DWR Aeration Facility Final Report and Possible TMDL Implementation

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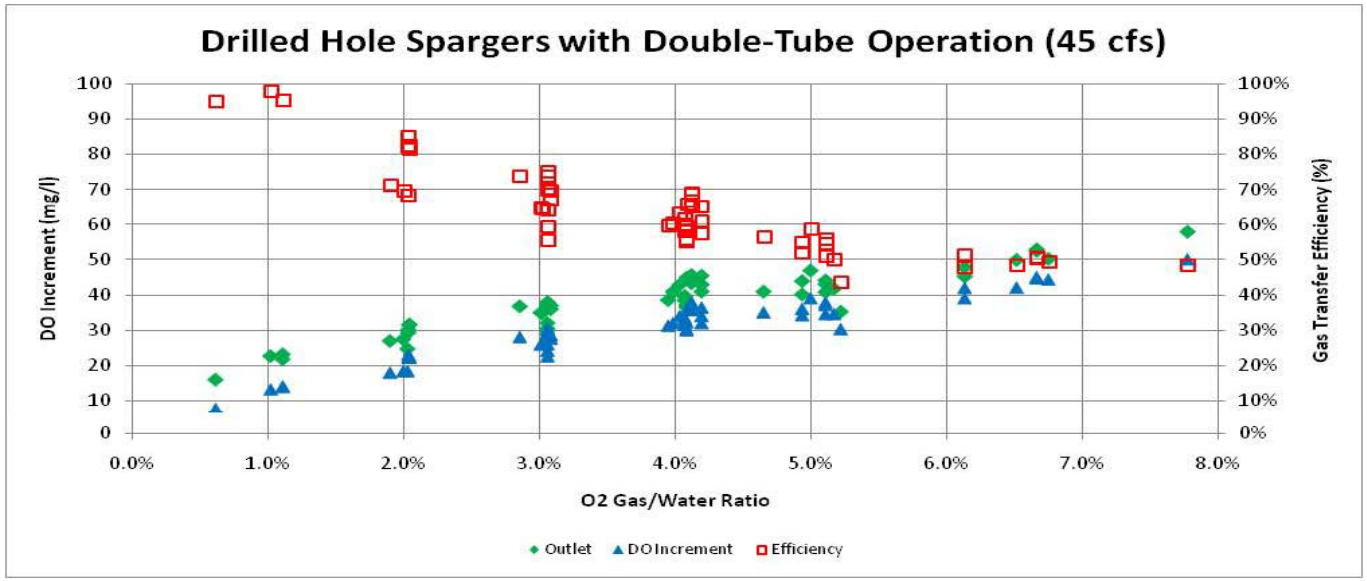
For DWR Bay-Delta Office

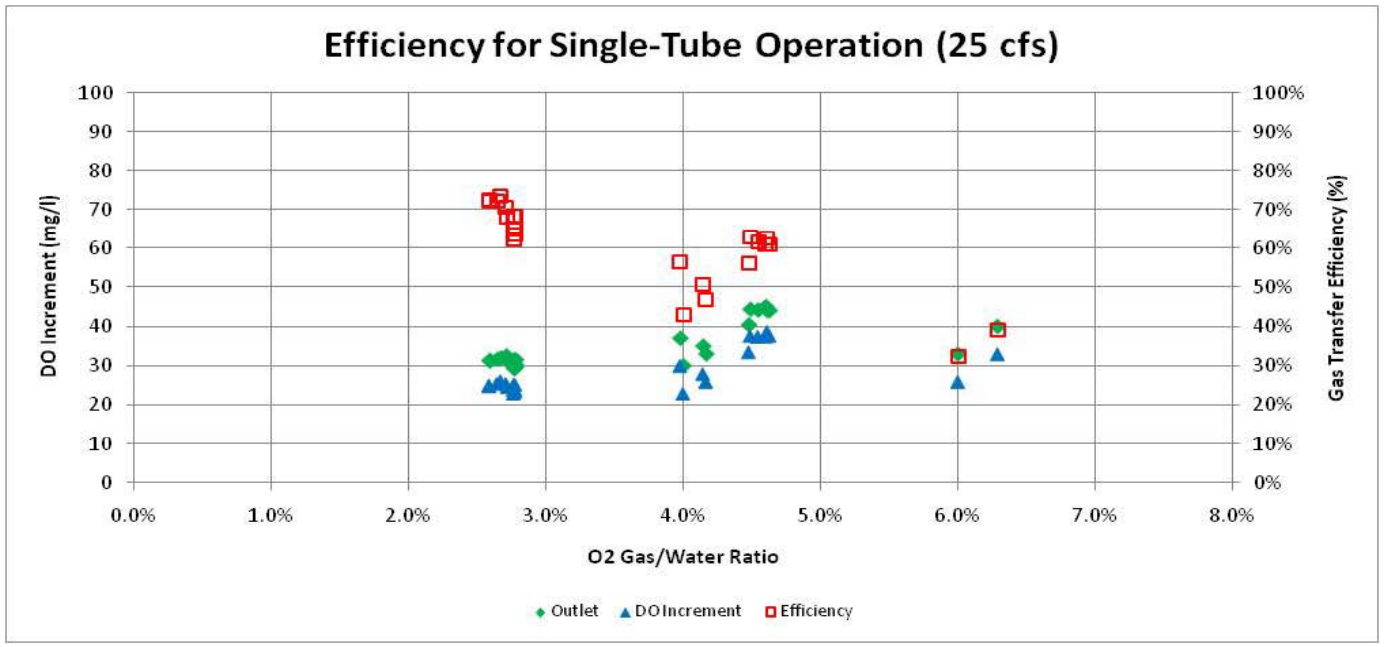
Final Report is being reviewed by DWR and should be available in December 2010

Demonstration Objectives

- How well does the RRI station (surface) represent natural DO in the DWSC?
- Is the diffuser location appropriate for adding DO to the DWSC?
- How much DO can be added to the DWSC?
- How is the added DO distributed in the DWSC at high-tide and low-tide?
- Will the DO objectives always be achieved?
- Should anything else be done for the TMDL?

Aeration Facility Efficiency





Aeration Facility Operational Parameters

Table 2. Aeration Facility DO Increment, Effficiency and DO Delivery Capacity (lb/day) for a Range of Operations

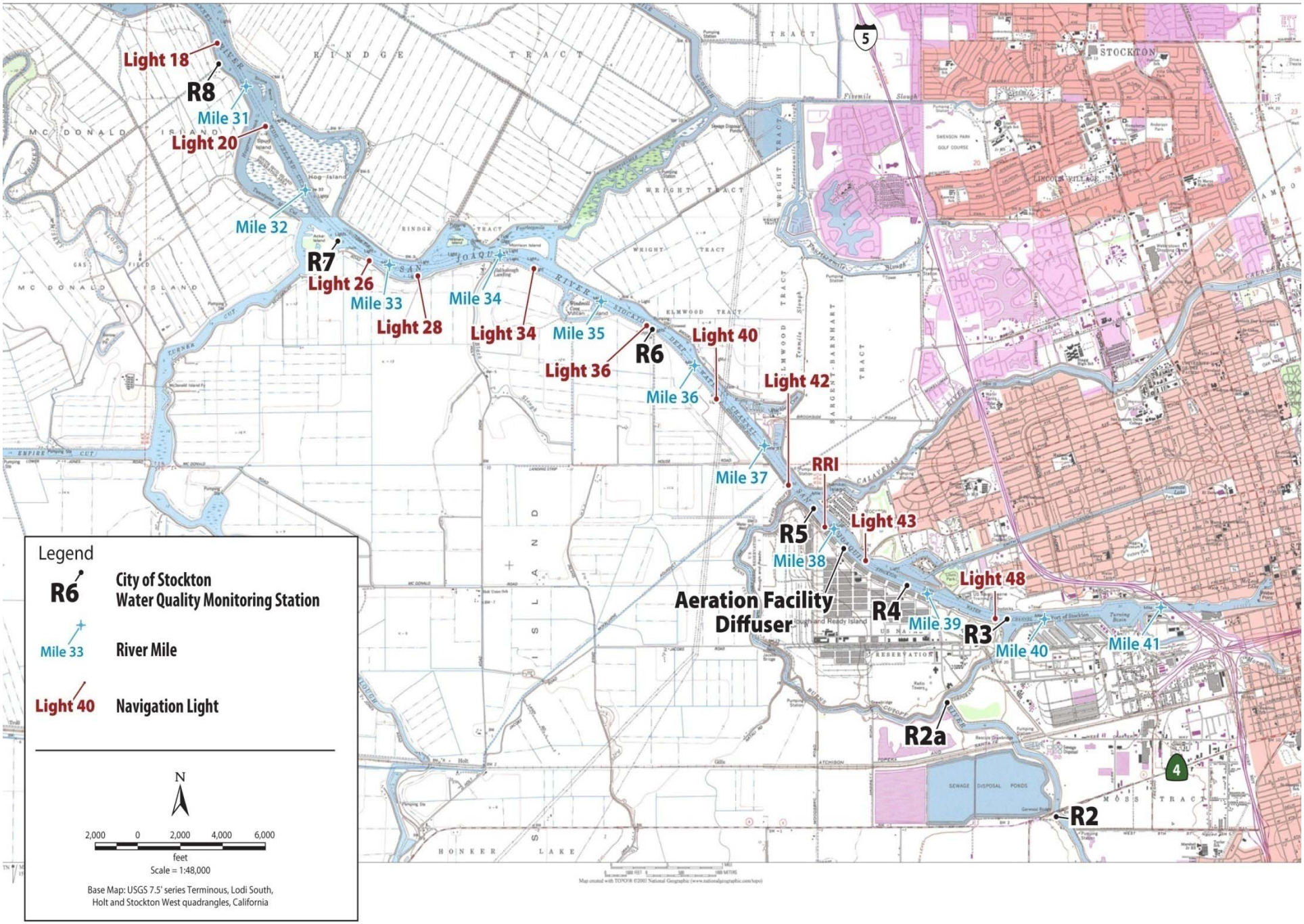
gas/water ratio		1%	2%	3%	4%	5%	6%	gas density at 80 F
								.0814 lb/ft^3
								water desnity at 80 F
Gas Supply for 1-pump (scf/hr)		900	1,800	2,700	3,600	4,500	5,400	62.2 lb/ft^3
Supply (for each tube) with 2-pumps (scf/hr)		810	1,620	2,430	3,240	4,050	4,860	
Maximum								1% gas/water estimate
DO Increment (mg/l)		13	26	39	52	65	78	13.1 mg/l
Assumed Efficiency		90%	75%	65%	58%	53%	50%	
DO Increment (mg/l)		12	20	25	30	34	39	
	Flow (cfs)							
DO Delivery with 1-pump	25	1,580	2,633	3,422	4,072	4,651	5,265	
DO Delivery with 2-pumps	45	2,843	4,739	6,160	7,329	8,371	9,477	
								Pumps only
Cost for 1-pump operation		$816	$991	$1,167	$1,342	$1,518	$1,693	$640
Cost for 2-pump operation		$1,596	$1,912	$2,228	$2,544	$2,860	$3,175	$1,280
Cost/lb for 1-pump operation		$0.52	$0.38	$0.34	$0.33	$0.33	$0.32	
Cost/lb for 2-pump operation		$0.56	$0.40	$0.36	$0.35	$0.34	$0.34	
Assumed Power Cost	0.16	$/kwhr	166 kw pumps (220 hp) require 4,000 kwhr per day of operation					
Assumed Oxygen Cost	0.10	$/lb						
Notes:	The cost per pound of oxygen is surprisingly uniform for 3% to 6% gas/water ratio							
	The most cost effective operation is higher gas/water ratio because the pumping csots are fixed and							


Navigation
Light 48
Navigation
Light 43
Approximate
Diffuser Location
RRI Monitoring Station
Aeration Facility


Light 40 is 1.6 miles downstream of diffuser
Light 42 is 0.7 miles downstream of diffuser
RRI is 0.2 miles downstream of diffuser
Diffuser is 1,000 feet upstream of RRI

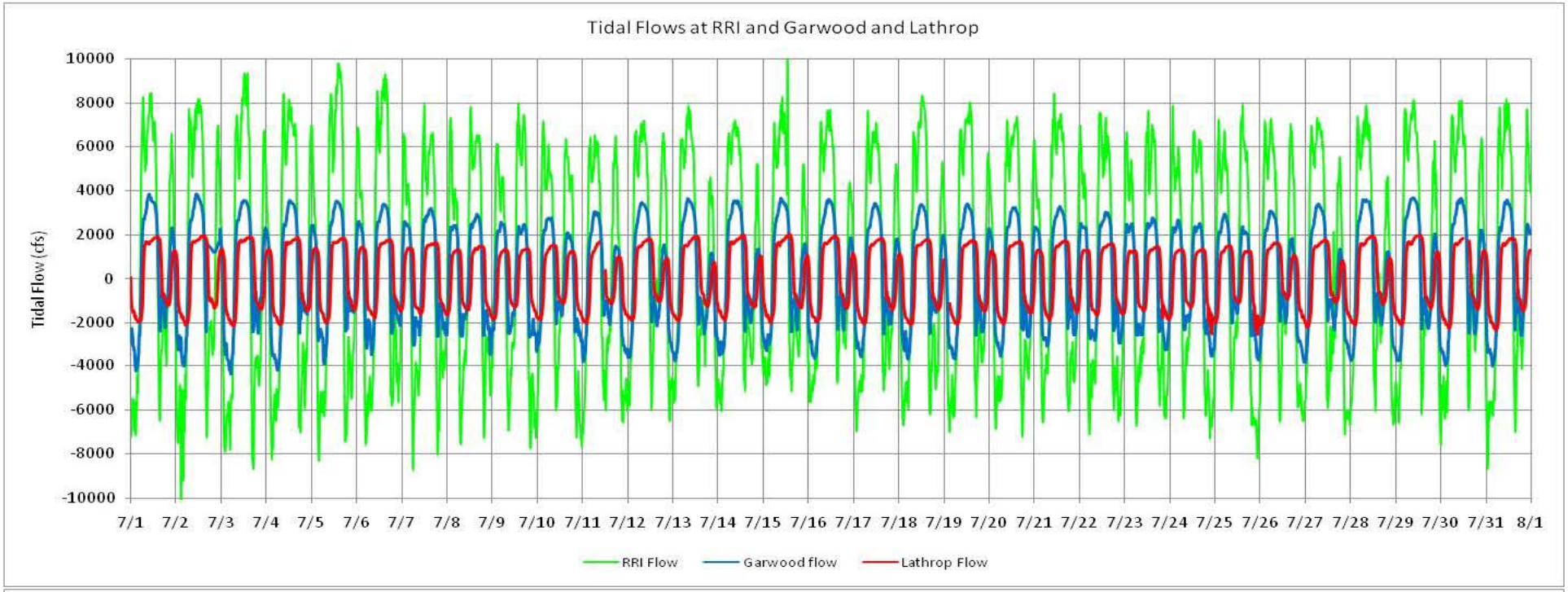
Effectiveness Evaluation Methods

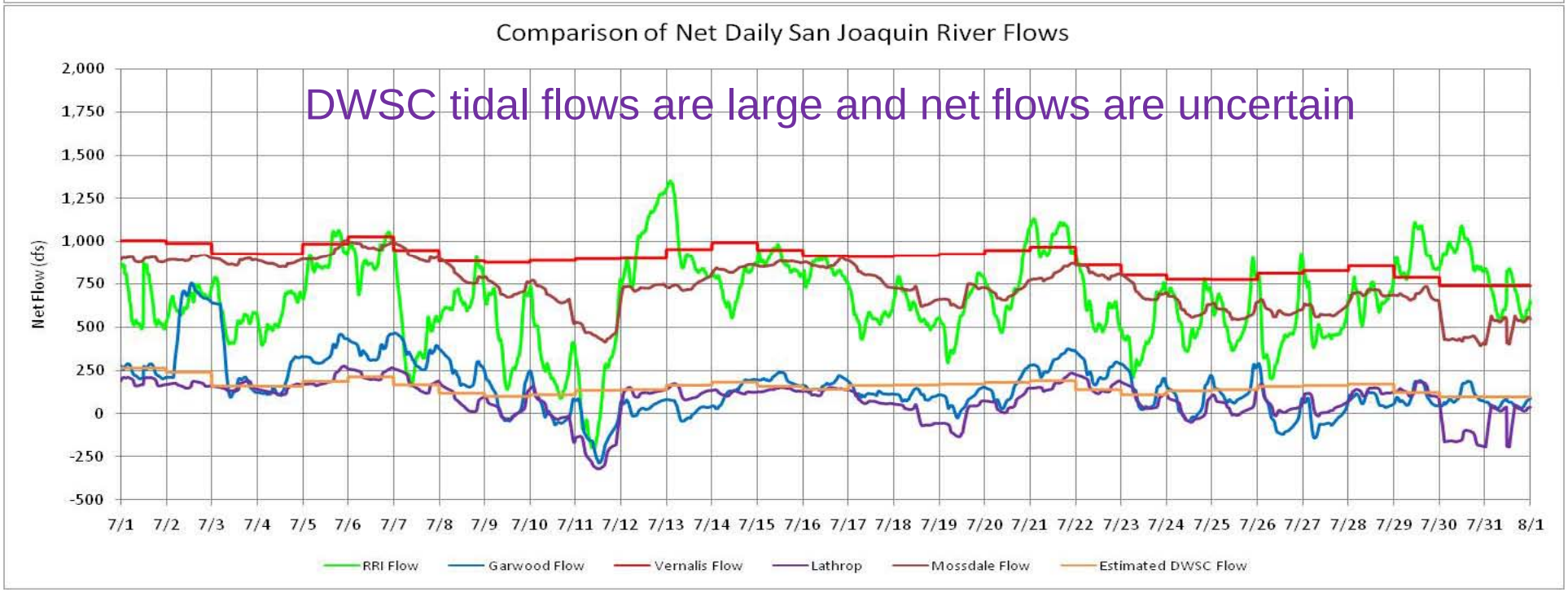
- Tidal movement and spreading of added DO from the Aeration Facility diffuser,
- DWSC DO measurements from the DWR *San Carlos* boat surveys (DWSC DO Model),
- 15-minute DO data at the five DWR monitoring stations (RRI and 4 Light stations) during the pulsed operations (DO Increment Model),
- UOP boat survey measurements of DO profiles from three depths in the DWSC, and
- City of Stockton effluent and river sampling data-effects of nitrification on DO in DWSC.


Light 18
R8
Mile 31
Light 20
Mile 32
R7
Light 26
Mile 33
Light 28
Mile 34
Light 34
Mile 35
Light 36
R6
Light 40
Mile 36
Light 42
Mile 37
RRI
R5
Light 43
Mile 38
Aeration Facility
Diffuser
R4
Mile 39
Light 48
R3
Mile 40
Mile 41
R2a
R2
STOCKTON
MC DONALD ISLAND
RINDGE TRACT
WRIGHT TRACT
ELMWOOD TRACT
ARGENT-BARNHART TRACT
MOSS TRACT
HONKER LAKE
Legend
R6
City of Stockton
Water Quality Monitoring Station
Mile 33
River Mile
Light 40
Navigation Light
N
2,000 0 2,000 4,000 6,000
feet
Scale = 1:48,000
Base Map: USGS 7.5' series Terminous, Lodi South,
Holt and Stockton West quadrangles, California

Tidal Movement and Mixing

- Tidal movement is about 1.5 to 2.5 miles each day between high tide and low tide.
- DWSC volume is 2,000 af per mile.
- Diffuser and tidal mixing of the added DO (30 mg/l in 45 cfs) is rapid, so the maximum DO incremental at RRI is about 1.5 mg/l.
- Dye studies indicate that vertical and lateral mixing is nearly complete and longitudinal spreading is about 3.0 miles after one day.

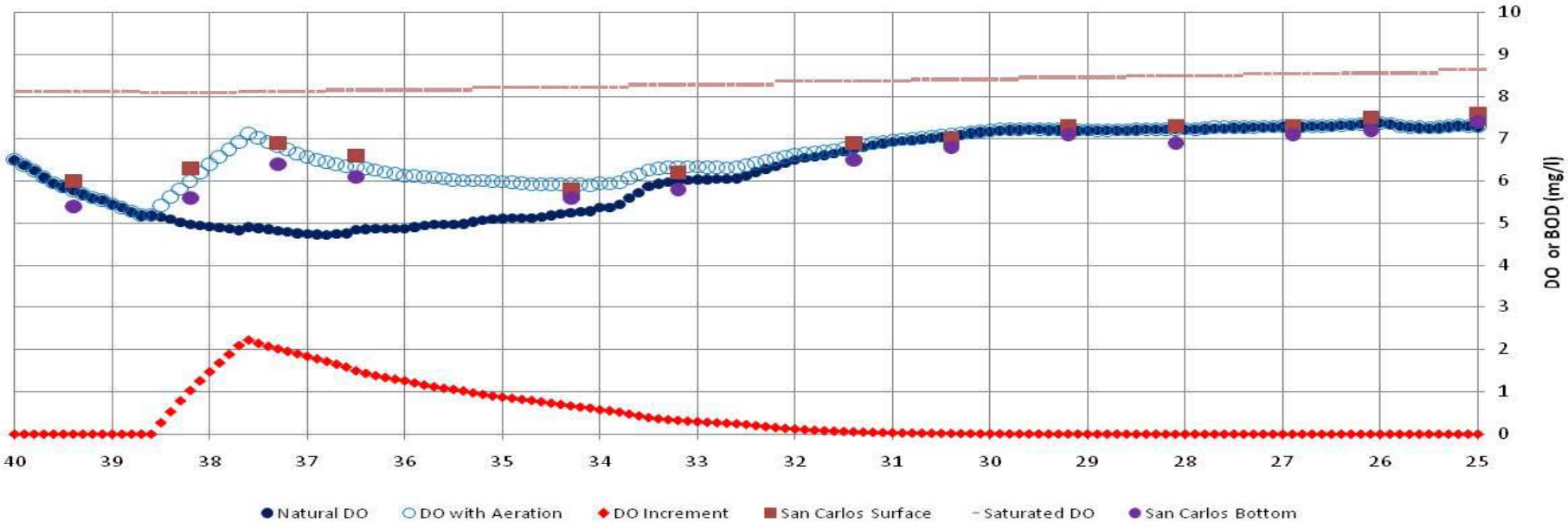

Tidal Flows at RRI and Garwood and Lathrop
Tidal Flow (cfs)
10000
8000
6000
4000
2000
0
-2000
-4000
-6000
-8000
-10000
7/1 7/2 7/3 7/4 7/5 7/6 7/7 7/8 7/9 7/10 7/11 7/12 7/13 7/14 7/15 7/16 7/17 7/18 7/19 7/20 7/21 7/22 7/23 7/24 7/25 7/26 7/27 7/28 7/29 7/30 7/31 8/1
RRI Flow
Garwood flow
Lathrop Flow


Comparison of Net Daily San Joaquin River Flows
DWSC tidal flows are large and net flows are uncertain
Net Flow (cfs)
2,000
1,750
1,500
1,250
1,000
750
500
250
0
-250
-500
7/1 7/2 7/3 7/4 7/5 7/6 7/7 7/8 7/9 7/10 7/11 7/12 7/13 7/14 7/15 7/16 7/17 7/18 7/19 7/20 7/21 7/22 7/23 7/24 7/25 7/26 7/27 7/28 7/29 7/30 7/31 8/1
RRI Flow
Garwood Flow
Vernalis Flow
Lathrop
Mossdale Flow
Estimated DWSC Flow

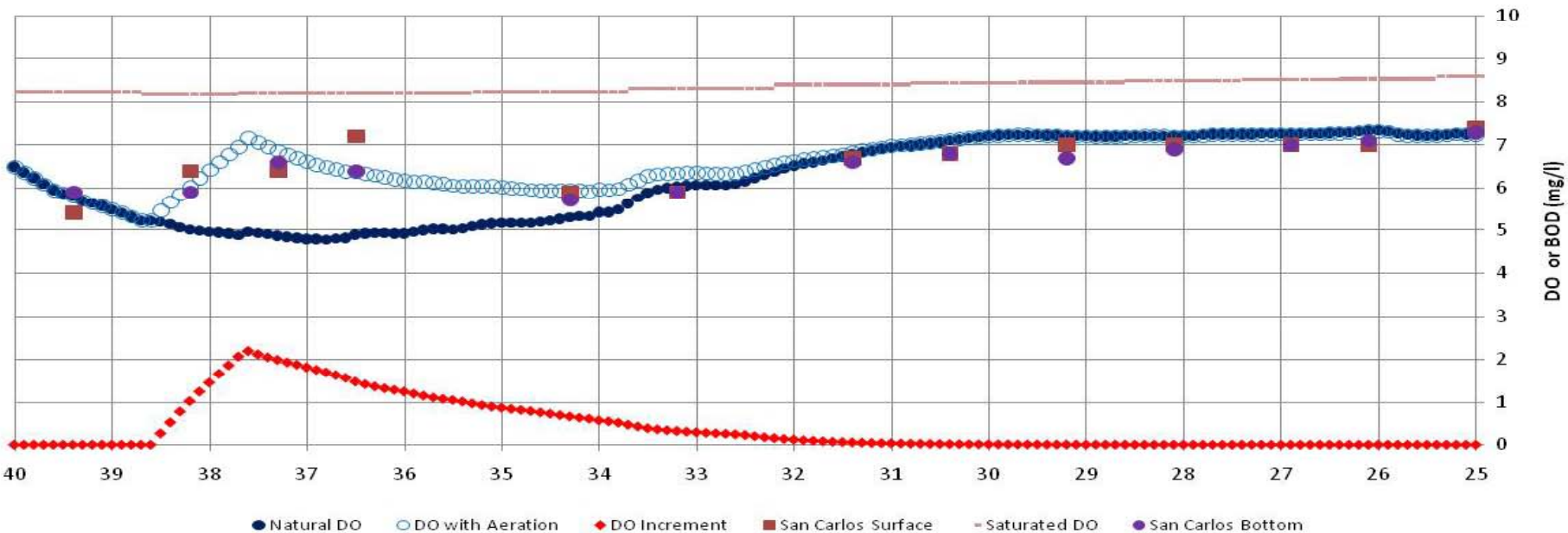
DWR *San Carlos* DWSC DO Surveys

- The longitudinal DO profile is determined by the flow (cfs) and the inflow BOD (mg/l). The minimum DO is determined by the inflow BOD.
- The DWSC DO Model was developed to evaluate this data (estimate BOD).
- The surface reaeration is about 20% of the DO deficit (saturated DO – actual DO) per day.
- The added DO increments decrease downstream because of reduced surface reaeration- 2/3 of the DO increment will be gone within 5 days.

DO in the DWSC for July 16, 2008 with flow of 500 cfs and BOD of 10 mg/l



DO in the DWSC for July 30, 2008 with flow of 500 cfs and BOD of 10 mg/l



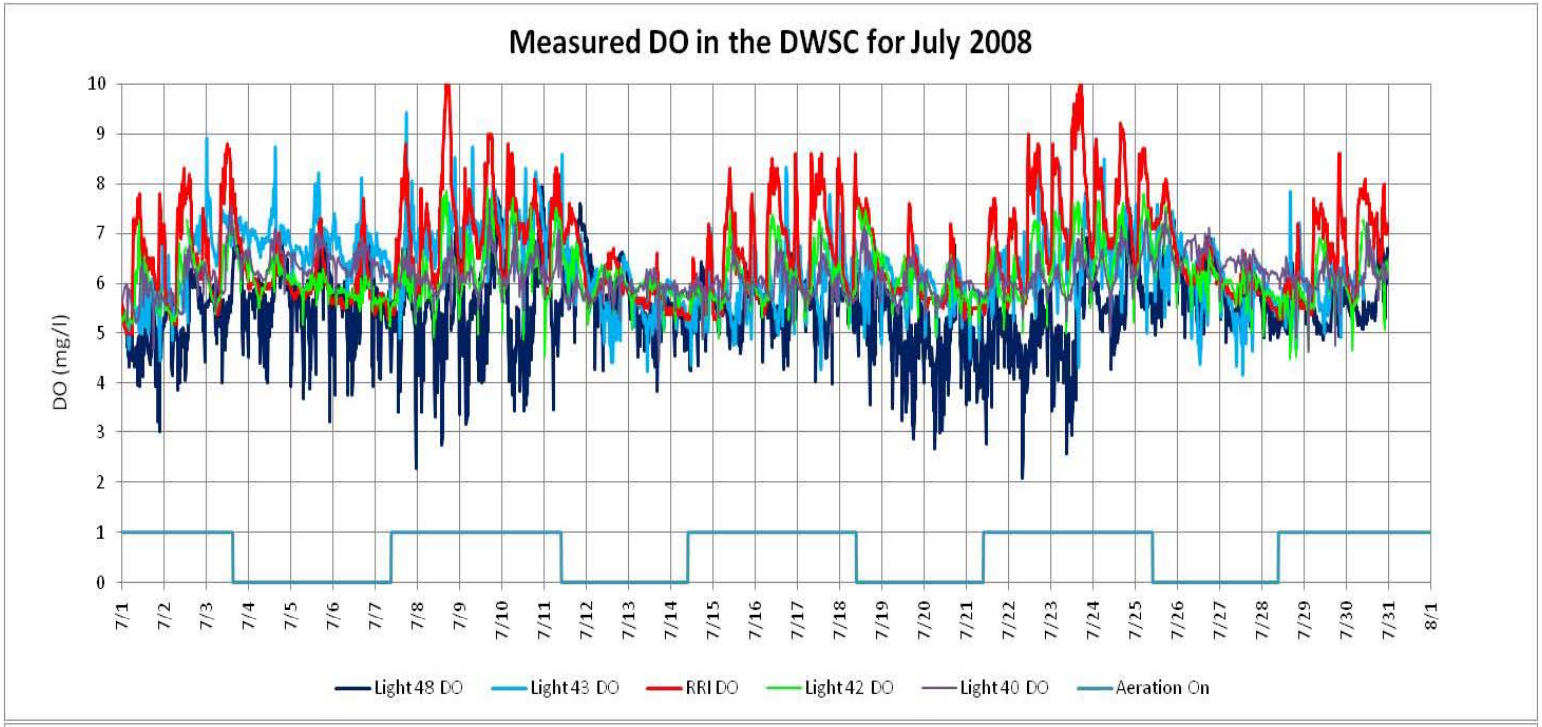
Downstream “Wedge” of DO Increments from Aeration Facility

Table 6. Calculated Dissolved Oxygen Increments in the Deep Water Ship Channel with Reaeration for Maximum Dissolved Oxygen Diffuser Output of 7,500 lb/day

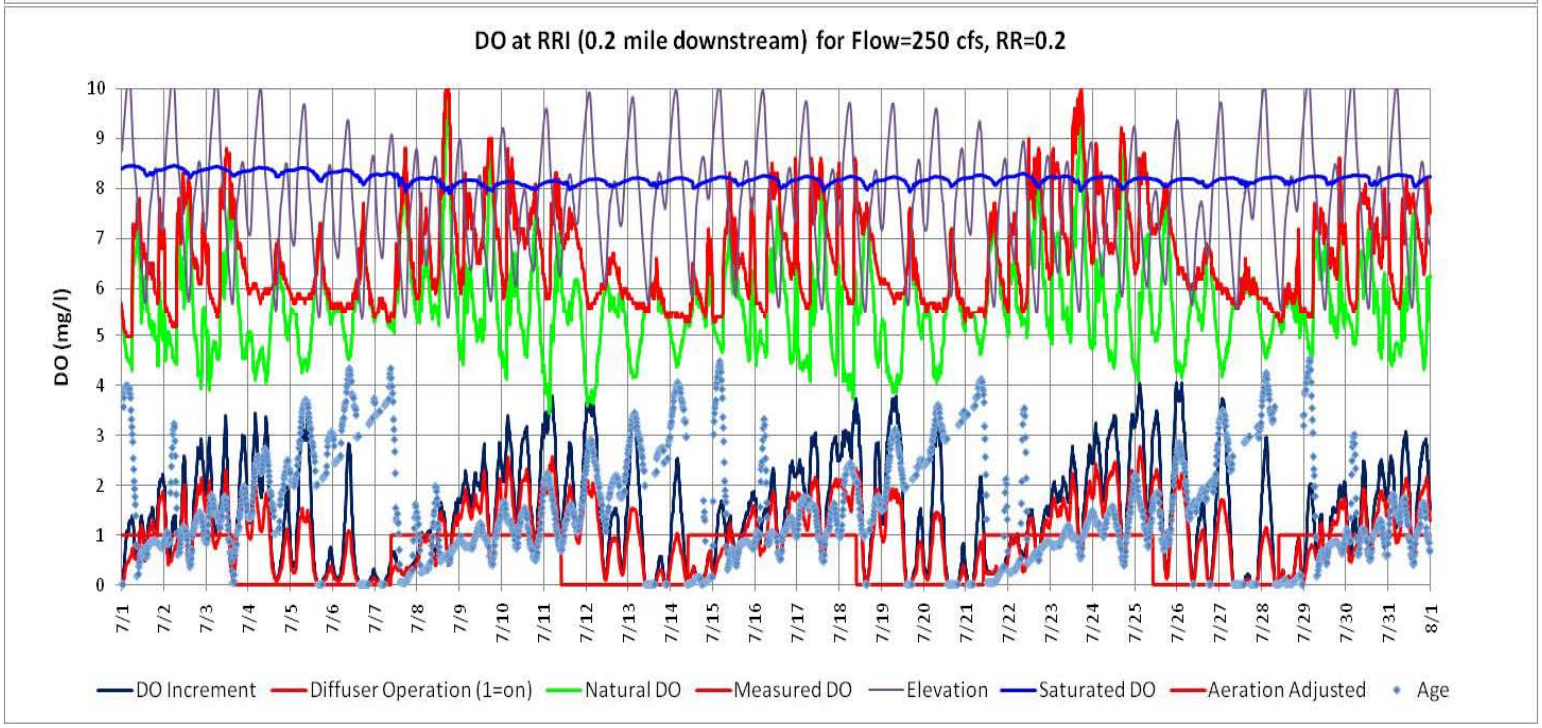
Location	Flow (cfs) / San Joaquin River Mile	250	500	750	1,000	1,250	1,500
	Maximum Possible DO Increment at Diffuser (mg/l)	5.6	2.8	1.9	1.4	1.1	0.9
	40.0	0.00	0.00	0.00	0.00	0.00	0.00
NA 48	39.5	0.00	0.00	0.00	0.00	0.00	0.00
	39.0	0.00	0.00	0.00	0.00	0.00	0.00
NA 43	38.5	0.51	0.27	0.18	0.14	0.11	0.09
DO Diffuser	38.0	2.55	1.46	1.02	0.78	0.63	0.53
NA 42	37.5	3.24	2.12	1.55	1.22	1.00	0.85
	37.0	2.37	1.82	1.40	1.13	0.94	0.81
NA 40	36.5	1.56	1.48	1.22	1.02	0.87	0.75
	36.0	1.10	1.25	1.09	0.93	0.81	0.71
	35.5	0.77	1.05	0.97	0.86	0.75	0.67
	35.0	0.52	0.87	0.85	0.78	0.70	0.63
	34.5	0.36	0.73	0.76	0.71	0.65	0.60
	34.0	0.22	0.57	0.65	0.63	0.59	0.55
	33.5	0.10	0.39	0.50	0.52	0.51	0.48
	33.0	0.05	0.29	0.42	0.46	0.46	0.44
Turner Cut	32.5	0.03	0.23	0.35	0.40	0.41	0.41
DO Retention to Turner Cut		23%	40%	49%	54%	57%	59%
Travel Time to Turner Cut (days)		19.1	10.1	7.0	5.5	4.6	4.0

DO Increments from the Aeration Facility

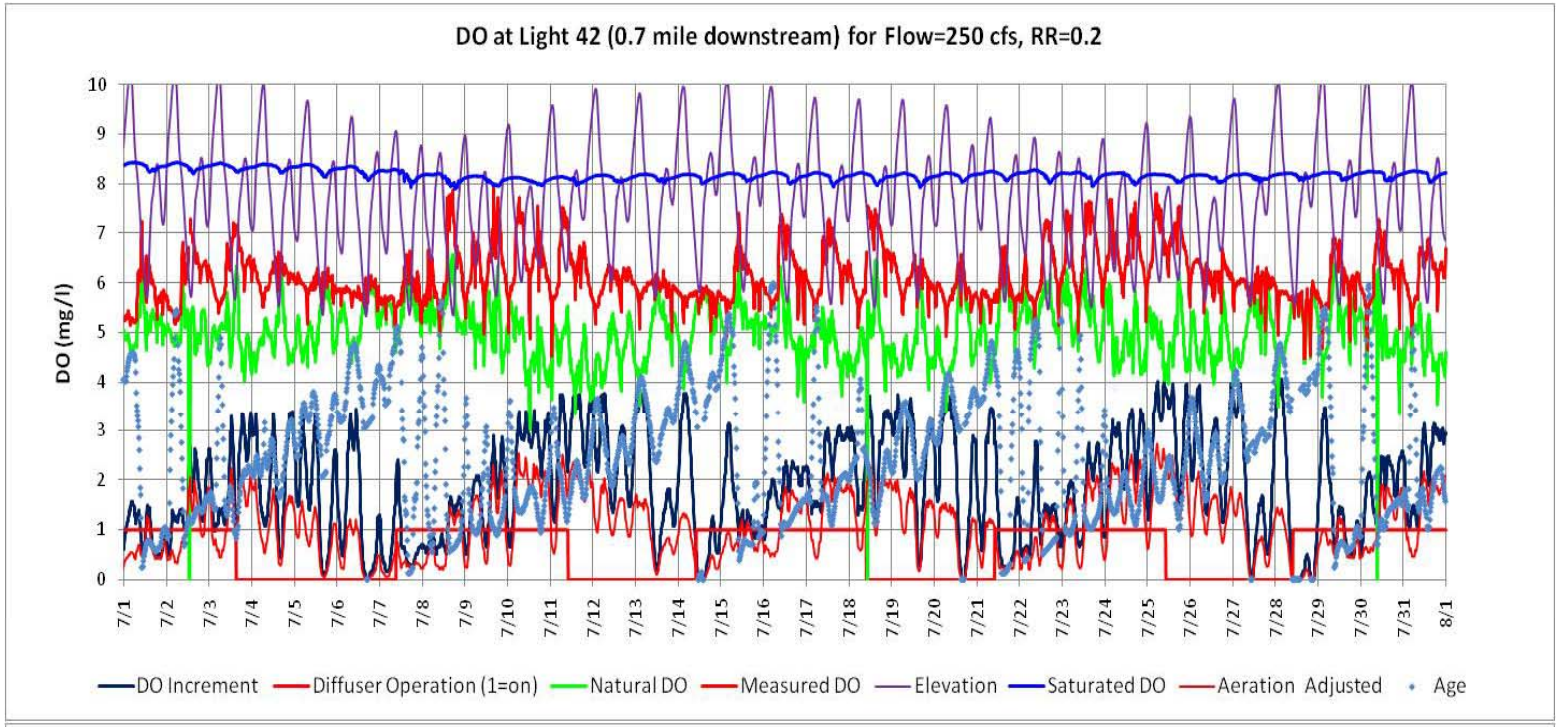
- The maximum fully-mixed DO increment should be observed at Light 42 (0.7 miles downstream).
- The added DO (7,500 lb/day) will tidally mix in about 1.5 miles of DWSC (3,000 af) and produce a daily DO increment of about 1 mg/l.
- The DO increments are decreasing at the same rate as surface reaeration (20% per day). This limits the total oxygen that can be added to the DWSC (about 4 time the daily capacity).
- The DO increments observed at each 15-minute DO station depends on the tidal movement of water past the diffuser and upstream or downstream to the monitoring stations. Follow the oxygen!



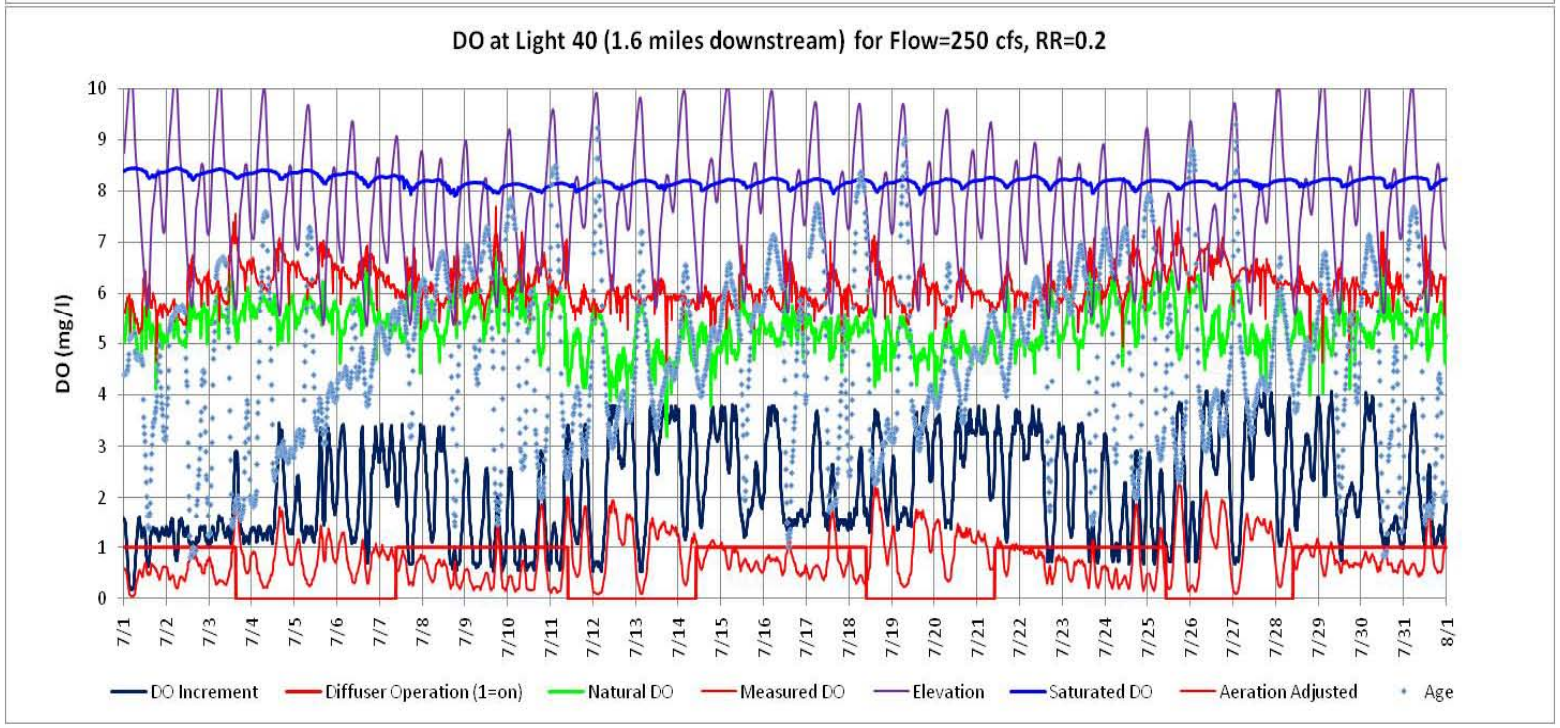
Can you tell how much DO is from the Aeration Facility?



The DO Increment Model may be able to estimate the natural DO.



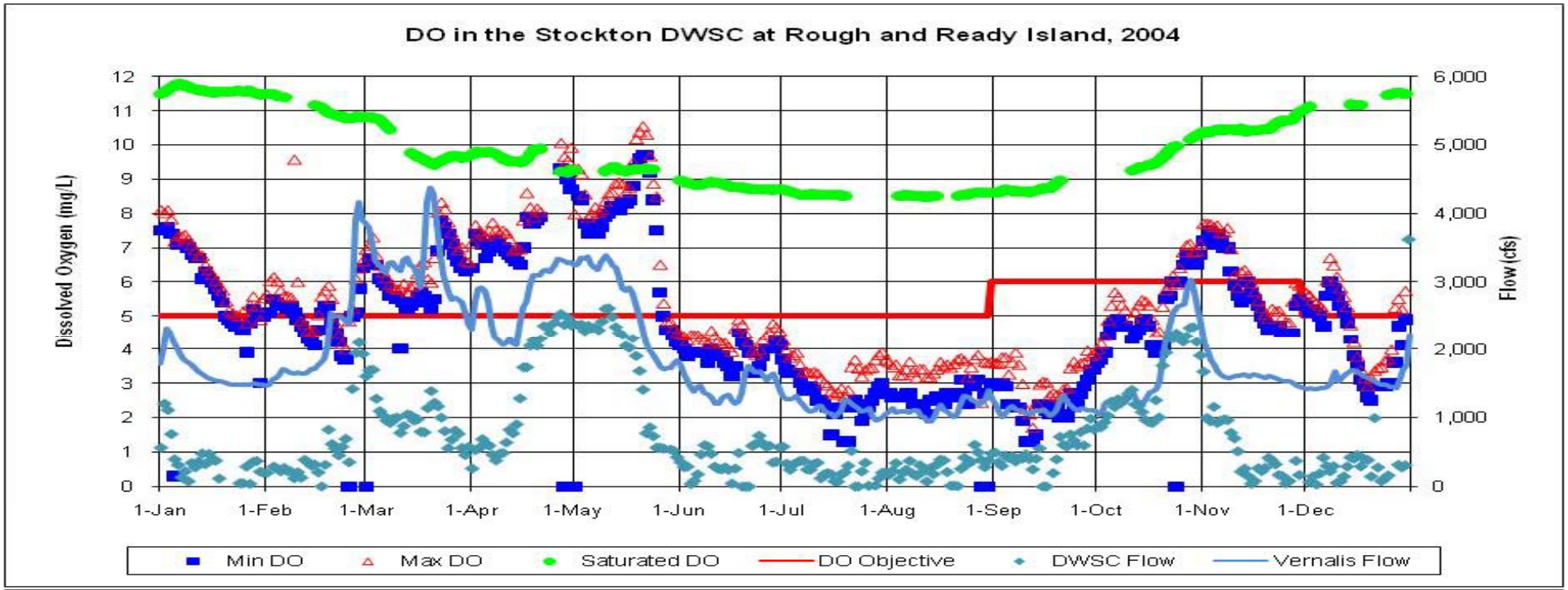
Greatest DO increments are estimated at Light 42

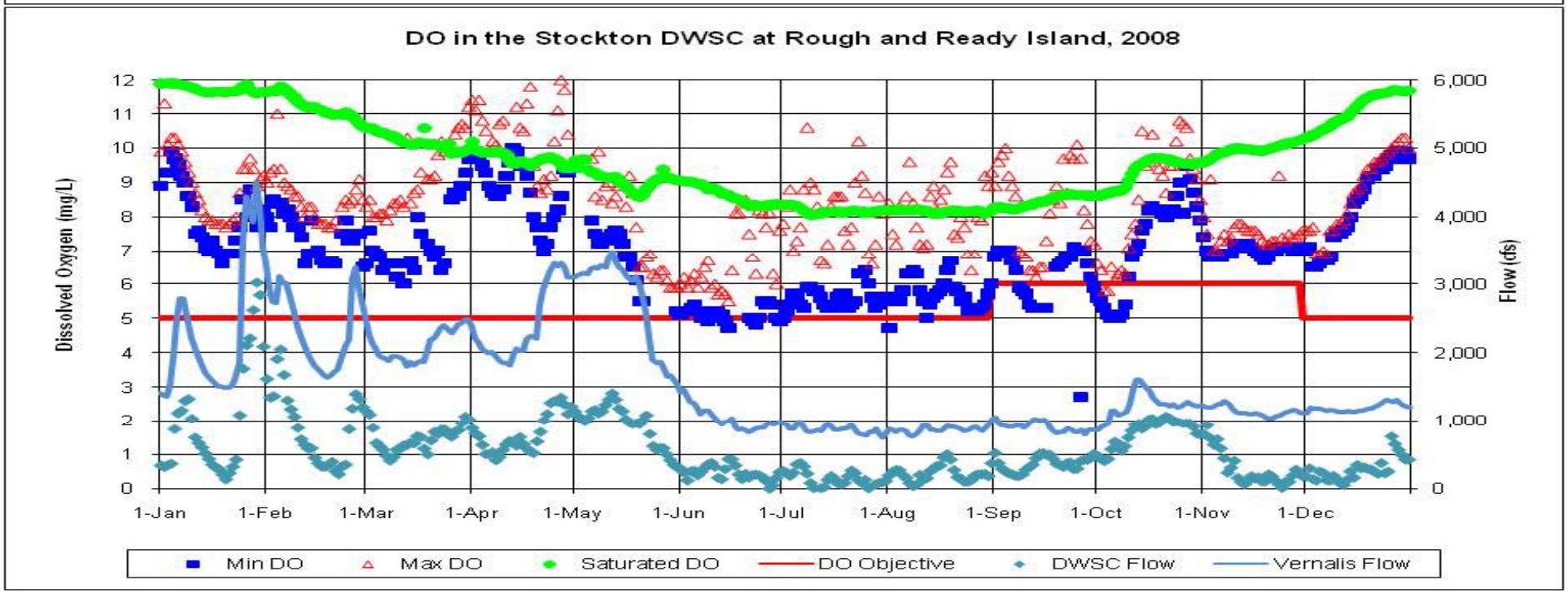


DO increments at Light 40 are largest at low tide.

Effects from City of Stockton RWCF Nitrification Facility (starting in 2007) on DWSC DO

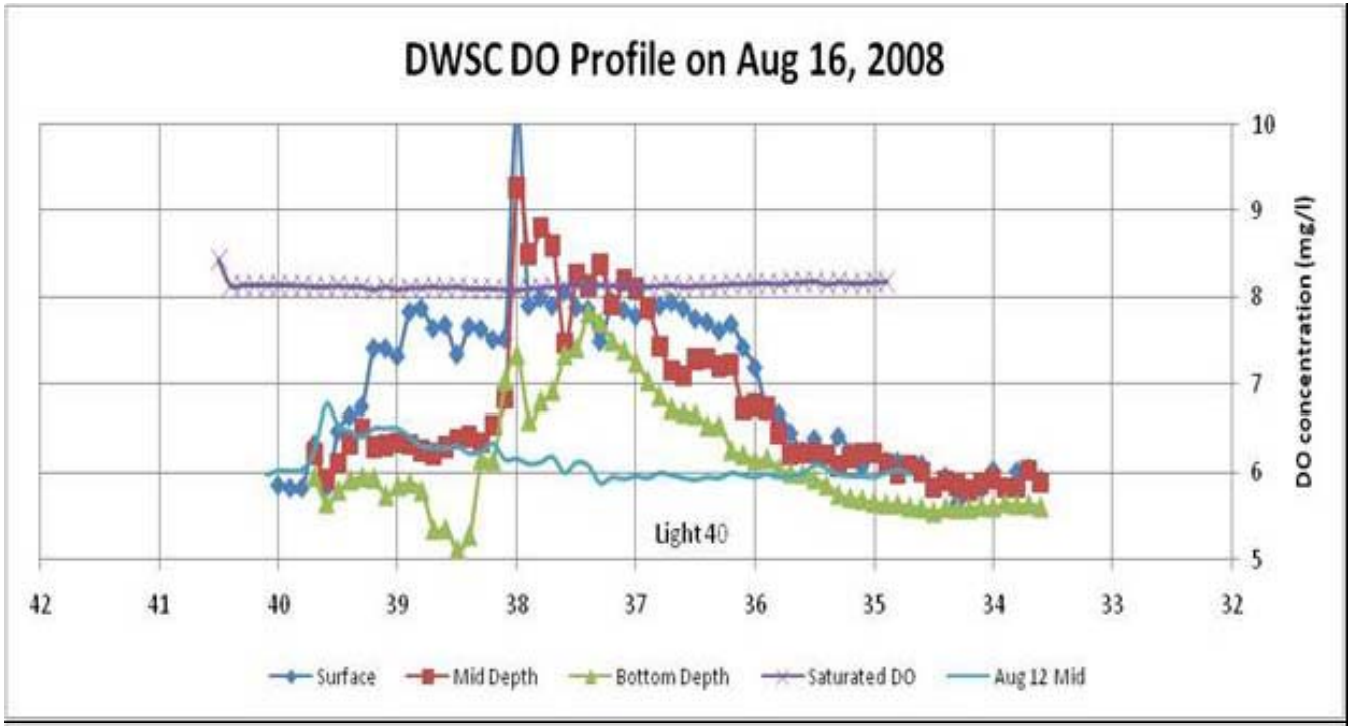
- Comparison of 2004 and 2008 DWSC DO concentrations suggests that the inflow BOD was reduced from 15-25 mg/l to 5-10 mg/l.
- The periods of DO deficits (below DWSC DO objectives) appear to be less frequent and smaller in magnitude since 2007.
- The Aeration Facility capacity of 7,500+ lb/day should be sufficient to maintain the DWSC DO objectives most of the time.


DO in the Stockton DWSC at Rough and Ready Island, 2004
Dissolved Oxygen (mg/L)
Flow (cfs)
0
1
2
3
4
5
6
7
8
9
10
11
12
0
1,000
2,000
3,000
4,000
5,000
6,000
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec
Min DO
Max DO
Saturated DO
DO Objective
DWSC Flow
Vernalis Flow

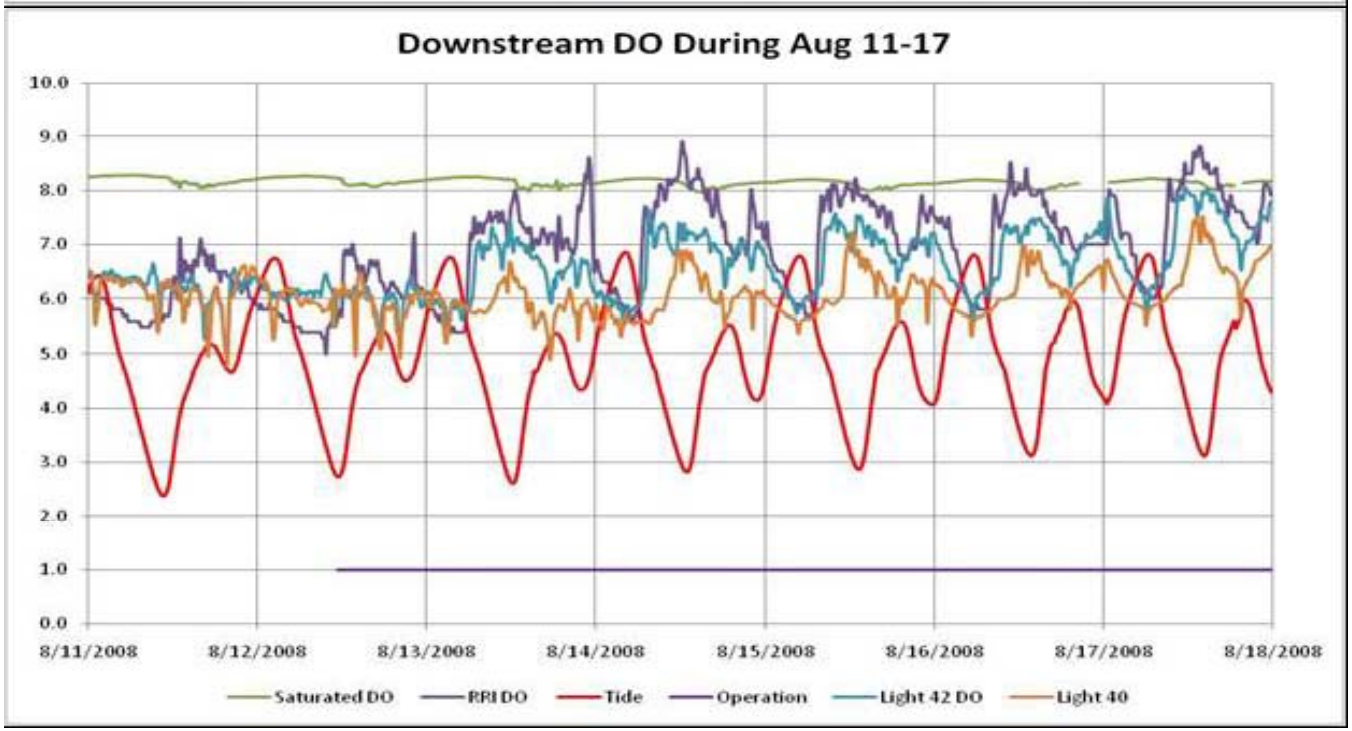

DO in the Stockton DWSC at Rough and Ready Island, 2008
Dissolved Oxygen (mg/L)
Flow (cfs)
0
1
2
3
4
5
6
7
8
9
10
11
12
0
1,000
2,000
3,000
4,000
5,000
6,000
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec
Min DO
Max DO
Saturated DO
DO Objective
DWSC Flow
Vernalis Flow

UOP Boat Surveys of Longitudinal DO Profiles

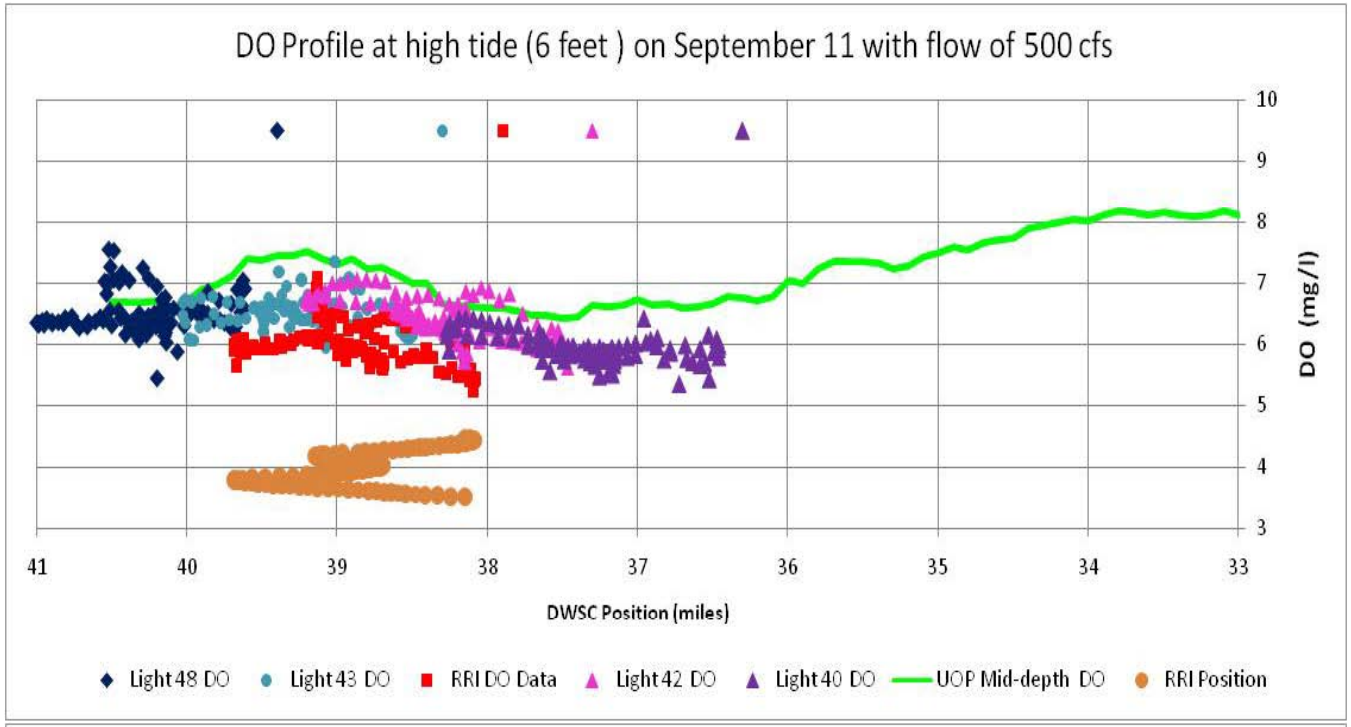
- Measurements of DO, temp, pH, turbidity, and fluorescence at 5-feet, 15-feet, and 25-feet demonstrate variability within the DWSC
- Surveys at low-tide and high-tide demonstrate the 2-mile tidal movement of the added DO
- Comparison with DO monitoring and San Carlos data shows effectiveness of Aeration Facility for increasing DWSC DO.
- The maximum wedge of DO represents about 30,000 lbs of DO (4 days of operations).



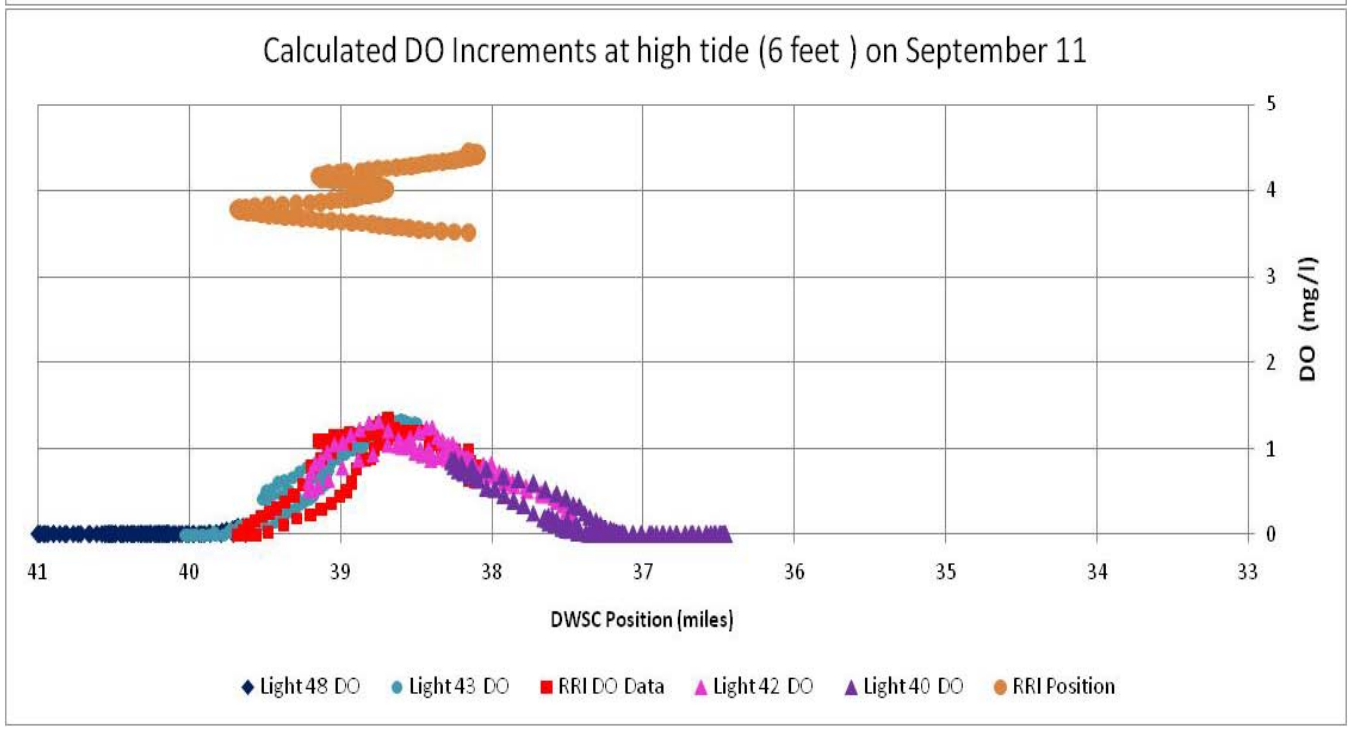
UOP Boat DO profiles after 4 days of operations



Downstream DO monitoring at RRI, Light 42 and Light 40 during August 11-17, 2008



UOP DO Survey and high-tide DO Profile from monitoring stations on Sept 11, 2009



"DO Increment Model" estimated distribution of added DO on Sept 11, 2009 at high tide

Aeration Facility Recommendations

- A long-term DWSC DO monitoring plan is needed to track natural DO and the added DO from the Aeration Facility.
- A long-term operational strategy for the Aeration Facility is needed to increase DO to meet the DWSC DO objectives.
- Integration of the Port of Stockton aeration facilities with the DWR Aeration Facility should be evaluated.
- TMDL implementation “accounting procedures” should be developed to: 1) track the likely causes of DO deficits, 2) estimate the benefits (credits) achieved with nitrification, the aeration facility, upstream river flows, and DWSC flows.

Possible Long-term Operations Strategy for the Aeration Facility

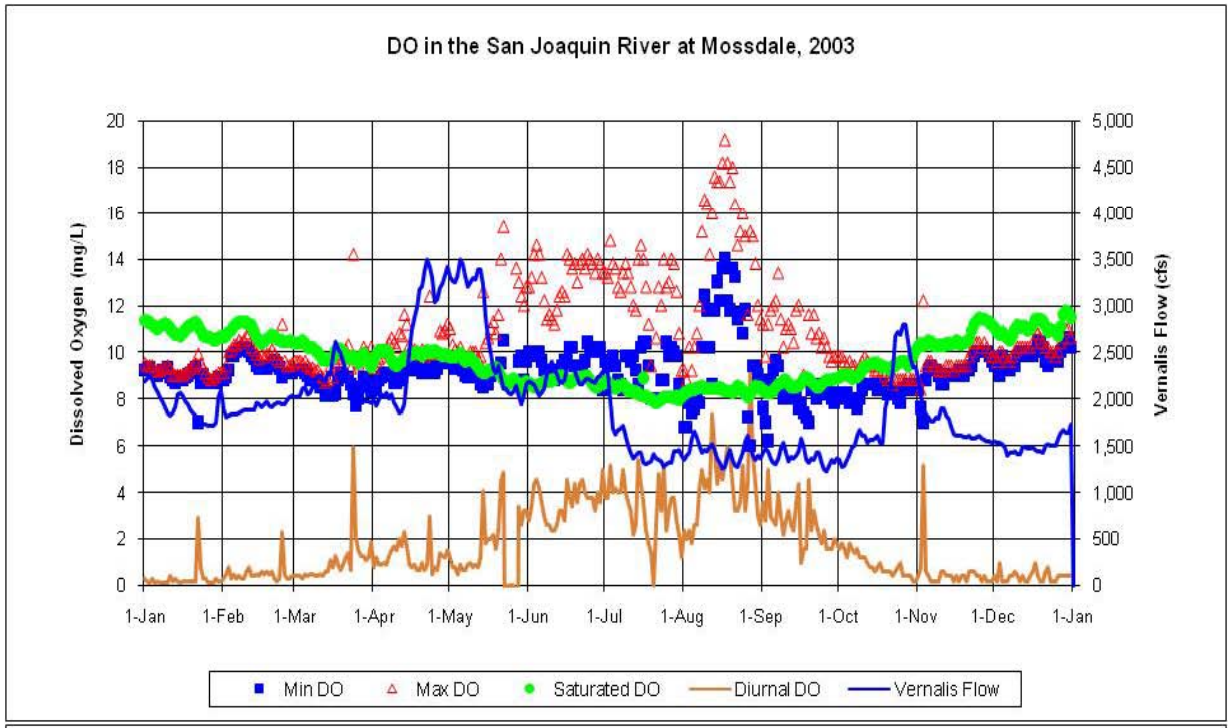
- The Aeration Facility is a reliable method for reducing periods when DO is below the DWSC objective and reducing the need for upstream BOD load reductions or SJR flow management.
- The TMDL accounting procedures could provide a forecast of needed aeration operations, based on SJR flow and algae.
- The effects of the Aeration Facility on the DWSC DO can be accurately estimated.
- The development and approval of TMDL “accounting procedures” by the CVRWQCB and stakeholders is necessary for determining responsibilities for future operations of the Aeration Facility.

Possible DO TMDL Accounting Procedures

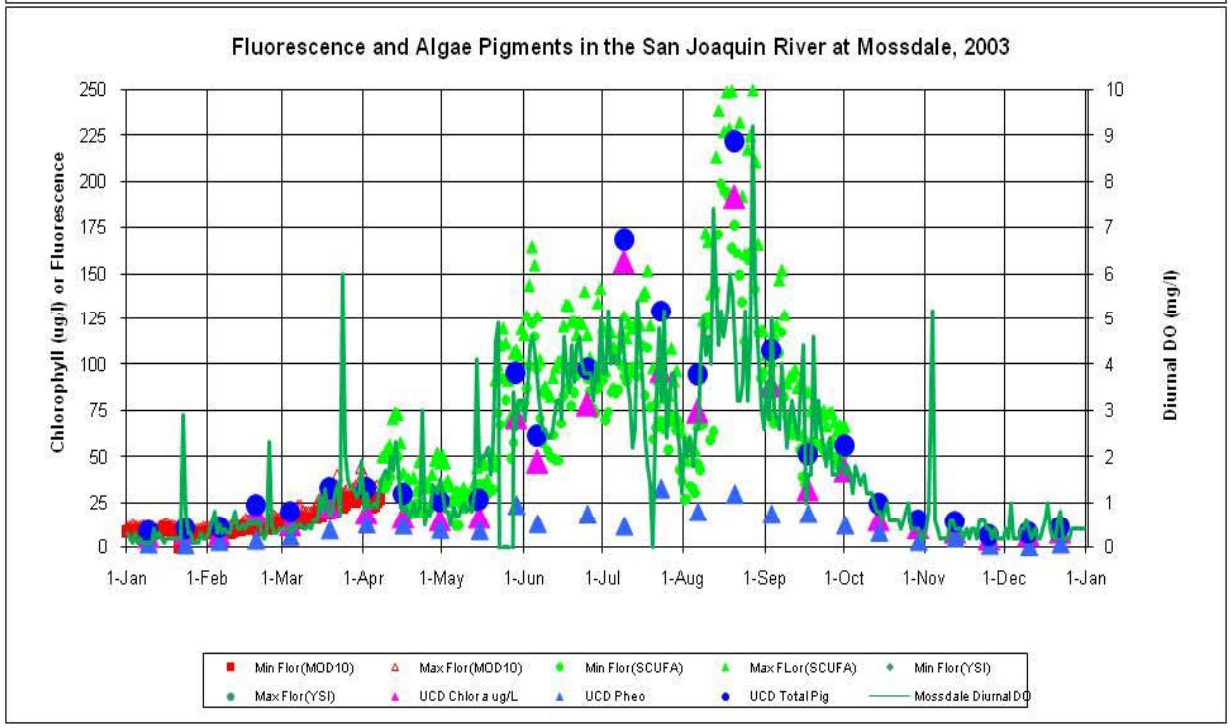
- What are the upstream SJR flow and algae effects on BOD concentrations at Mossdale?
- What are the effects of SJR flow (below the head of Old River) on transport of river BOD and dilution of RWCF?
- What are the combined effects of flow and inflow BOD on the minimum DO in the DWSC?
- What DO “credits” should be given to nitrification, flow augmentation or Aeration Facility operation?

Estimating the Upstream SJR Algae Pigment (and BOD) at Mossdale

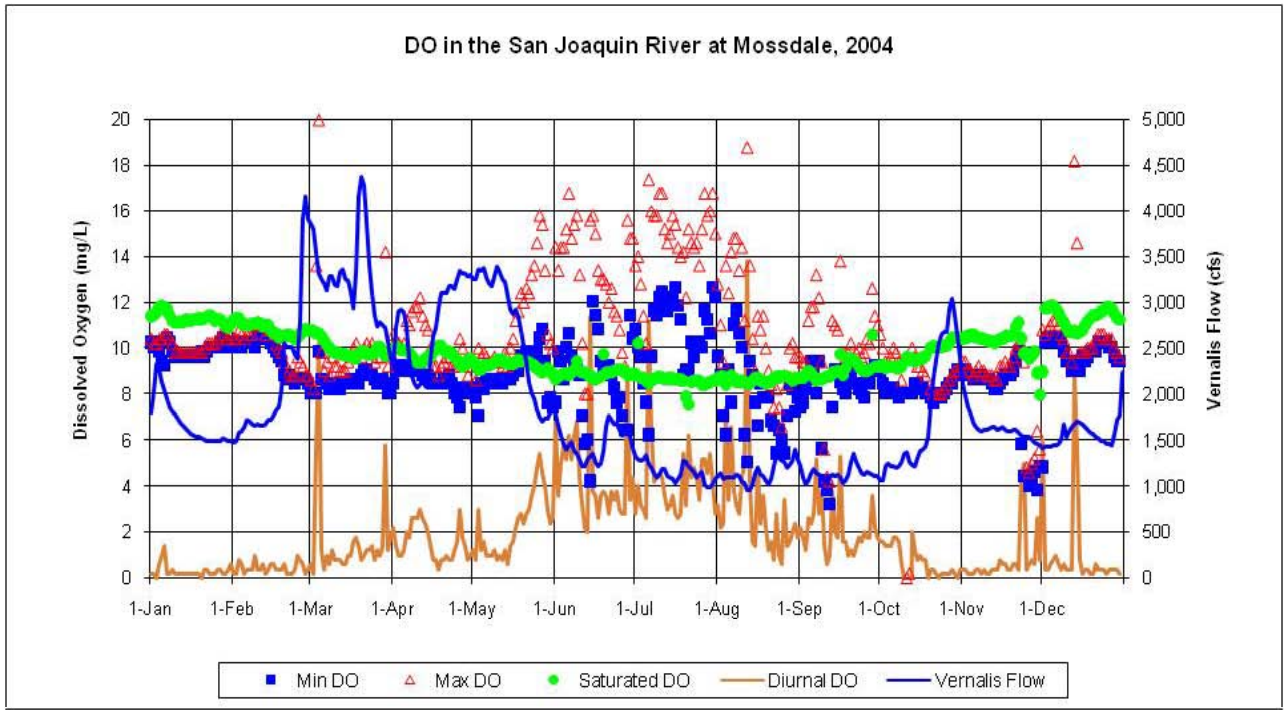
- Upstream TMDL studies and routine DWR monitoring at Mossdale indicate the maximum algae biomass is limited to the summer months of June-September
- There is a general correlation between algae pigment (µg/l), and fluorescence, and the diurnal range of DO (max – min), and pH, and VSS (mg/l), and BOD (mg/l).
- The maximum algae biomass occurs when the SJR flows in the summer months of June-September are less than 1,500 cfs.
- The chlorophyll concentration can be 200 µg/l with a daily DO range of 8 mg/l and an ultimate BOD of 20 mg/l

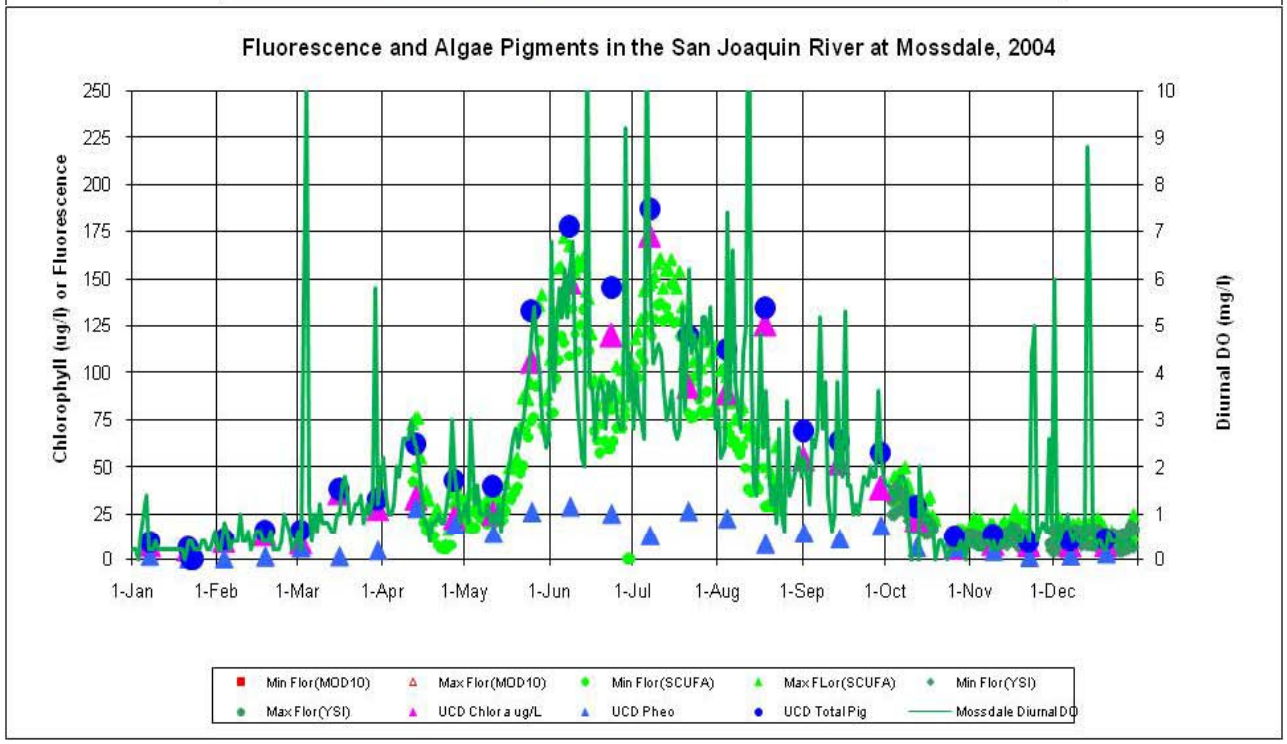


The daily DO range at Mossdale appears to be correlated to the algae biomass and pigment concentration (and fluorescence).



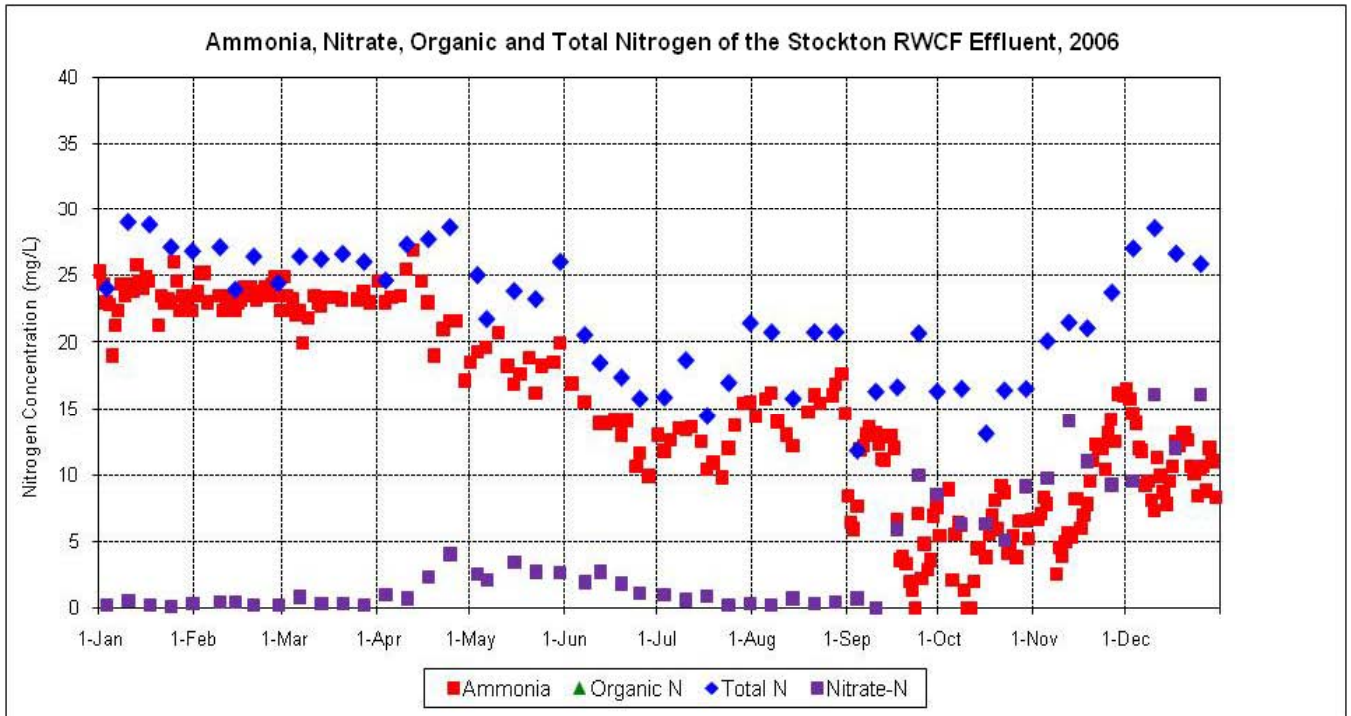
UC Davis data suggests that 1 mg/l of DO range is equivalent to about 25 µg/l of algae pigment.

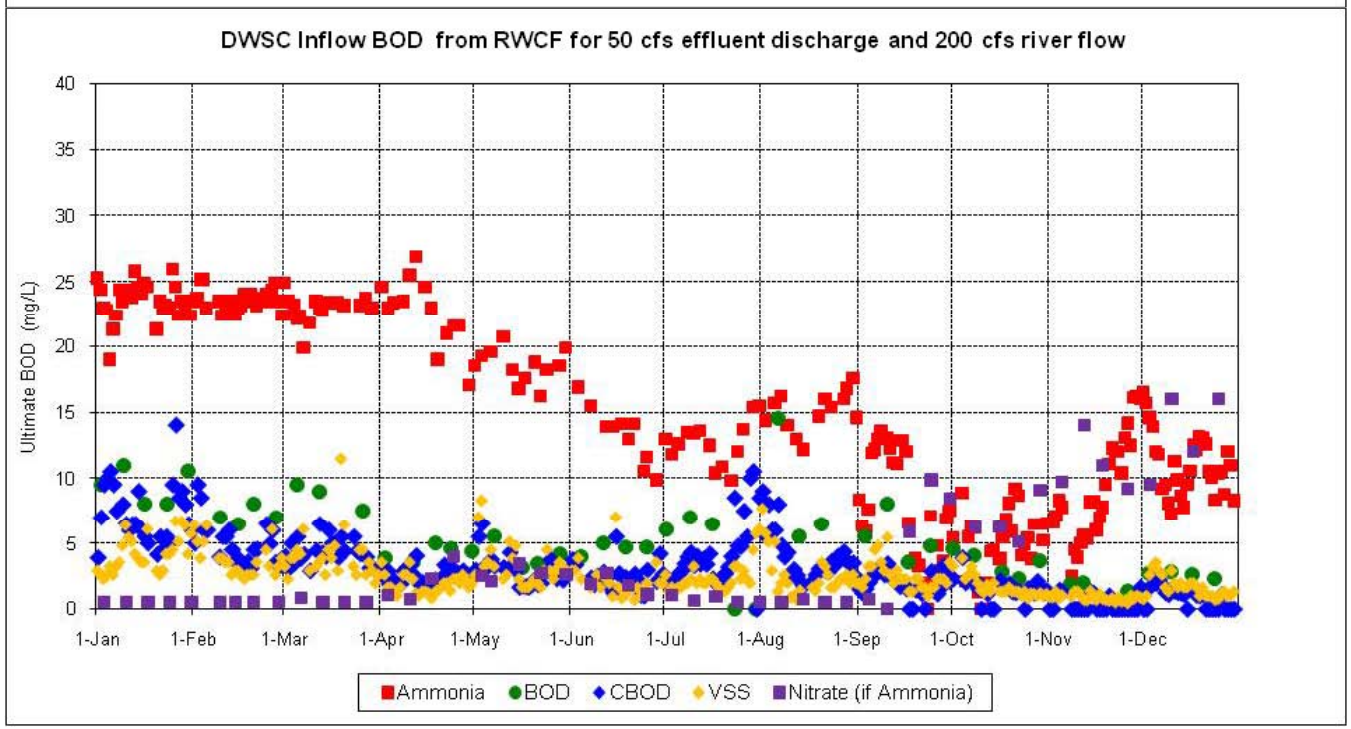




More analysis of the Mossdale DO and pH data should provide a more accurate estimate of algae BOD, and the relationship between SJR flow and algae.

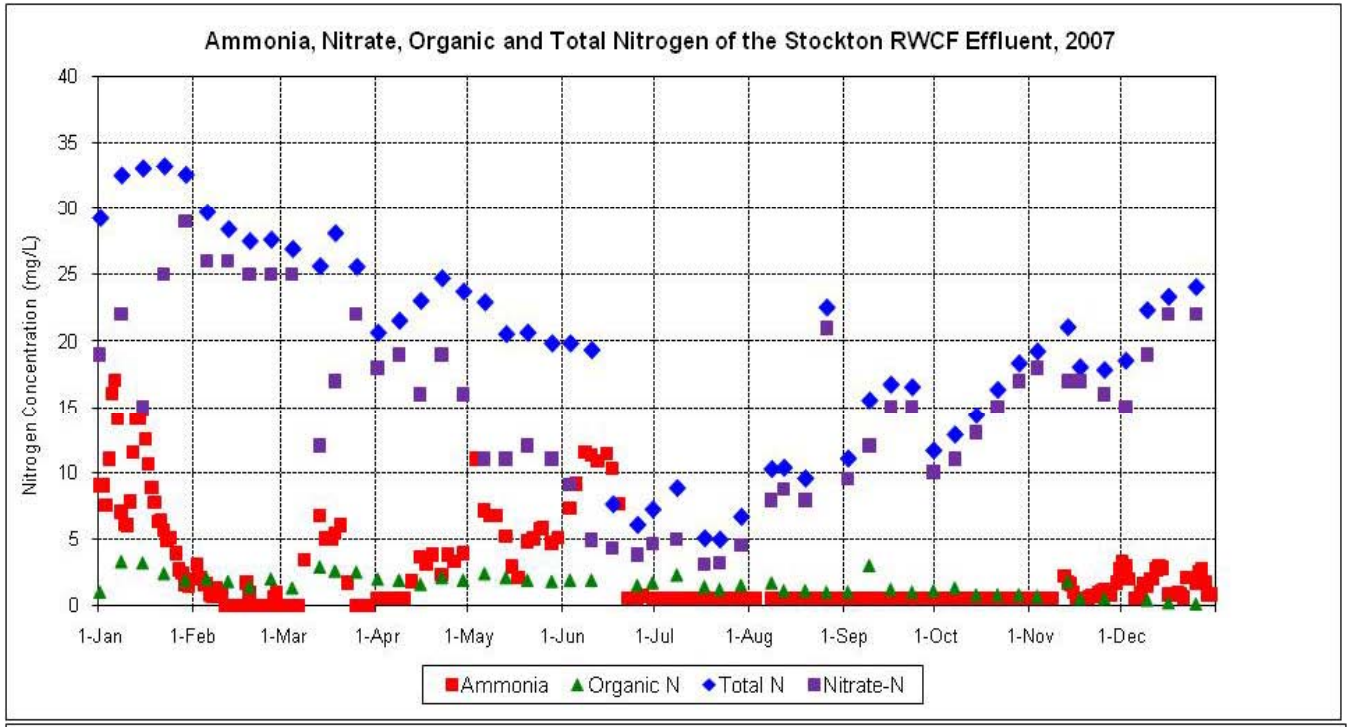
Additional BOD, VSS, and algae pigment samples from Mossdale would allow more accurate accounting of river algae effects on DWSC DO.



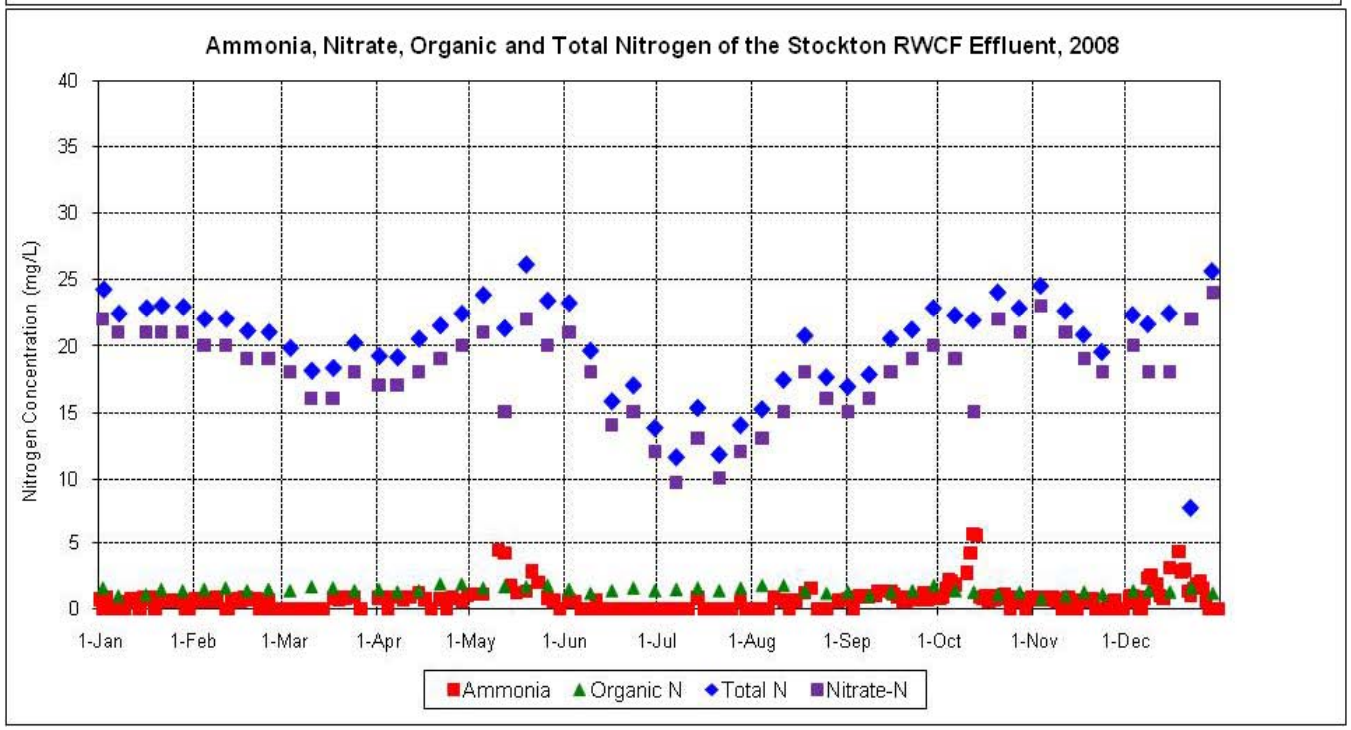


The RWCF CBOD and BOD concentrations are relatively low (5-10 mg/l). The major effect on DWSC DO has been ammonia.

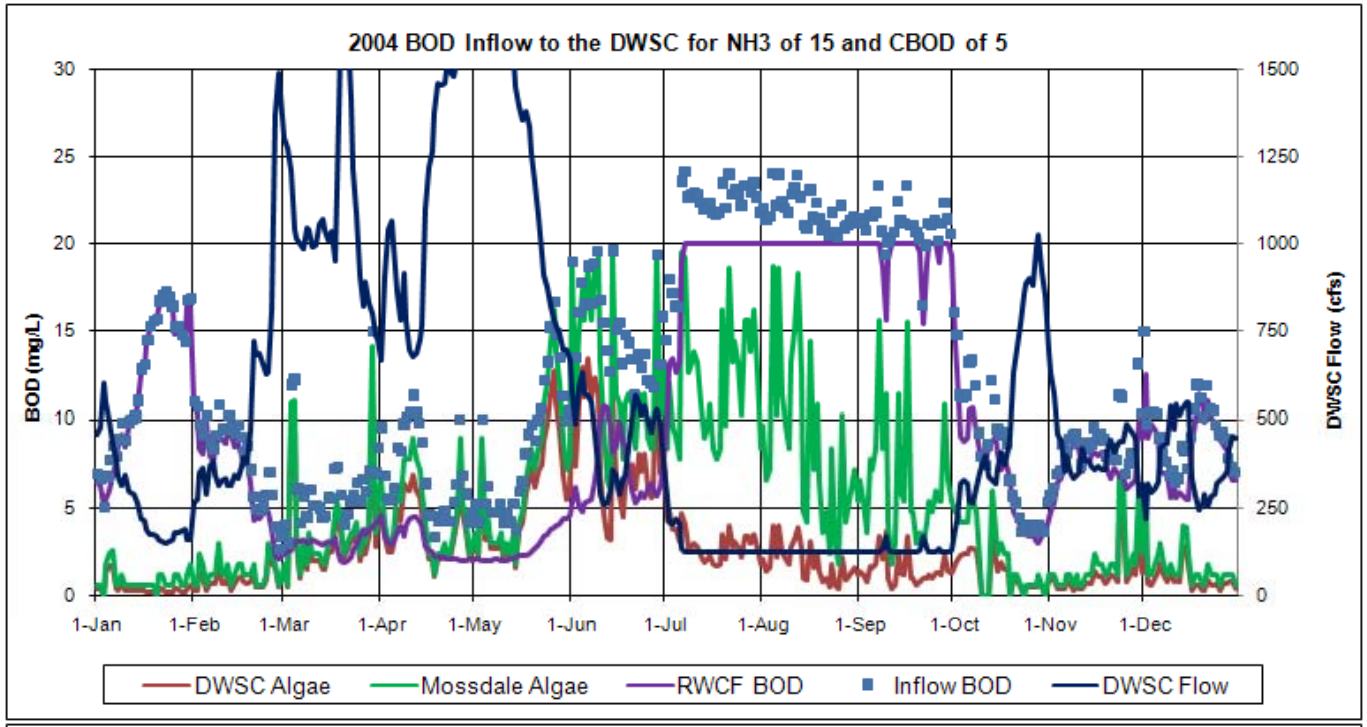
If the 50 cfs of RWCF effluent is diluted with 200 cfs of river water, the ultimate BOD inflow to the DWSC would be about 10 mg/l BOD and 25 mg/l from nitrification of the ammonia.



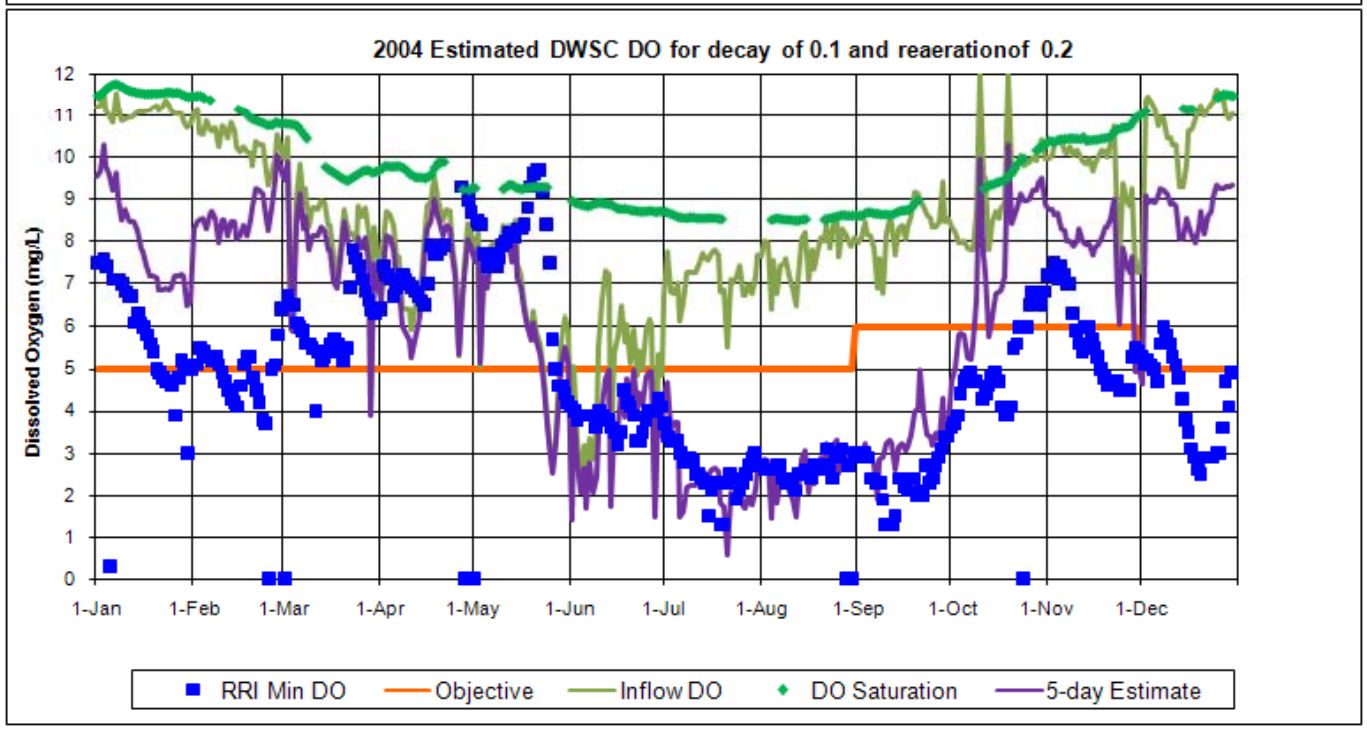
Since 2007 the RWCF effluent ammonia has been less than 2 mg/l.



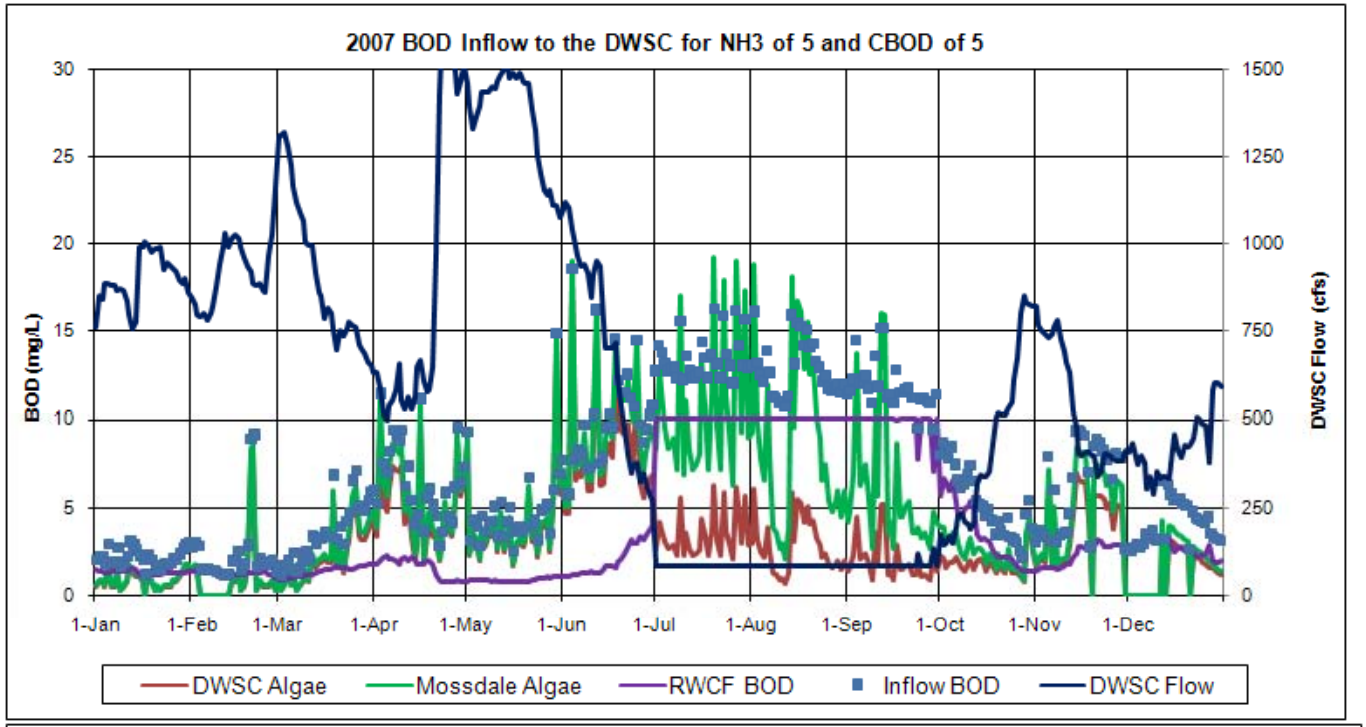
The DWSC DO Model indicates that a reduction of 4 mg/l of BOD will increase the minimum DO by 1 mg/l.



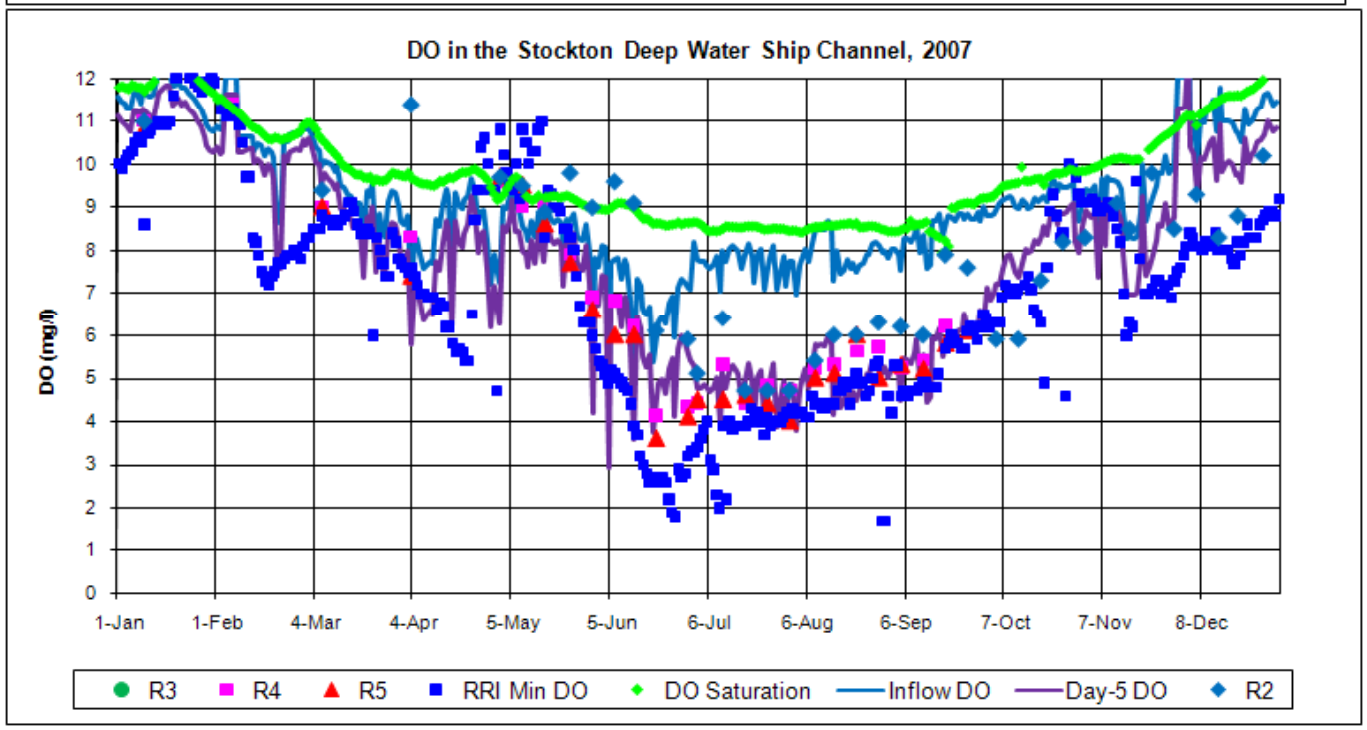
Estimates of inflow BOD from Mossdale algae (with decay) and RWCF effluent (with dilution) of 20-25 mg/l looks promising.



The estimates of inflow DO and 5-day (minimum) DO with a BOD decay of 0.1 per day appear to match the daily minimum RRI DO for 2004



RWCF nitrification reduced the inflow BOD to between 10 and 15 mg/l in 2007



The estimated 5-day (minimum) DO of 4-5 mg/l in the DWSC was higher in 2007 and matched the daily minimum RRI DO

TMDL Implementation Accounting

- Daily data reporting and accounting
- Data Atlas format for sharing and exploring
- Easy to compare and test assumptions
- Responsibility for operating aeration facility
- Identify effects of DWSC flow management
- Show nitrification benefits for DWSC DO