2618	7843	5069	0.59	24916	12.81	9.56	11.18
9/13/2007	4800	5280	2958	8238	5325	0.58	25712	13.62	10.44	12.03
9/14/2007	4800	5280	3082	8362	5404	0.56	25292	14.86	9.83	12.35
9/15/2007	4850	5335	2729	8064	5212	0.55	23829	14.10	8.57	11.34

ND - No Data
 % - percent
 cfs - cubic feet per second
 MGD - million gallons per day
 mg/L - milligrams per liter
 lbs - pounds
 ppt - parts per thousand
 Q_s - effective seawater flow rate in test segment
 Q_T - total flow rate of seawater
 C_{DO} - instream oxygen concentration

Prepared by: TRK 5/21/2009
 Checked by: MET 8/12/2009

Table 3.1
Effect Size Analysis for Continuous Monitoring Points

Column	1	2	3	4	5
Continuous Monitoring Locations	Magnitude of the Expected Effect (Delta DO)(mg/L) ¹	Standard Deviation of the DO (from Measured Data) (mg/L) ²	Model Standard Ratio Deviation ¹	Calculated Effect Size Ratio Column 1/Column 2 (dimensionless ratio)	Calculated Effect Size Ratio Column 1/Column 3 (dimensionless ratio)
Barge Shallow	0.17	0.84	0.39	0.20	0.44
Barge Mid	0.31	0.58	0.37	0.54	0.84
Barge Deep	0.52	0.51	0.42	1.03	1.24
USACE Shallow	0.17	0.55	0.37	0.31	0.46
USACE Mid	0.23	0.50	0.30	0.46	0.77
USACE Deep	0.27	0.42	0.25	0.64	1.08
USGS Savannah	0.27	0.44	0.25	0.61	1.08
GP A Shallow	0.15	0.49	0.48	0.31	0.31
GP A Mid	0.19	0.37	0.36	0.51	0.53
GP A Deep	0.27	0.33	0.31	0.82	0.87

Notes:

1 Source model Delta DO and Standard Deviation from TetraTech 2009 June (50th Percentile)

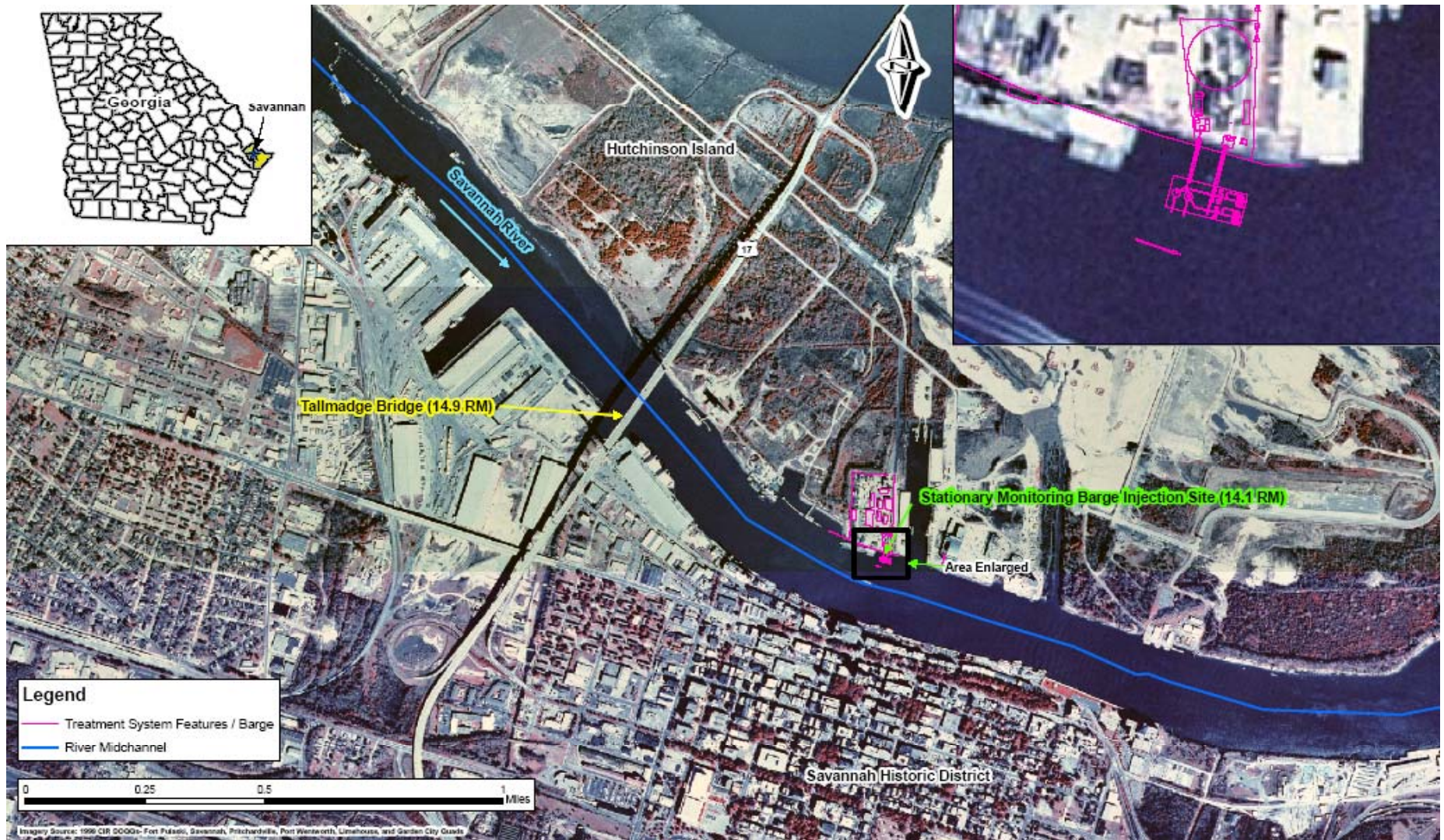
2 MACTEC measured sonde data 2007

Data from ReOx demonstration system operation between 8/8/2007 to 9/15/2007

Prepared By: TRK 07/10/09

Checked By: MET 07/13/09

FIGURES



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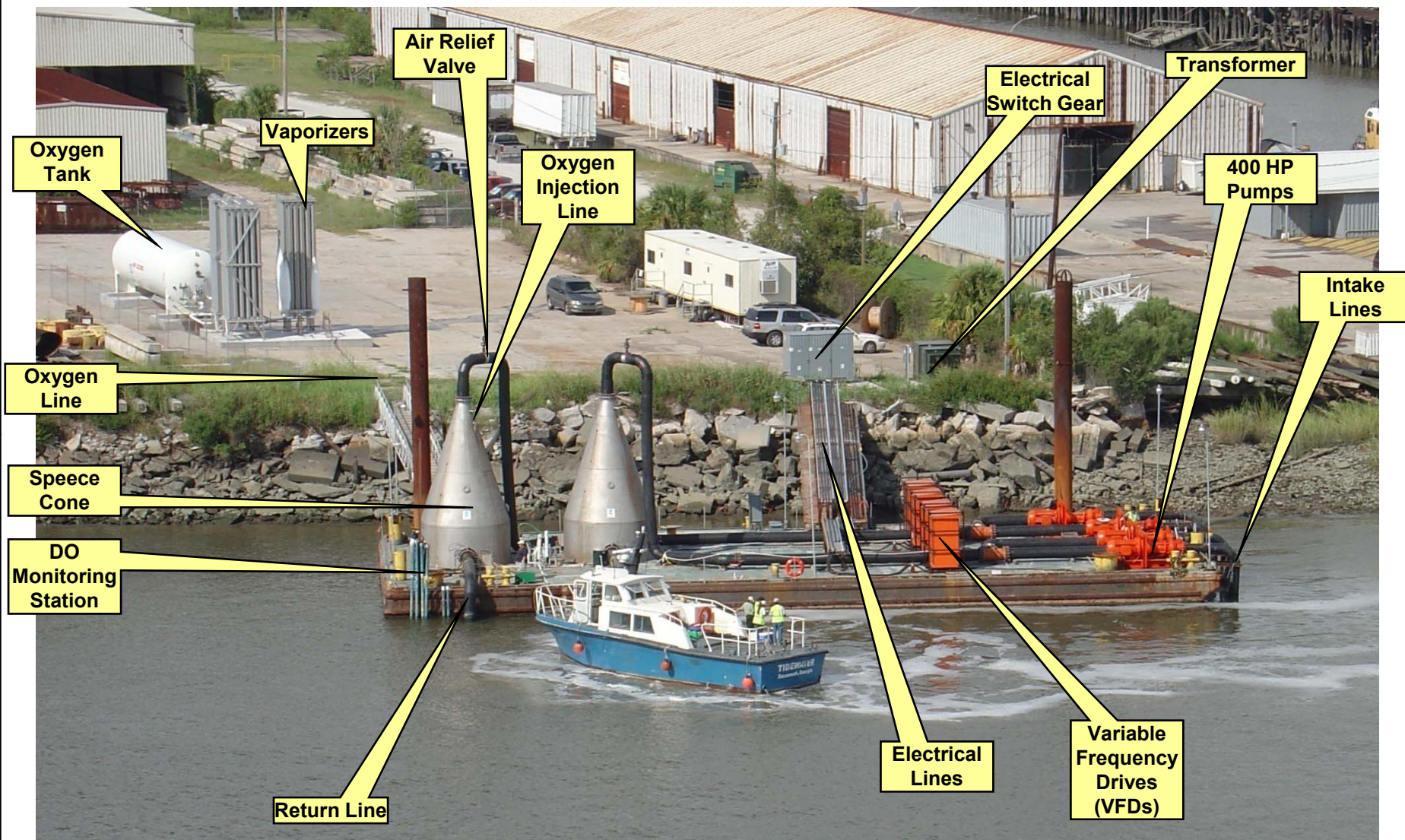
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ReOx Demonstration System Location

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Figure 1.1



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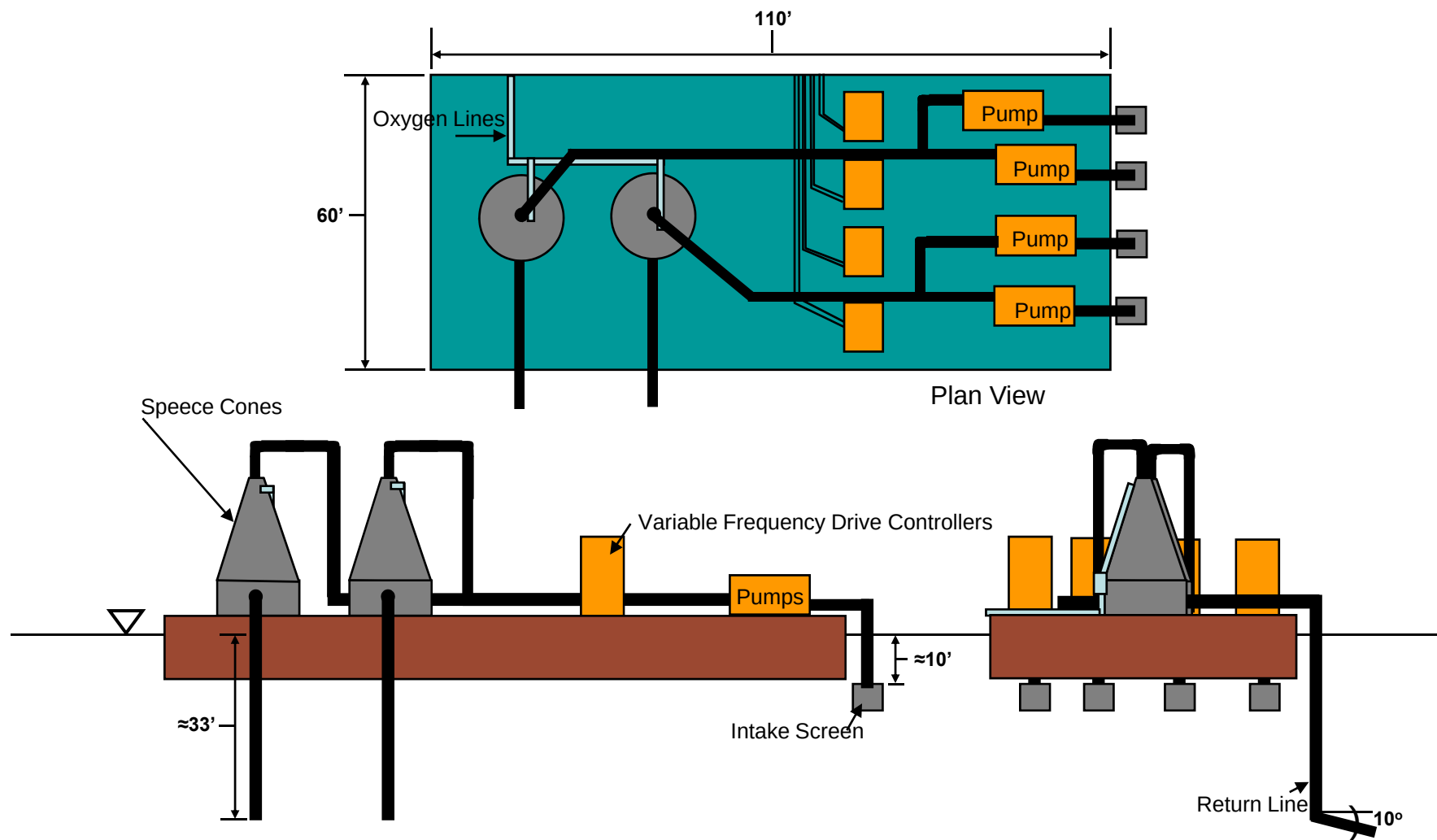
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ReOx Demonstration System Components

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Figure 1.2



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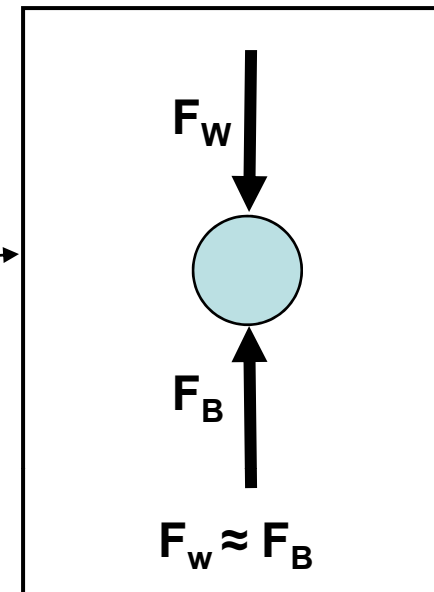
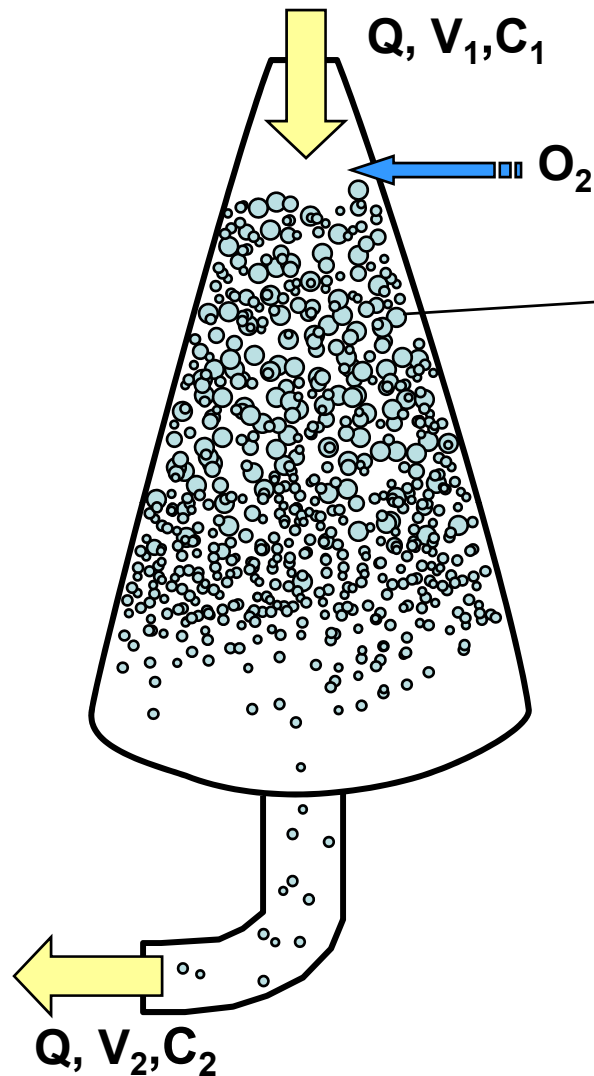
ReOx Demonstration System Components Schematic

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Figure 1.3

$$C_1 \ll C_2$$

$$V_1 = V_2$$



Where:

Q = volumetric flowrate through the cone

V = water velocity

C = dissolved oxygen concentration

O_2 = molecular oxygen

F_w = downward force of water

F_B = buoyant force of a bubble

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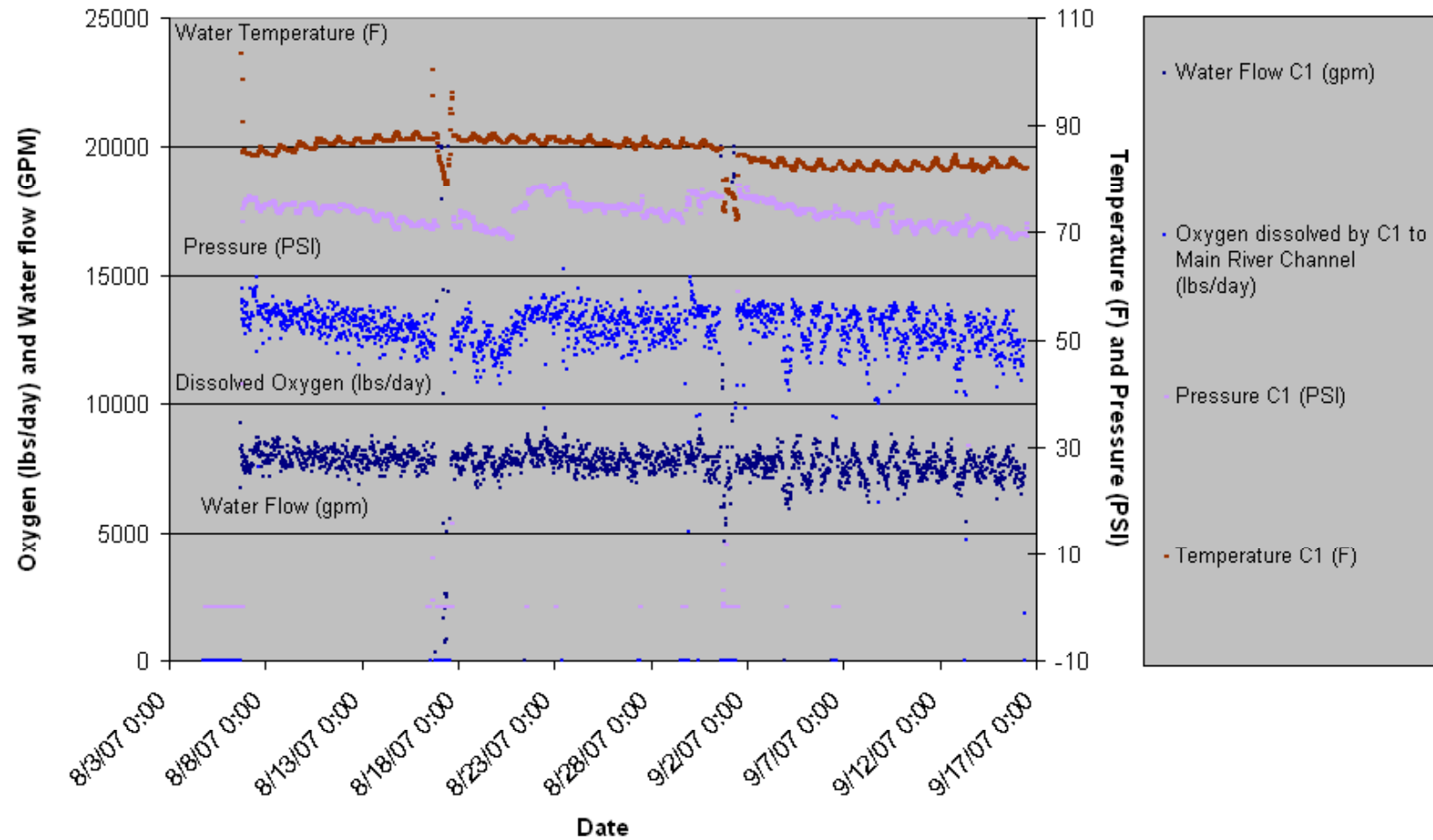
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Theoretical Operation of a Speece Cone

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Figure 2.1

Cone 1 Operation



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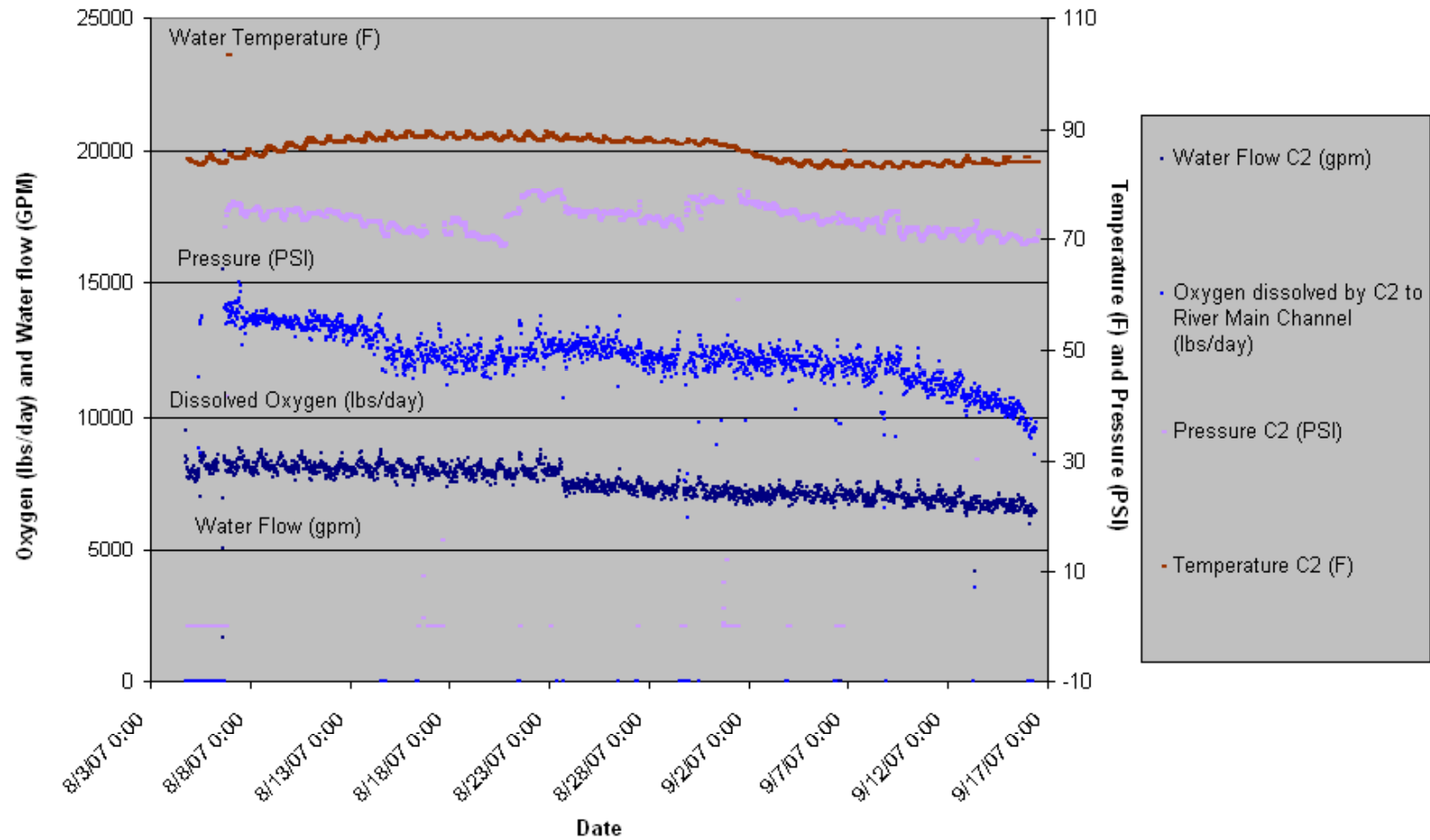


Cone 1 Operation

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Figure: 2.2

Cone 2 Operation



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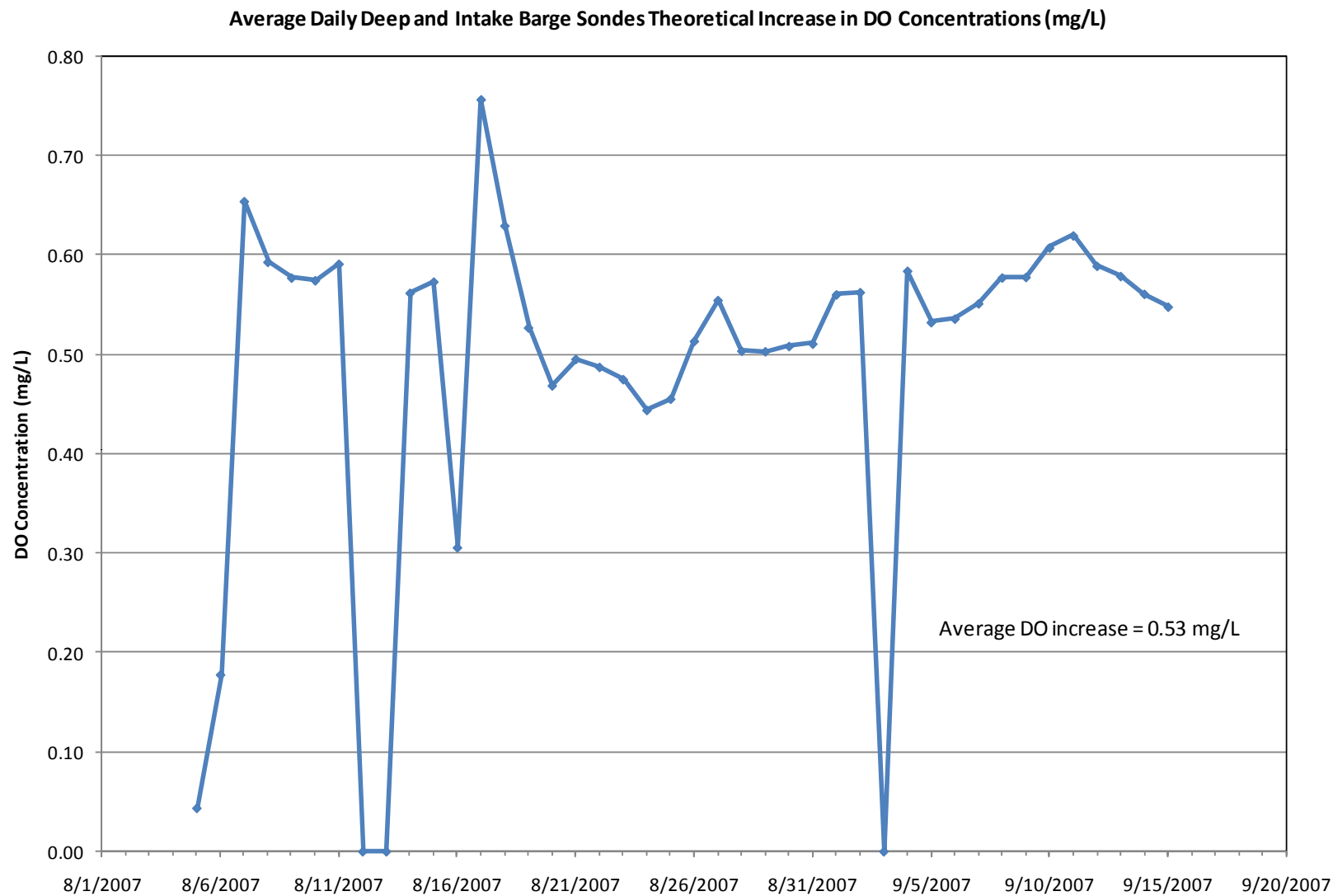
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Cone 2 Operation

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Figure: 2.3



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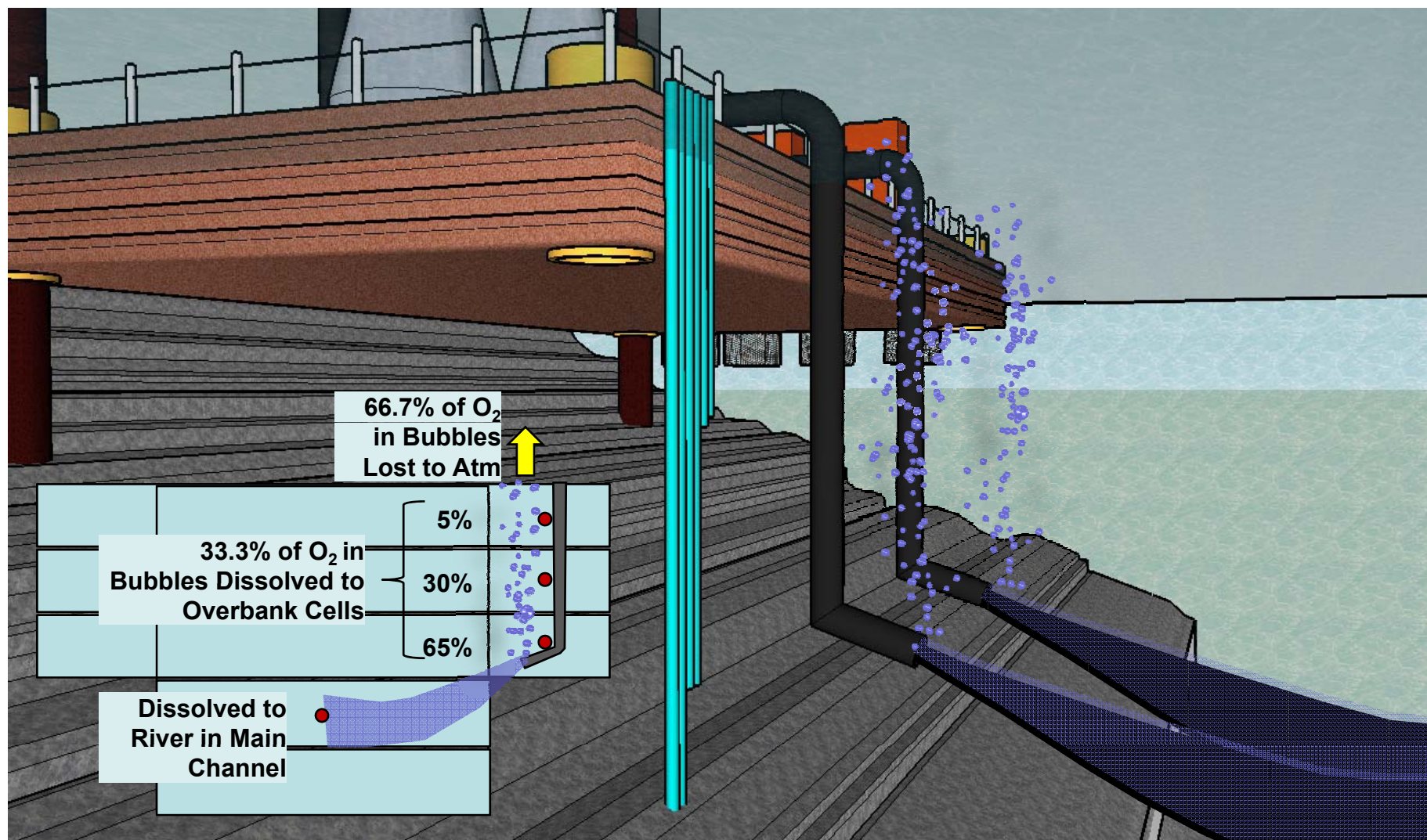
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Average Daily Deep and Intake Barge Sondes
Theoretical Increase in DO Concentrations

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Figure 2.4



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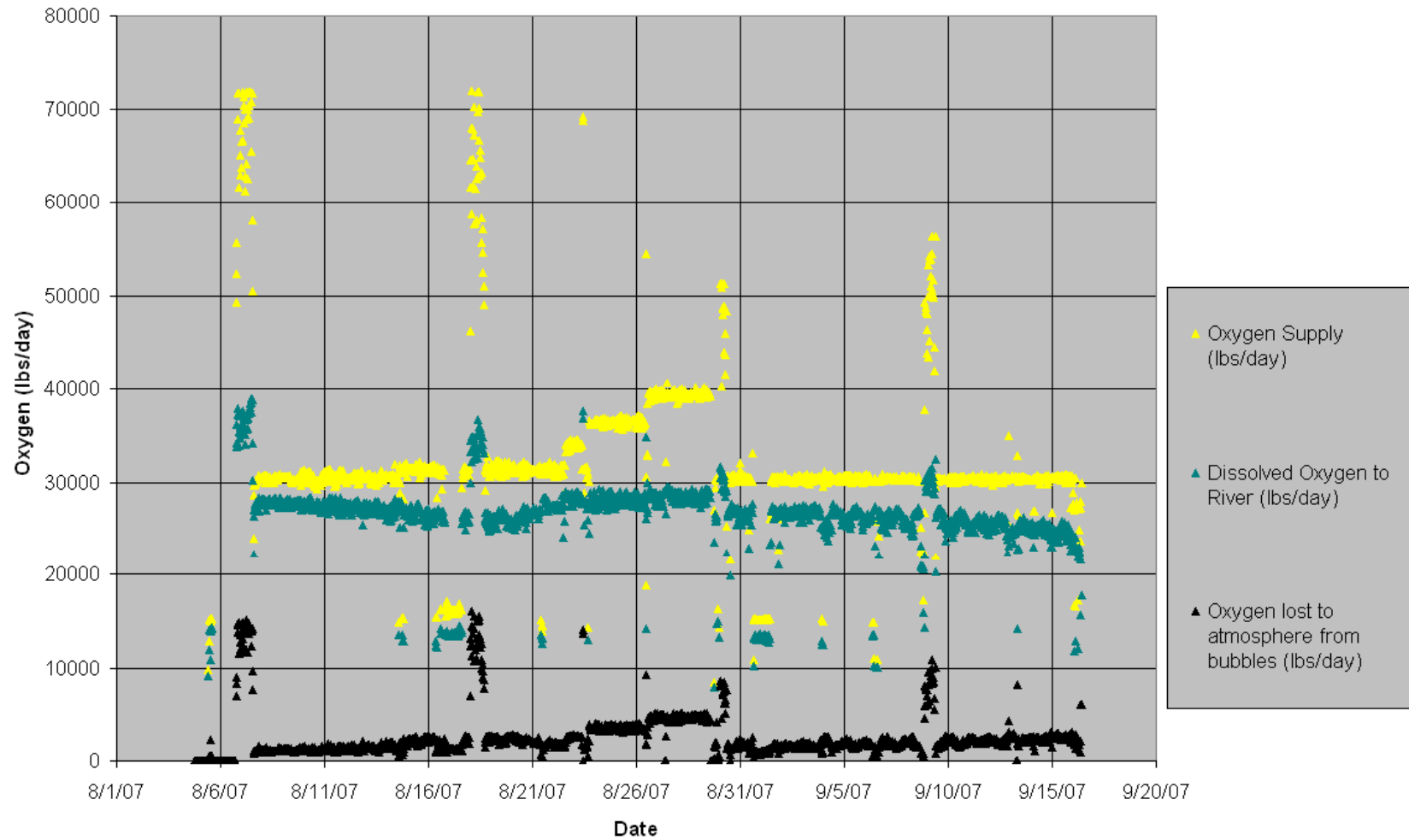
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Oxygen Delivery to the River

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Figure: 2.5

Total Oxygen Balance



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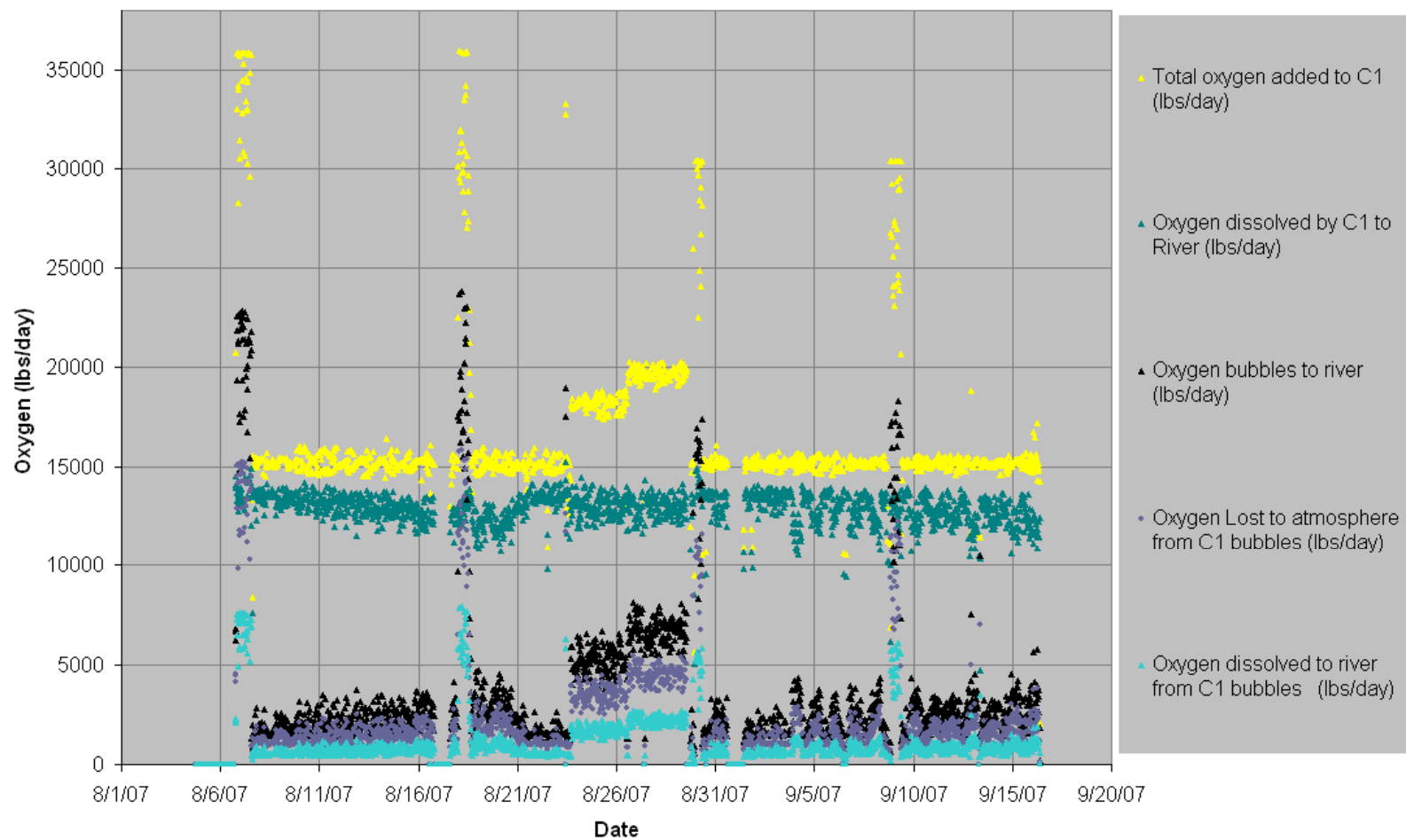


System Oxygen Balance

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Figure 2.6

Oxygen Balance C1



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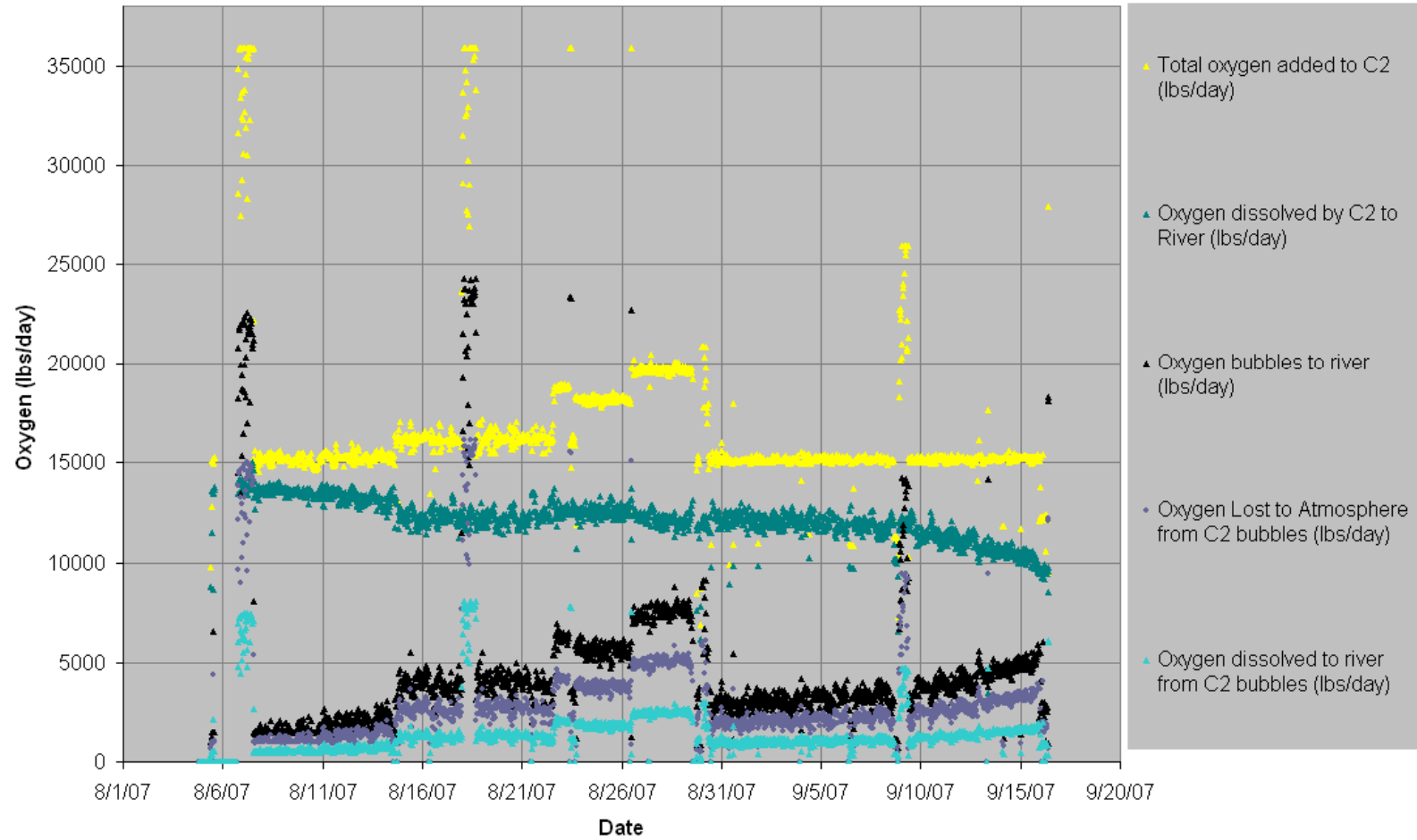


Cone 1 Oxygen Delivery Balance

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Figure: 2.7

Oxygen Balance C2



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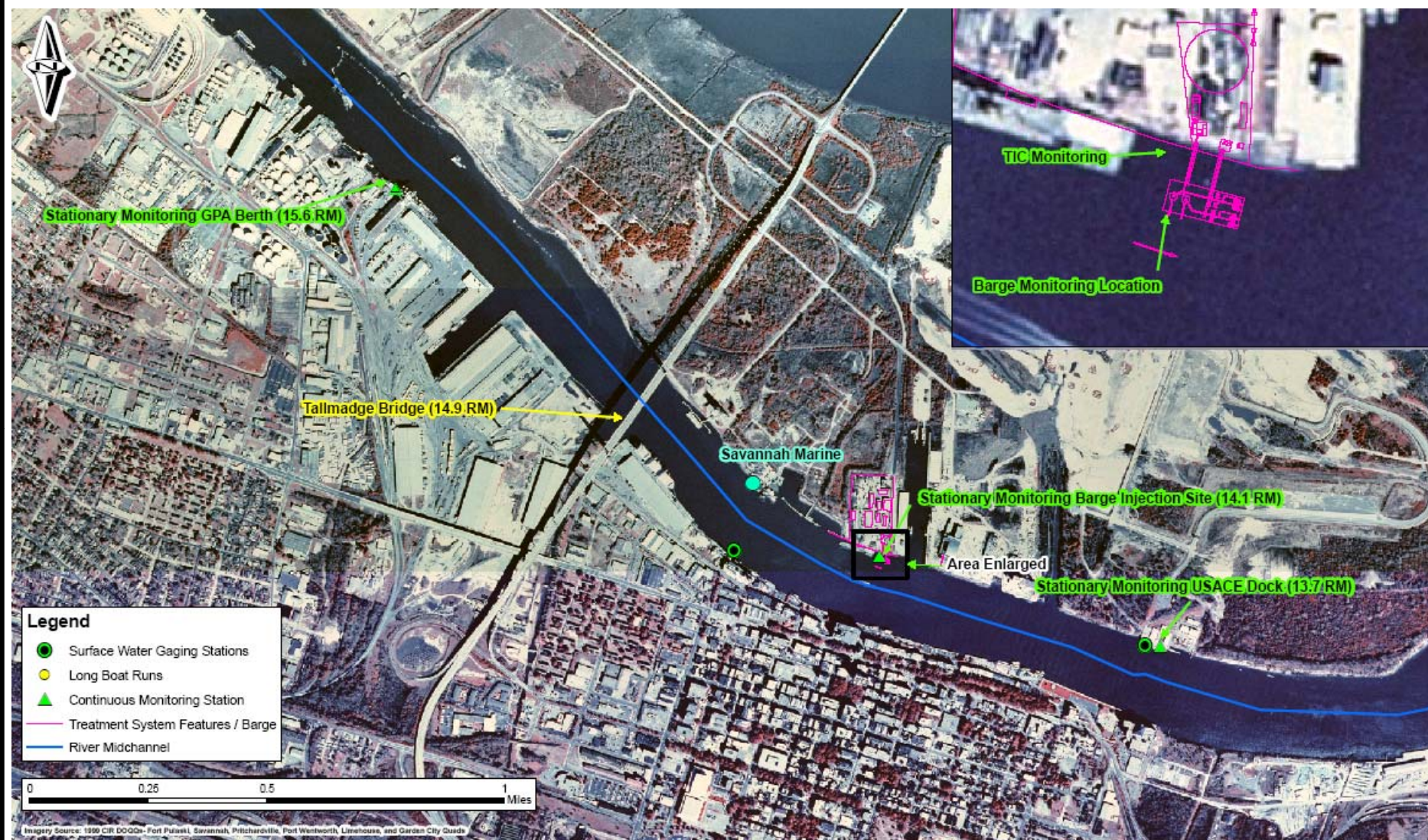
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Cone 2 Oxygen Delivery Balance

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Figure: 2.8



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Stationary Monitoring

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Figure: 3.1



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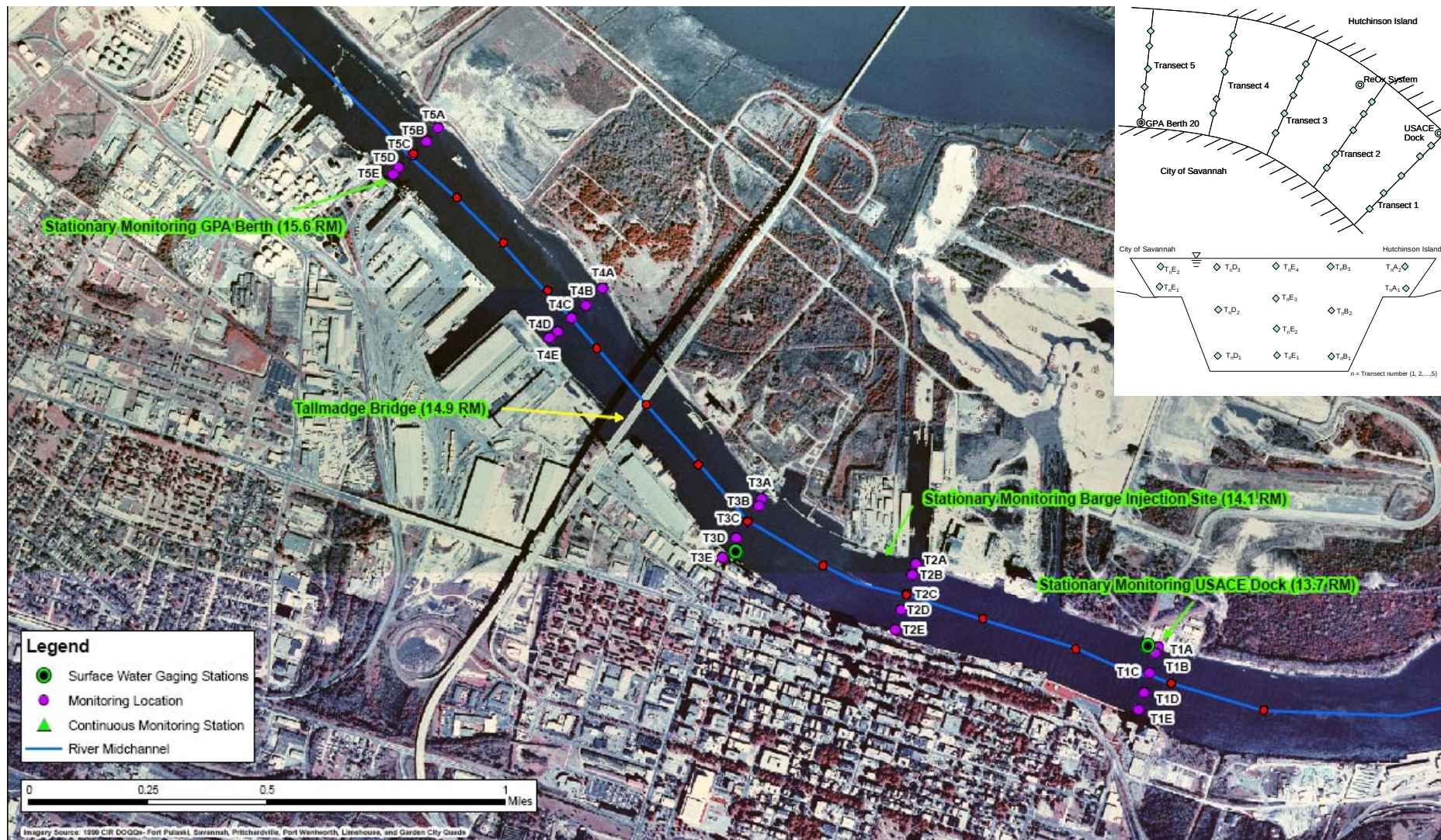
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Mid-Channel Profile Stations

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Figure: 3.2



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Cross Channel Transect Locations

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Figure: 3.3



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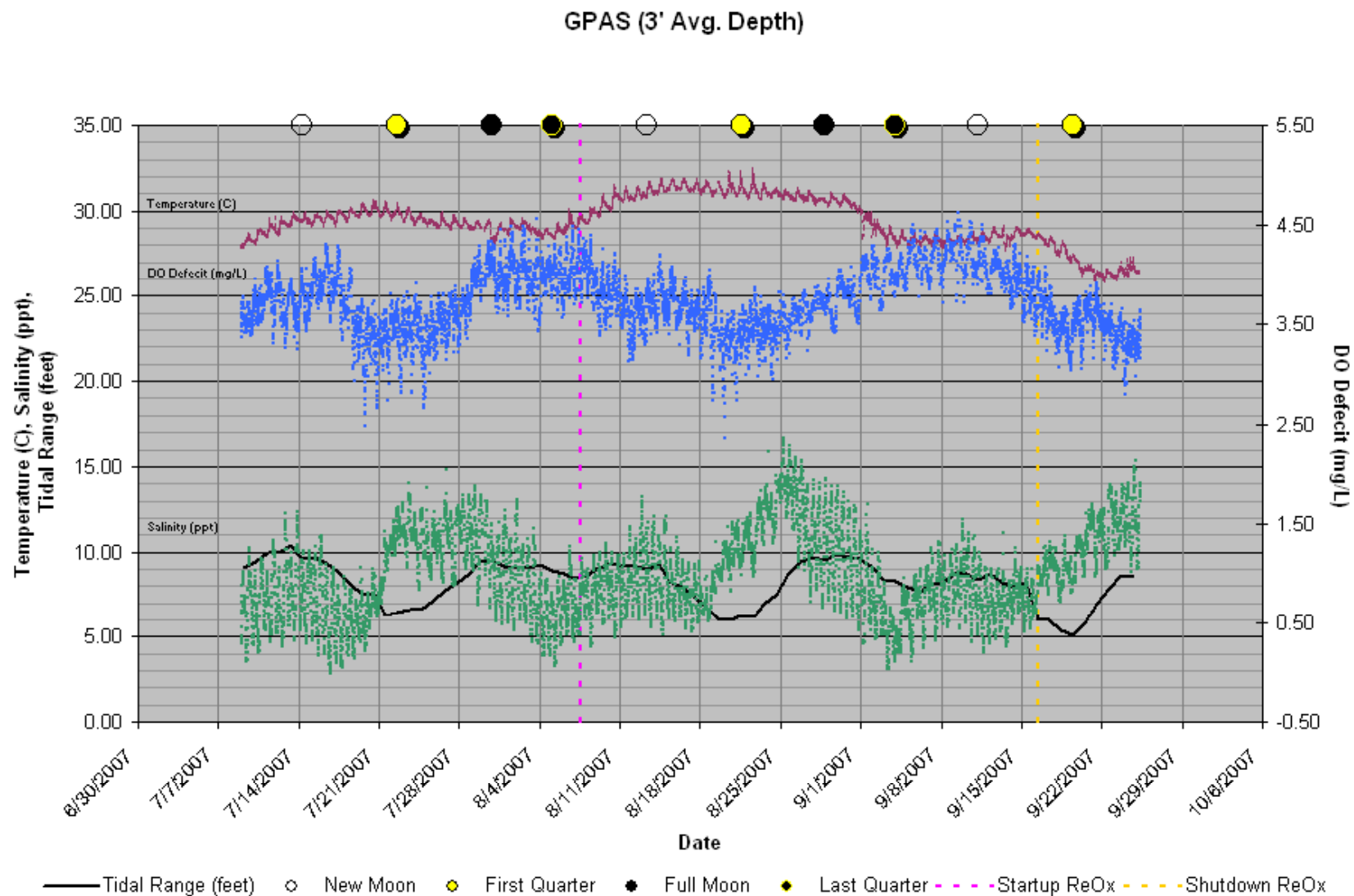
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Long Run Mid-Channel Sampling Locations

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Figure: 3.4



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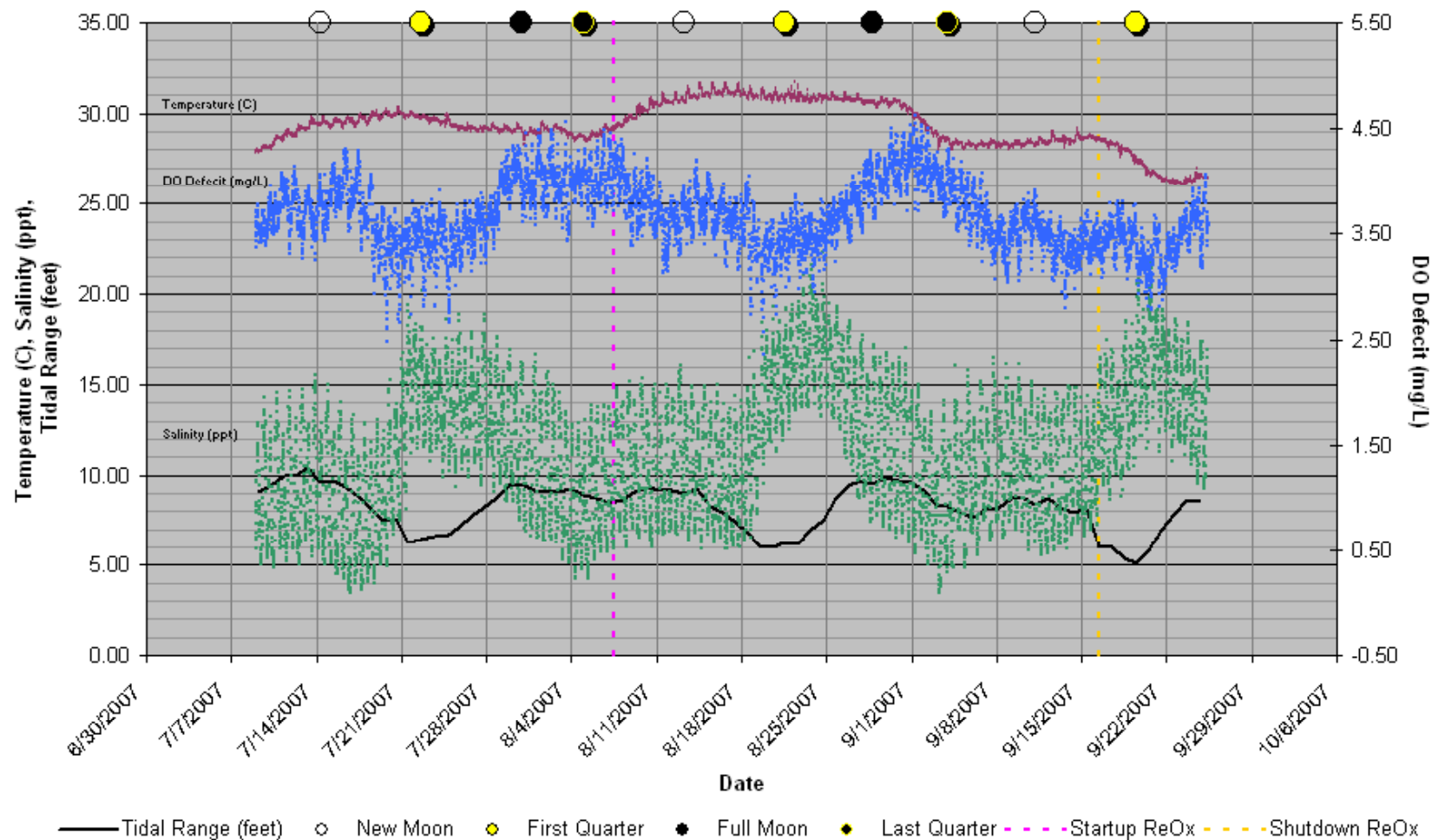


GPAS: Tide, Salinity, Deficit Patterns

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Figure: 3.5

GPAM (21' Avg. Depth)



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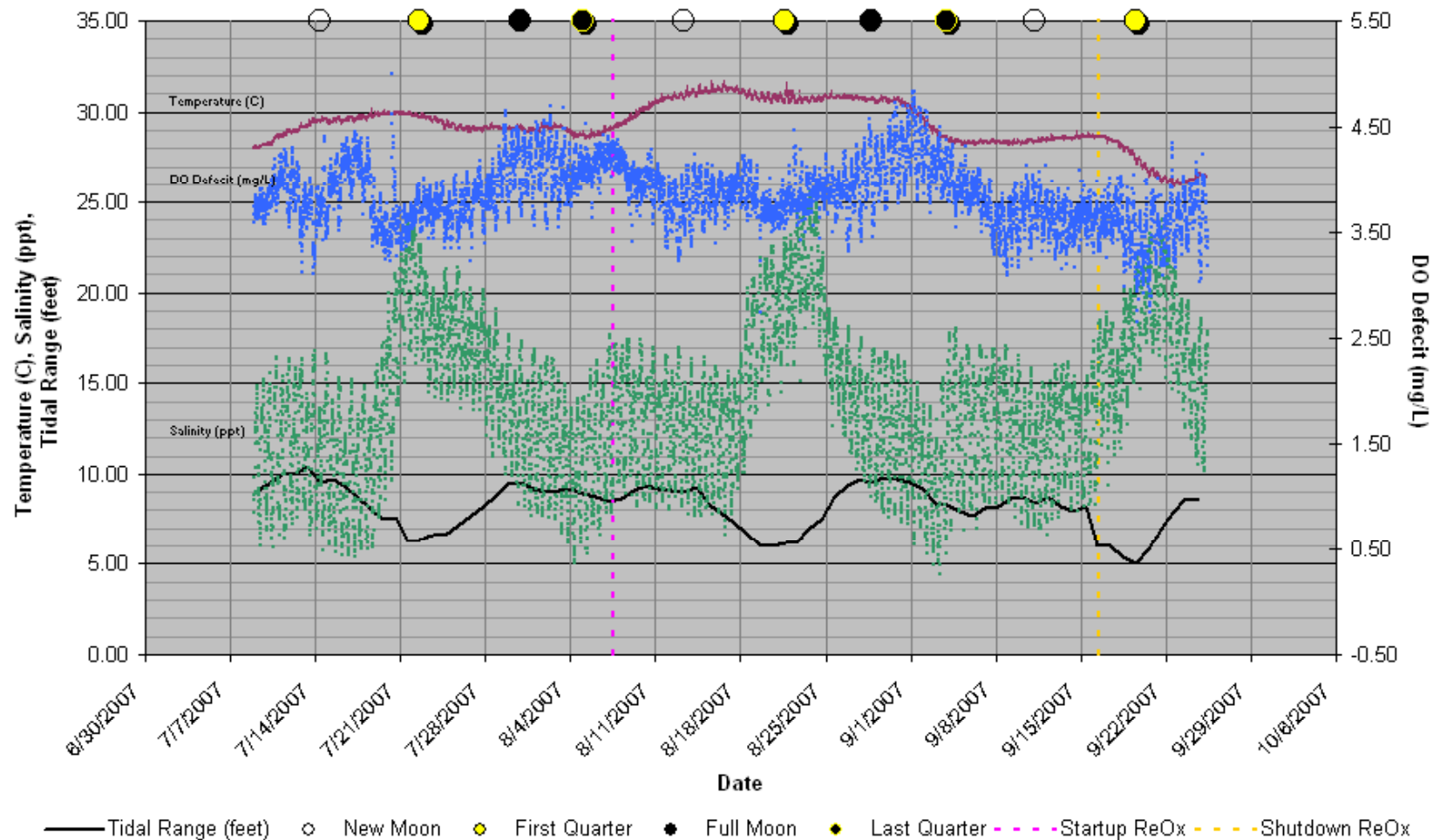


GPAM: Tide, Salinity, Deficit Patterns

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Figure: 3.6

GPAD (35' Avg. Depth)



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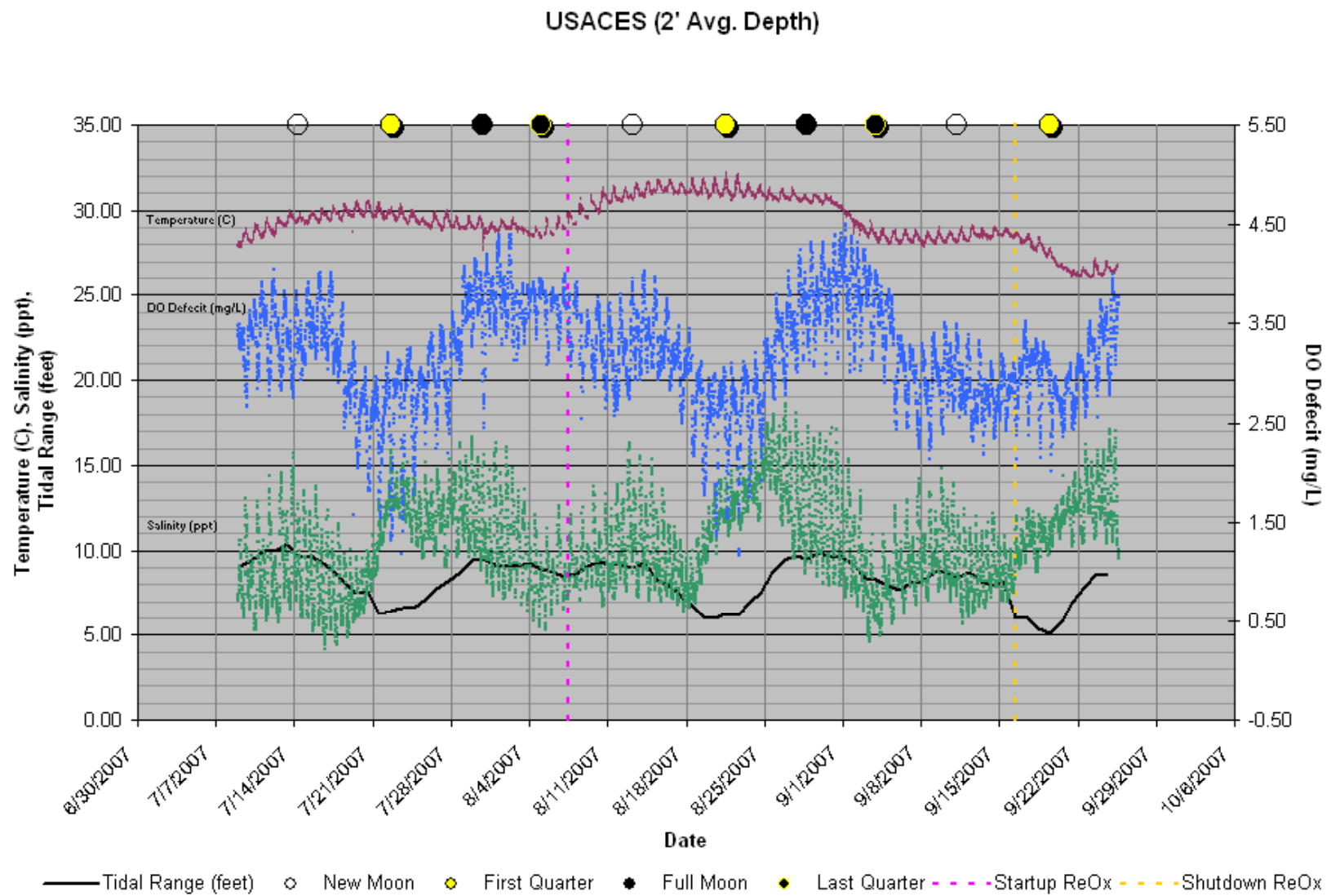
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GPAD: Tide, Salinity, Deficit Patterns

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Figure: 3.7



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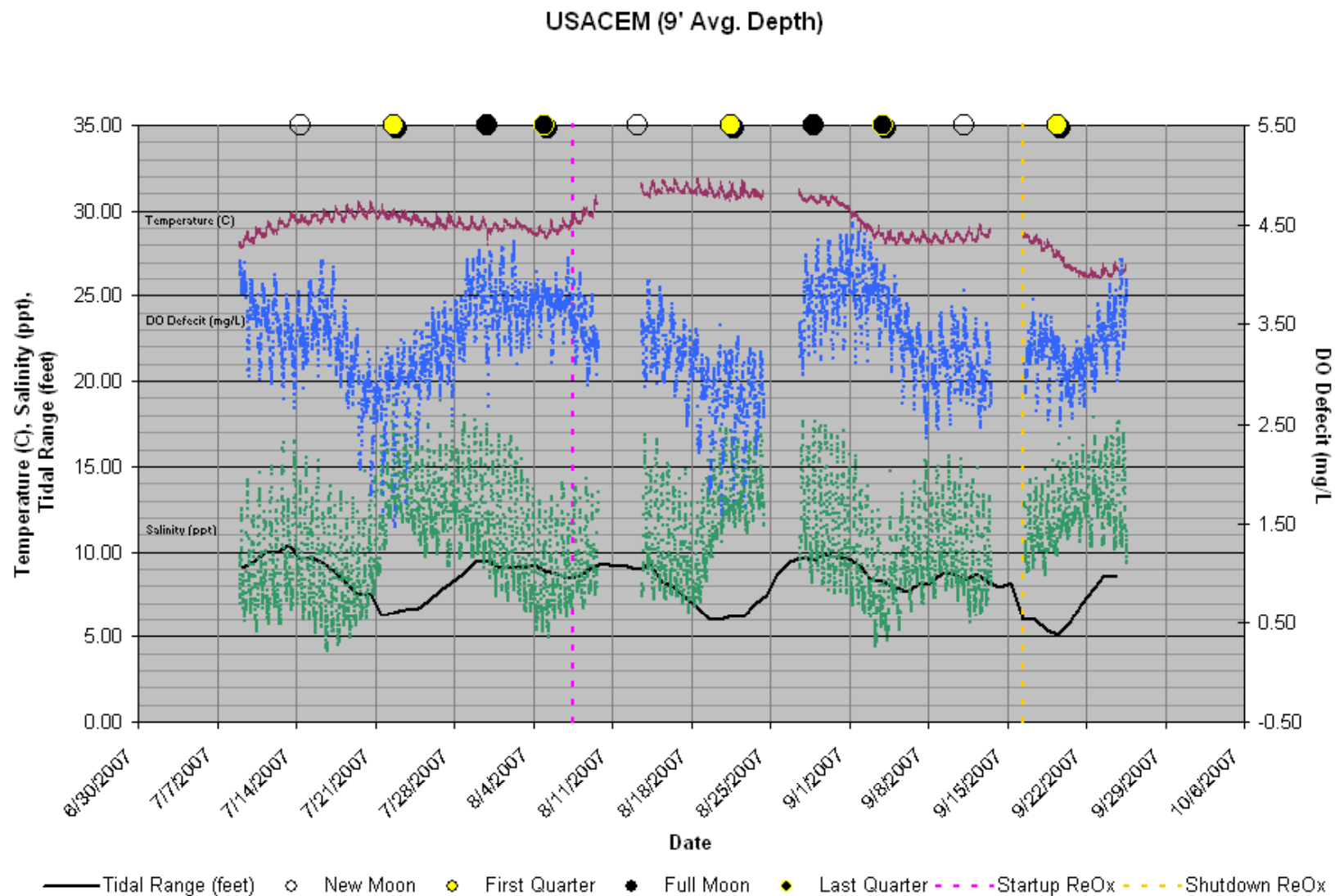
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USACES: Tide, Salinity, Deficit Patterns

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Figure: 3.8



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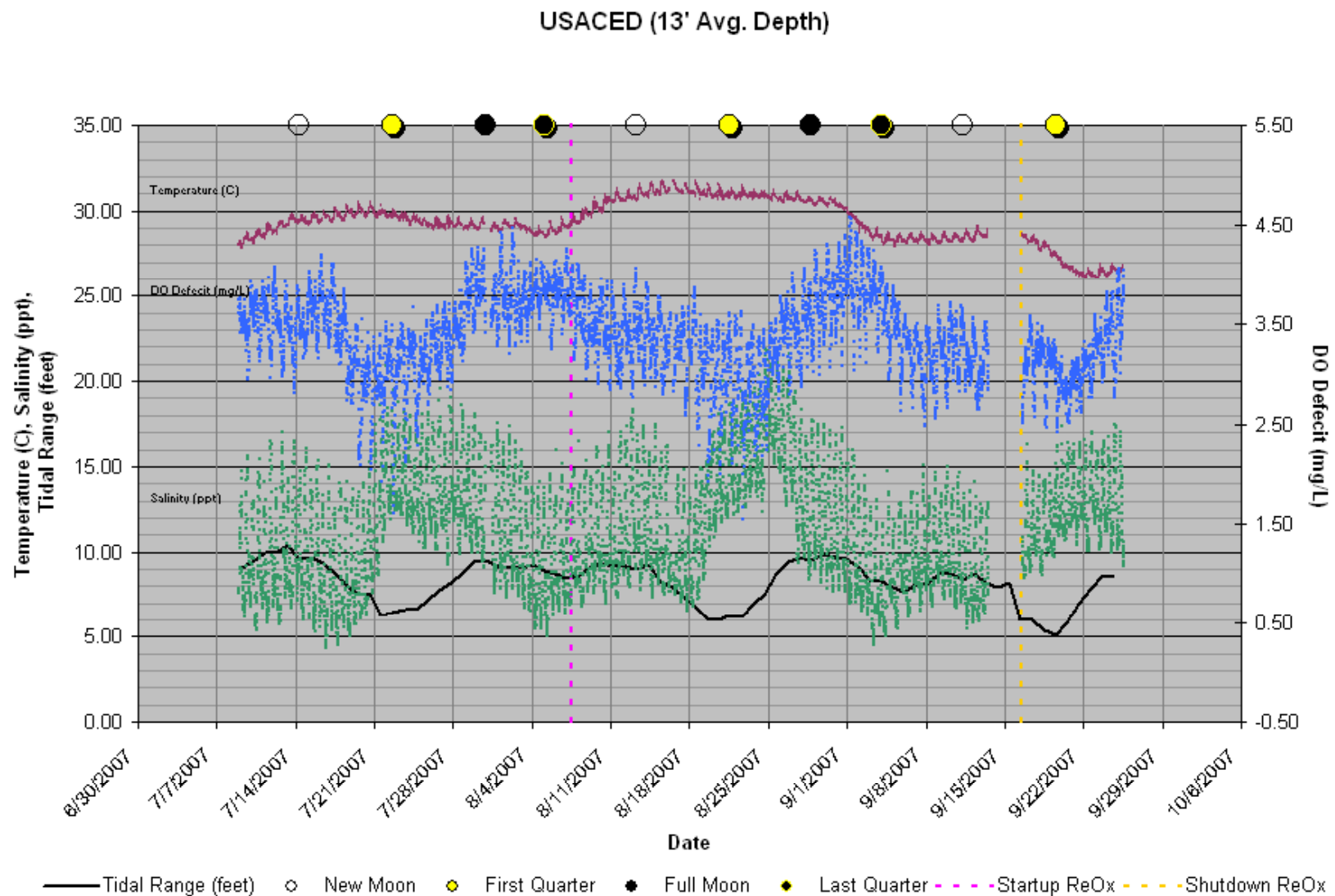
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PROJECT
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SAVANNAH, GEORGIA



USACEM: Tide, Salinity, Deficit Patterns

Project Number: 6110-08-0064

Figure: 3.9



Prepared by: LRP 1/14/09

Checked by: TRK 1/14/09

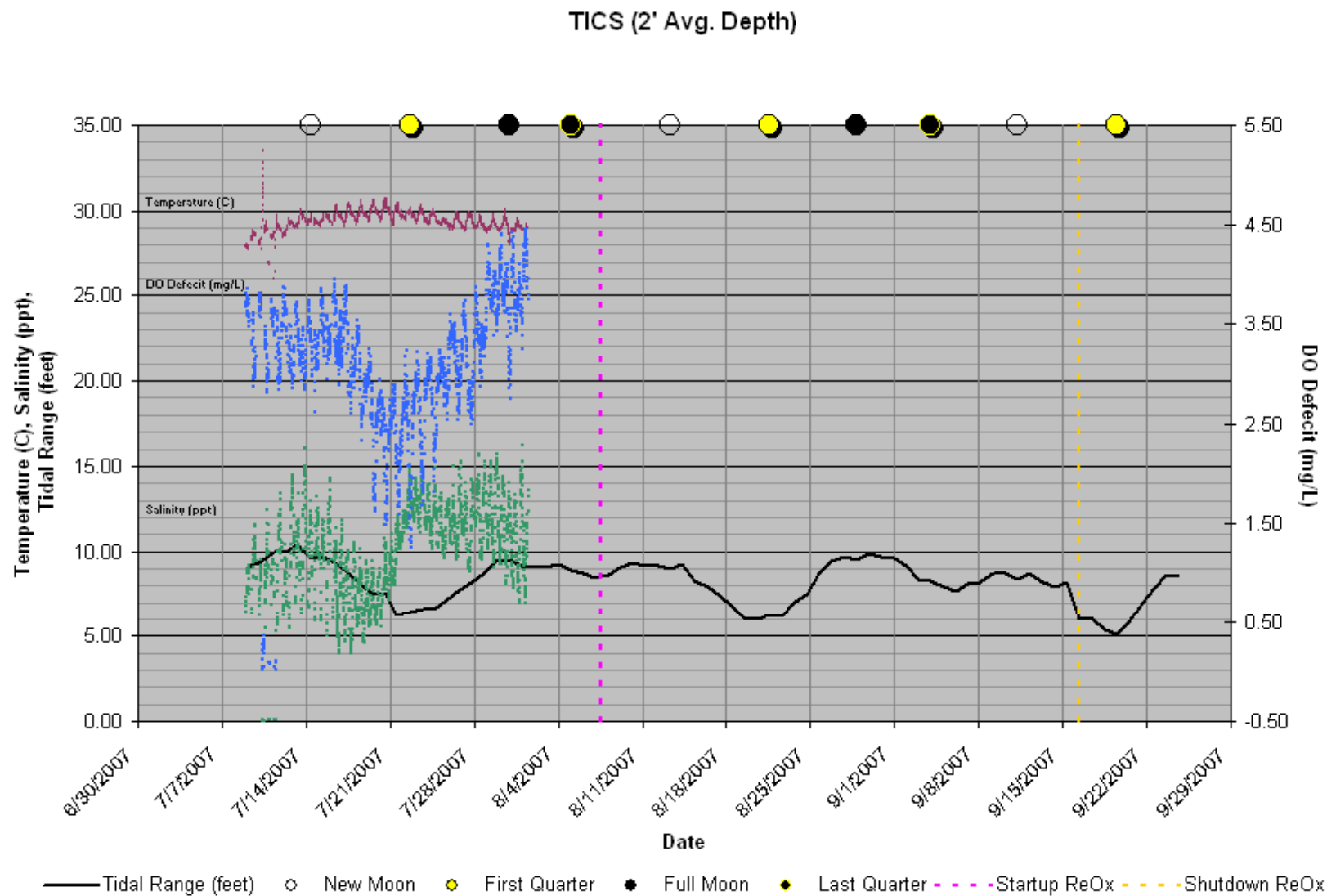
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USACED: Tide, Salinity, Deficit Patterns

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Figure: 3.10



Prepared by: LRP 1/14/09

Checked by: TRK 1/14/09

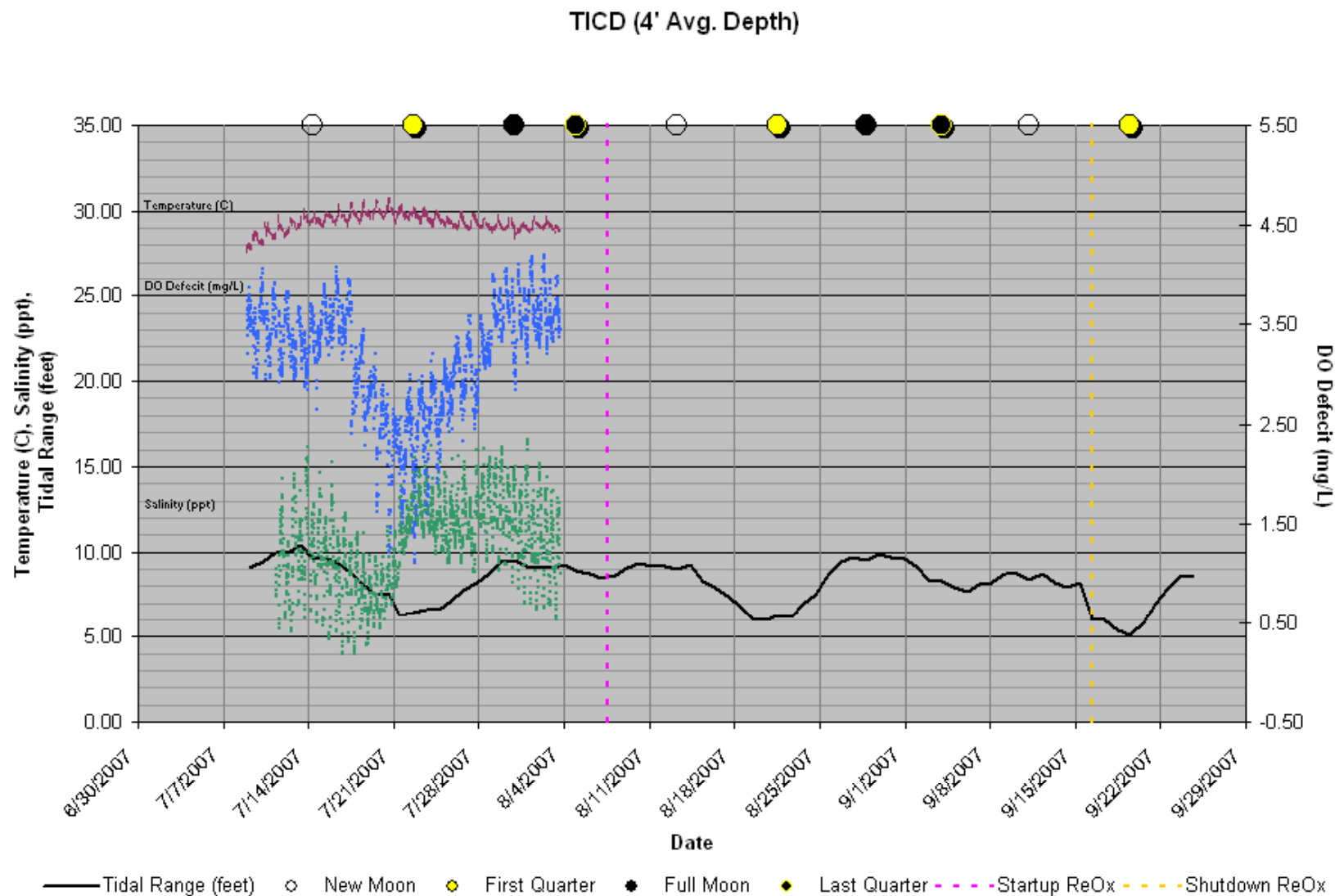
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TICS: Tide, Salinity, Deficit Patterns

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Figure: 3.11



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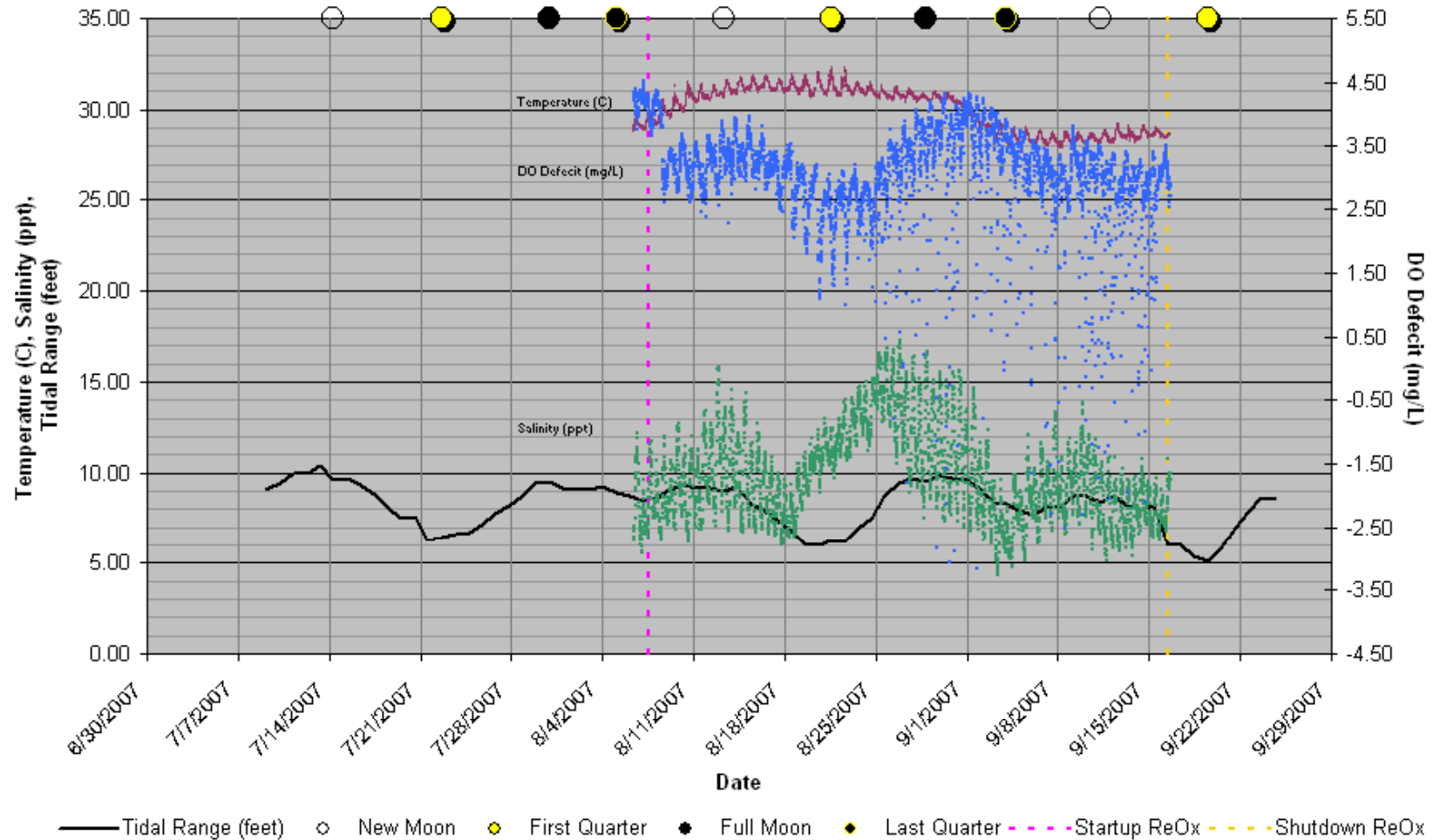


TICD: Tide, Salinity, Deficit Patterns

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Figure: 3.12

BS (2' Avg. Depth)



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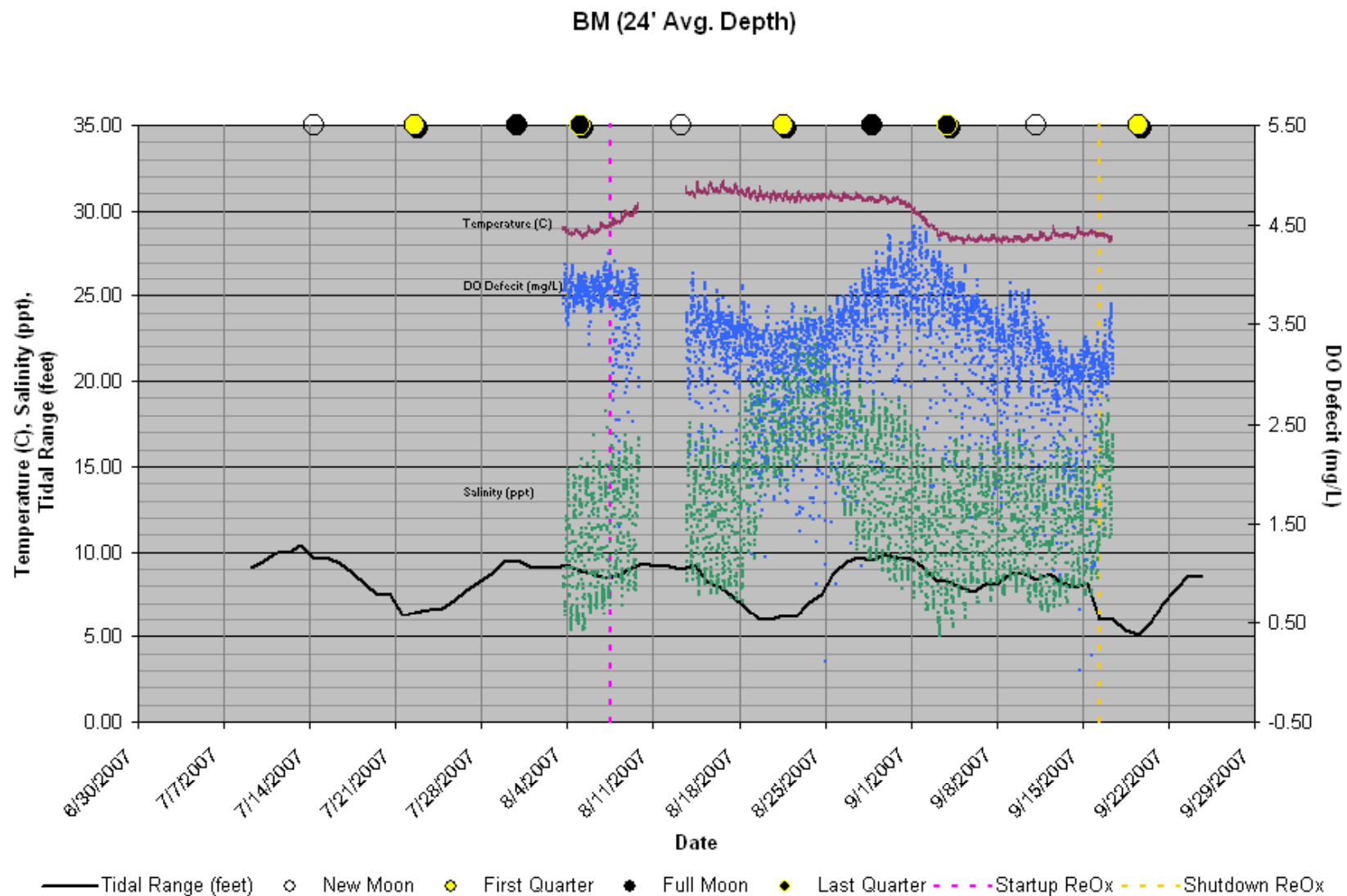
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Figure: 3.13



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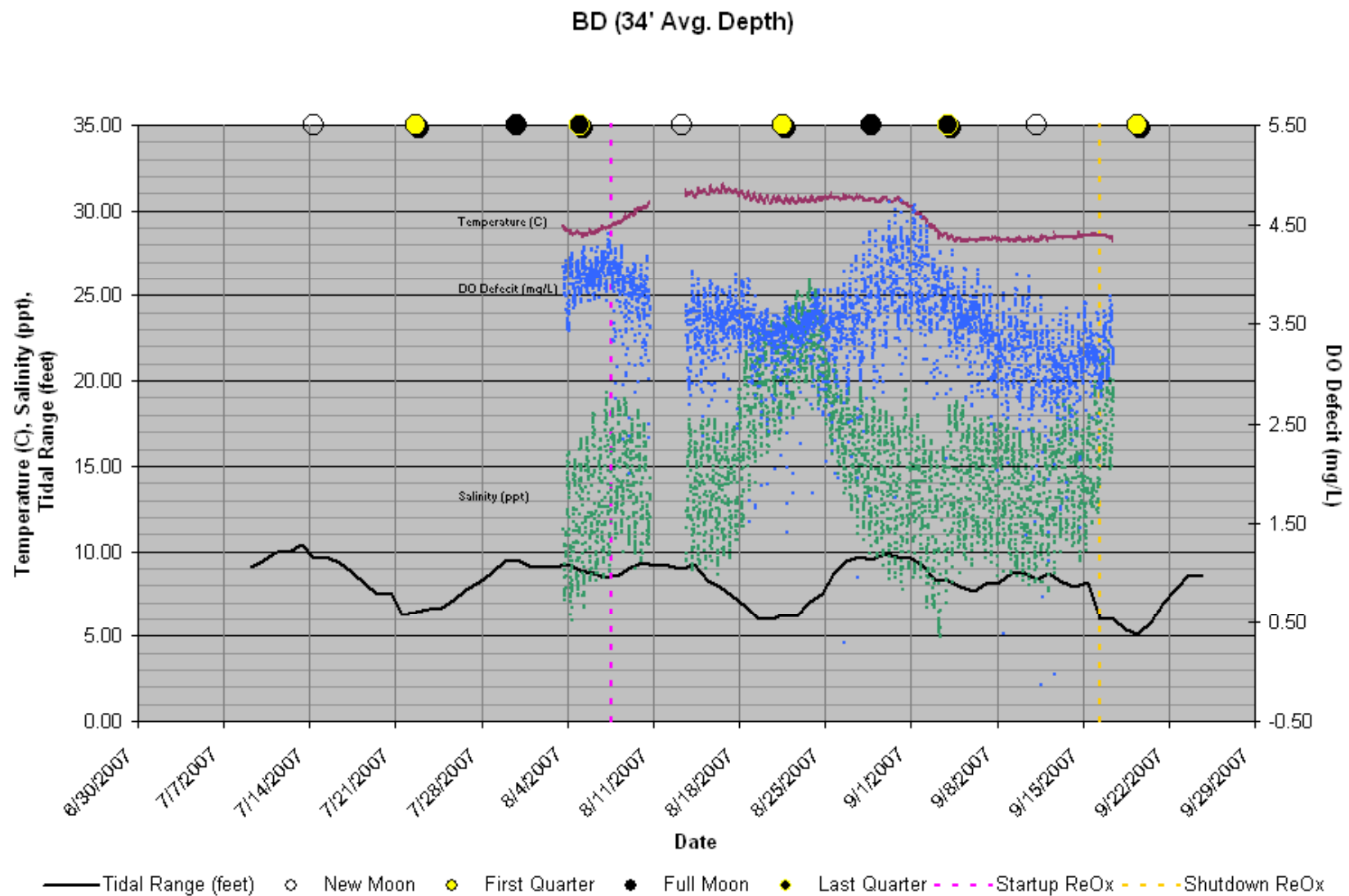
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Figure: 3.14



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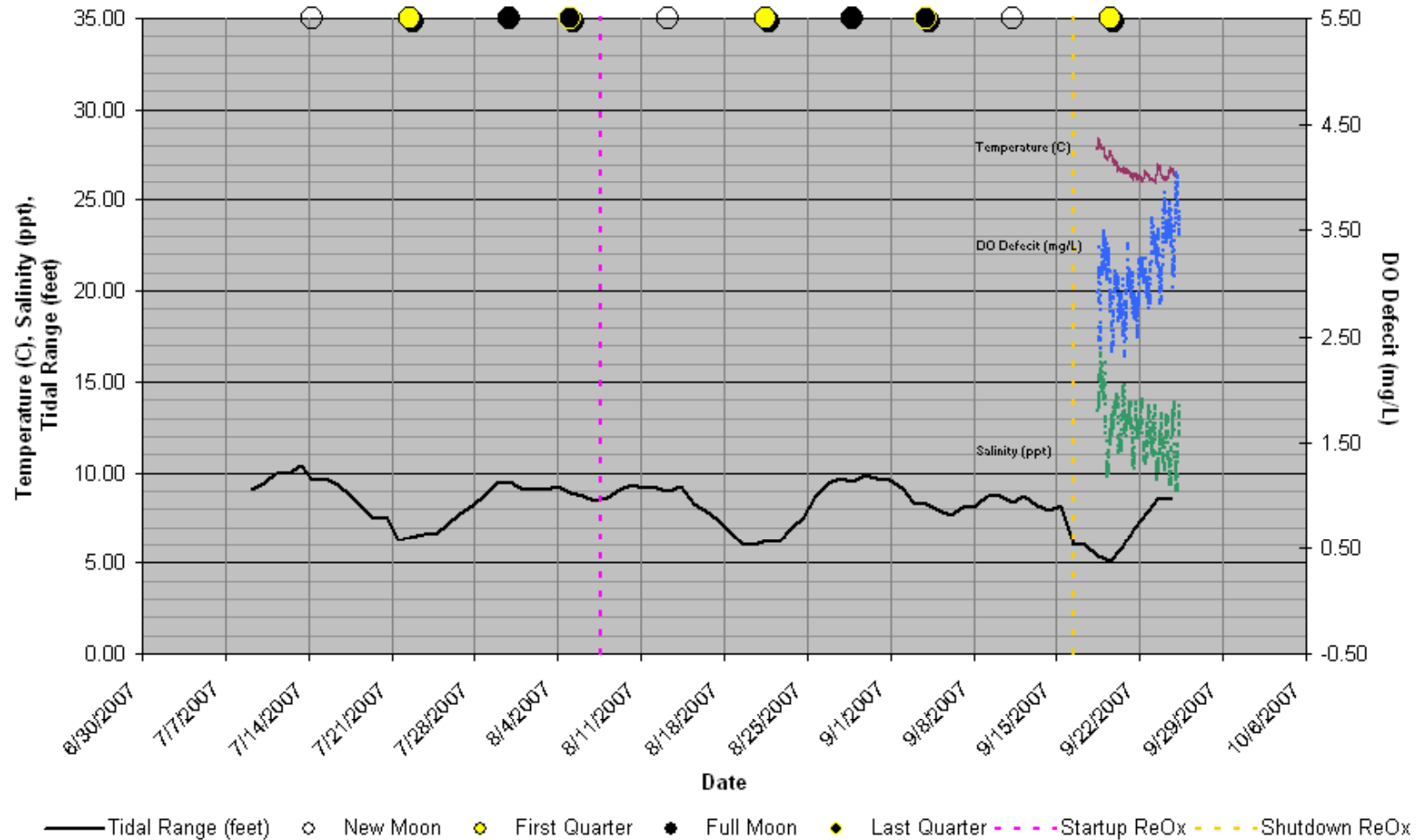


BD: Tide, Salinity, Deficit Patterns

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Figure: 3.15

SMS (2' Avg. Depth)



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Figure: 3.16