ARE WETLANDS A PROBLEM OR SOLUTION FOR BACTERIAL POLLUTION?

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ABSTRACT

Beaufort County partnered with the Town of Bluffton and BJWSA to evaluate the impacts of freshwater discharges during the cycle testing of BJWSA's new Aquifer Storage and Recovery (ASR) system. The cycle tests required discharging large amounts of treated drinking water into a ditch that flowed through a wetland. During earlier testing of the ASR system, a spike in fecal coliform was detected as part of a routine monitoring program. As a result of this spike, a monitoring plan was developed to better understand the implications of high quality water being discharged through a ditched wetland that ultimately flows to tidal creeks and tributaries of the May River.

The monitoring confirmed earlier data that increased freshwater discharge to ditched wetlands can lead to unexpected increases in fecal coliform loading to salt water estuaries. Increased fecal coliform loads have led to shellfish harvesting closures in certain areas of the County. These findings highlight the need to reduce excessive stormwater volume from development and recognize the finite hydraulic capacities of wetland receiving systems. Results from ongoing monitoring and the BJWSA testing are presented herein.

KEYWORDS

Runoff volume control, wetland hydraulics, ASR discharge impacts, fecal coliform loadings

INTRODUCTION

Beaufort County, SC is located between Charleston, SC and Savannah, GA. Due to its prime coastal location, the County has long been an attractive location for resort and other types of development. The County and the Town of Bluffton have been challenged by its citizens and leaders to be progressive in coastal resource management. As such, they have recently incorporated volume control into their stormwater management ordinances. This type of progressive attitude has kept 85% of shellfish (oyster) grounds open to harvesting since water quality controls were first adopted in 1998, despite the County's population increasing by over 30%.

The County has several unique coastal characteristics: 1) 50% of the County consists of open areas and salt marshes; 2) little upstream freshwater input; 3) shellfish harvesting and fishing are major economic and recreational activities; and 4) population growth has been rapid in recent decades. The impetus for the County's and Town's stormwater regulations came from shellfish bed closures in the mid-1990s. These closures led to heightened public awareness and political will in the County. The first round of controls began in the late 1990s and focused on maintaining water quality through the application of best management practices (BMPs) to clean and slow stormwater runoff.

After another shellfish closure in the May River in 2009, the County and Town investigated possible causes, and the volume of stormwater came under increased scrutiny. Increased stormwater volume from development projects was implicated in salinity changes, increased discharges into wetlands with increases in fecal coliform at wetland outlets, and impacts to fisheries. With direction from County Council, the County and then the Town developed a volume-based criterion based on a 95^{th} percentile storm event (derived from the federal facilities standard in the 2007 Energy Independence and Security Act). This 95^{th} percentile storm event in Beaufort County amounts to 1.95 inches in 24 hours. In developing the BMP manual to meet this criterion, it was discovered that the Equivalent Impervious Cover (EIC) concept historically used for water quality control design could be adapted for the new volume control criterion.

In 2009, the County and Town amended their stormwater ordinances to include volume controls, and in 2010, the County updated its BMP Manual. The revised manual details volume reduction and EIC credits for six stormwater practices that infiltrate, evapotranspire, and/or reuse runoff:

1. Rooftop practices (green roofs, evaporative cooling on flat roofs)
2. Pervious pavement
3. Runoff capture and use for irrigation
4. Disconnection of impervious areas
5. Rain gardens and other devices
6. Swales for runoff from highways and roadways

The updated manual outlines EIC credits for various combinations of BMPs, soils, and ponding depth/storage. It also contains a compliance worksheet to calculate EIC resulting from using a combination of practices. The County has applied these controls to individual lots if the development in which they are located failed to meet volume controls. These practices and volume reduction credits were described in a presentation at the 2010 SCEC conference (Wagner, 2010) and the on-lot controls at the 2011 SCEC conference (Ahern et al., 2011).

Given the pace of development within the County that only recently slowed due to the economic downturn, there was obvious concern for undetected fecal coliform loads being discharged by constructed stormwater management systems. Of some surprise, however, was that routine monitoring by the County and Town had shown unexpected increases in fecal coliform loads from wetlands and natural drainage systems. Fortunately, a unique partnering opportunity presented itself to shed light on this issue by testing uniform freshwater discharges during the cycle testing of Beaufort Jasper Water and Sewer Authority's (BJWSA) new Aquifer Storage and Recovery (ASR) system. A monitoring plan was developed with the help of local scientists, to better understand the result of high quality water being rapidly discharged in high volume through a ditched wetland.

MONITORING PLAN

The County and Town had been collecting weekly fecal coliform data in the May River and on January 13, 2012, detected an unusual increase in flow and fecal coliform concentration near a wetland outfall referred to as PBR-9 in Figures 1 and 2. This increase coincided in time with the initial test of the BJWSA ASR system. Further examination of fecal coliform concentrations in relation to BJWSA ASR system testing was viewed as an opportunity to learn more about the potential impacts on water quality of high volume discharges through wetlands and other natural drainage systems.

A monitoring scoping meeting was held March 11, 2011 and local scientists were invited to assist in developing a fecal coliform monitoring study that would assess the impacts of freshwater discharges to a small unnamed tributary of the May River. The location of the watershed and sampling locations are shown in Figure 1. The wetland area that the discharge passed through is shown in Figure 2. The watershed size of the unnamed tributary to the May River is about 400 acres. That portion of the watershed above the discharge point is 50 acres, while that portion above the last monitoring point before exiting the wetland (BECY 1.5) is 200 acres.

A sampling regimen was developed for the next ASR test scheduled for March 16-18, 2011 at a constant discharge rate of 1,700 gpm. The discharge started at 1700 hours on March 16 and ended at 1900 hours on March 18. This discharge rate is roughly equivalent to that generated by a 90th percentile storm (1.6 inch in 24 hours). Water samples were collected before, during and after the three day discharge at all locations following the schedule shown in Appendix 1. During the entire monitoring period there were no rainfall events. Fecal coliform concentrations are shown in Appendix 2 and average fecal coliform values for each sampling site are given in Table 1 below. As there was a concern that fecal coliform concentrations might vary throughout the water column, samples were taken near the surface (H) and approximately 2 inches from the bottom (L). This practice was discontinued during monitoring of the subsequent discharge test, as fecal coliform concentrations appeared to be rather uniform throughout the water column (see Appendix 3).

Table 1 – Sampling Point Averages Values in CFU/100 ml

Date/Site	PS	OPR4	BECY 1.5	PBR 9	SC-13
March 14, 2011	3	4781	1889	1088	903
March 15, 2011	15	3939	2136	2109	548
March 16 – pre discharge	122	7725	3401	12515	198
March 16 – after discharge	87	24308	21661	379	20
March 17, 2011	11	210	195	543	730
March 18, 2011	25	150	176	1243	556
March 19 – post discharge	27	2241	3396	2844	26
March 20, 2011	157	2590	6118	1324	22
March 21, 2011	10	1740	3900	9583	36

Based on the results of the March discharge test, modifications to the monitoring plan for the final discharge test were made. The final discharge was for 10 days (April 12-20, 2011) at a rate of 1700 gpm. Single water column samples and a new sampling station (SC-14, tributary to SC -13) were added to the protocol. Data for the final discharge test are presented in Appendix 4. Plans had been made to sample on the final day of discharge, but the discharge was discontinued early and samples were not taken.

FINDINGS

Both the March and April tests indicated that little flow left the watershed before and after the BJWSA discharge. Concentrations in wetland areas OPR4 and BECY 1.5 were high before discharge, increased precipitously shortly after discharge began, and then fell below pre-discharge levels until discharge ceased, at which time concentrations increased. While fecal coliform concentrations after the “first flush” rapidly decreased, the discharge obviously continued to result in substantial fecal coliform loadings to the May River as long as flow was adequate. While direct comparisons of the wetland concentrations of fecal coliform to the Food and Drug Administration’s shellfish harvesting criterion (14/43 Colony Forming Units (CFU)/100 ml) and South Carolina’s recreational criterion (200/400 CFU/100 ml) are inappropriate, they do serve to put the wetland results into context.

Data collected prior to the BJWSA discharge indicated that there were high background concentrations of fecal coliform within the ditched wetland that, under most conditions, never left the watershed. With the discharge, bacterial loading from the watershed dramatically increased. Estimated fecal coliform loadings during the March discharge are found in Table 2 below. Accurate estimates from the April test are more difficult to derive, as several minor rainfall events occurred in and around the time of discharge. Despite the obvious increase in loading that occurs, no clear evidence of an impact at the main stem station (SC-13) or its tributary (SC-14) was detected.

Table 2 – Estimated Fecal Load from Watershed in Total CFU

Date/Data	Wetland background concentration (BECY 1.5) in CFU/100ml	Load Leaving Wetlands at BECY 1.5 in Total CFU
March 14, 2011	1889	0
March 15, 2011	2136	0
March 16, 2011	3401/21661	585 billion
March 17, 2011	195	18.1 billion
March 18, 2011	176	12.9 billion
March 19, 2011	3396	0
March 20, 2011	6118	0
March 21, 2011	3900	0

SUMMARY

This study demonstrated that the fecal coliform load to the tidal headwaters of the May River is dependent, in part, upon the volume of water entering wetlands. Any additional discharge leaving a wetland above that which naturally occurs will increase loading, even if the discharge to the wetland has no load of its own. This is especially true when artificial conveyances exist in a wetland which limit its detention/retention capacity.

Wetlands have long been thought to be protective sinks for nutrient pollutants, a paradigm that might apply in many cases to bacterial pollutants as well. The data presented herein, however, suggest that wetlands may also serve as reservoirs for fecal coliform that can contribute significant loads to otherwise low concentration discharges. While the exact conditions under which this might occur are unknown in most cases, the reduction of stormwater runoff has the potential to significantly reduce bacterial loads exiting wetlands. Clearly, wetlands draining to tidal creeks have the capacity to do good. On the other hand, they can be hydraulically overloaded and such limitations need to be acknowledged.

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Ahern, D., Klink R., and Wagner, R. Developing On-Lot Stormwater Runoff Volume Controls, SCEC 2011 Annual Conference, March 2011.

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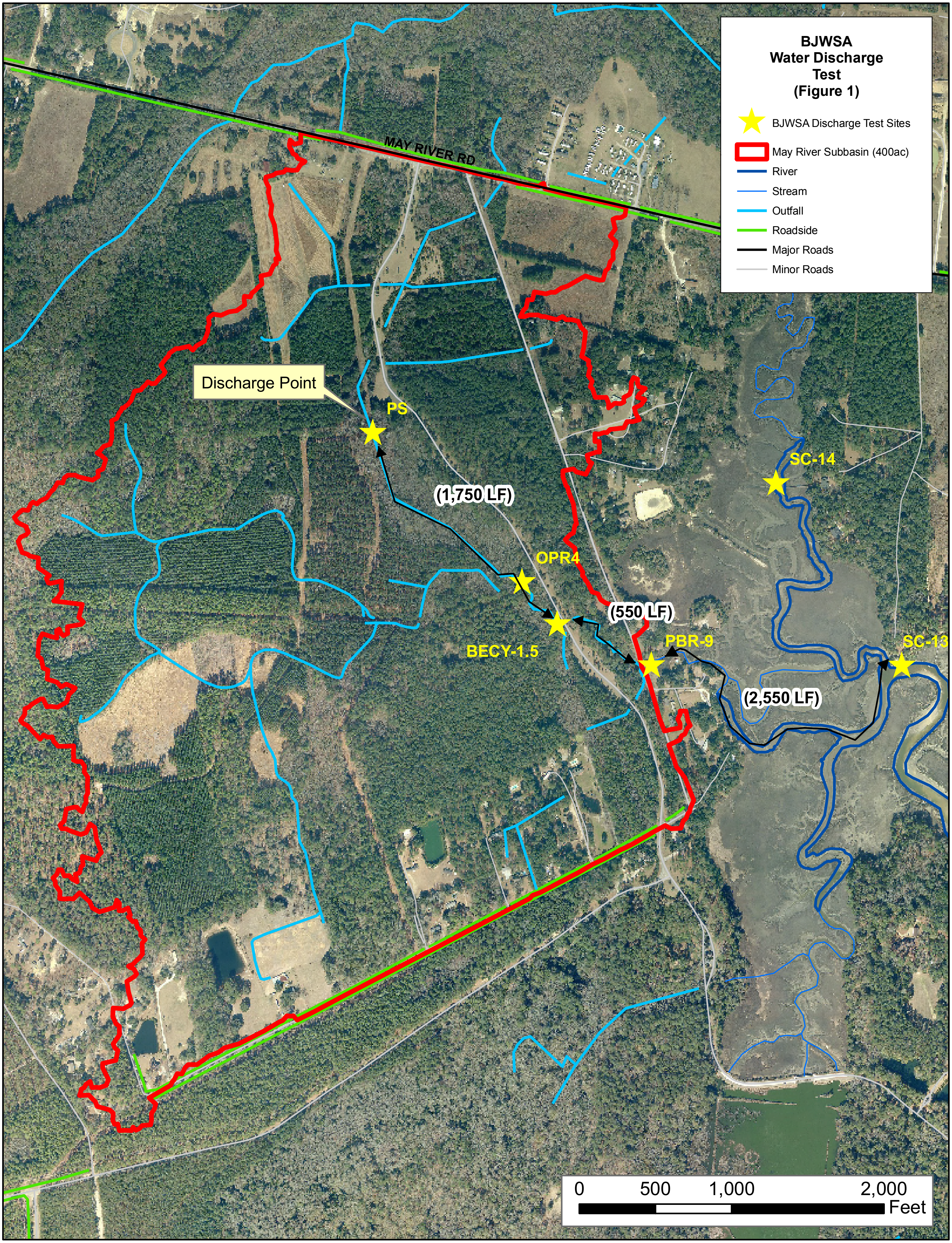
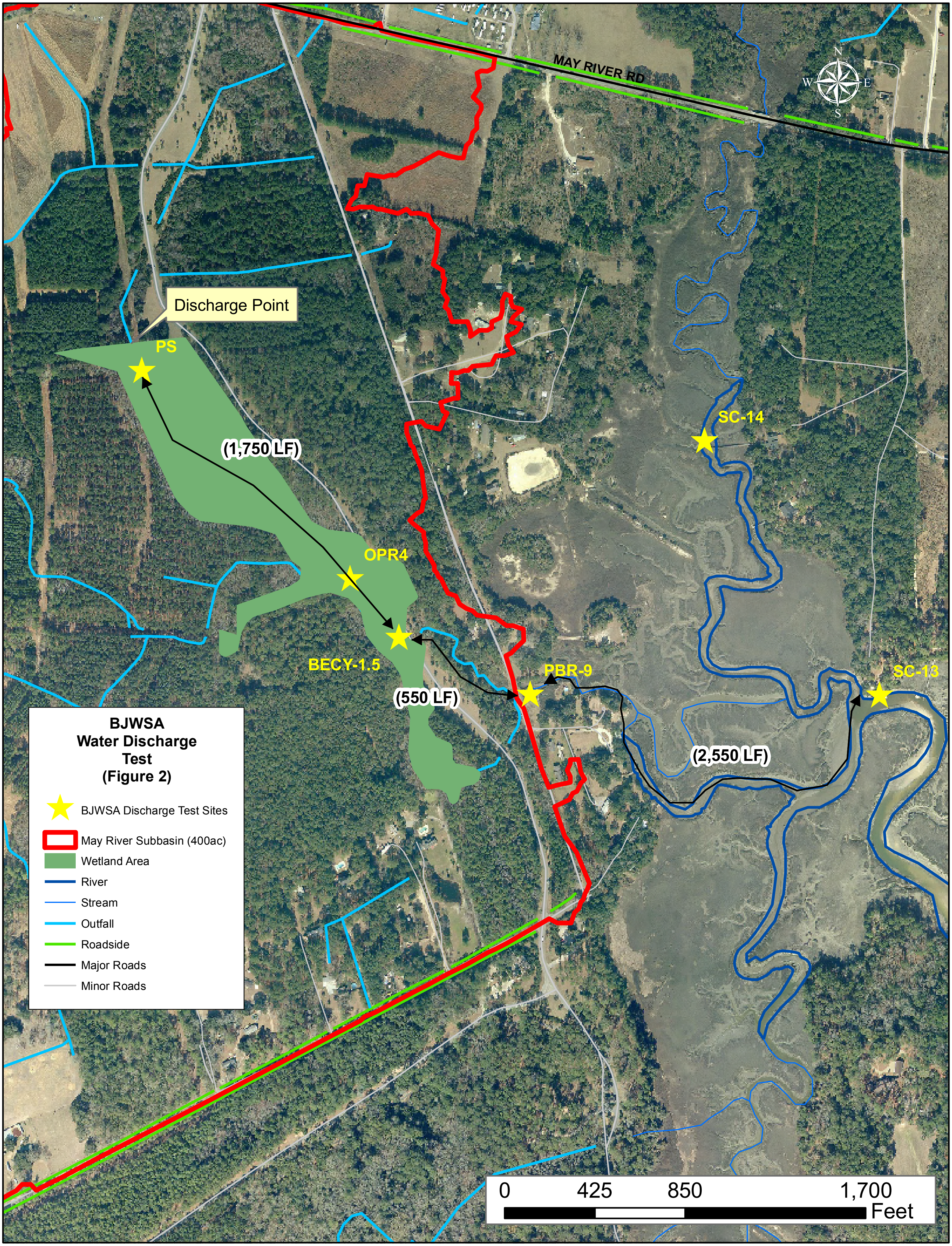
FIGURES

1. BJWSA Water Discharge Test
2. BJWSA Water Discharge Test wetlands

APPENDICES

1. BJWSA Field Sampling Schedule
2. Fecal coliform concentrations 3/14-3/21
3. High and Low Sample comparison
4. Fecal coliform results 4/11-4/25


BJWSA
Water Discharge
Test
(Figure 1)
BJWSA Discharge Test Sites
May River Subbasin (400ac)
River
Stream
Outfall
Roadside
Major Roads
Minor Roads
MAY RIVER RD
Discharge Point
PS
(1,750 LF)
OPR4
BECY-1.5
(550 LF)
PBR-9
SC-14
SC-13
(2,550 LF)
0
500
1,000
2,000
Feet



MAY RIVER RD
N
E
S
W
Discharge Point
PS
(1,750 LF)
OPR4
BECY-1.5
(550 LF)
PBR-9
SC-14
SC-13
(2,550 LF)
BJWSA
Water Discharge
Test
(Figure 2)
BJWSA Discharge Test Sites
May River Subbasin (400ac)
Wetland Area
River
Stream
Outfall
Roadside
Major Roads
Minor Roads
0
425
850
1,700
Feet

APPENDIX 1 – BJWSA ASR Field Sampling Schedule

H=SURFACE SAMPLES

L=LOWER SAMPLES (2” FROM BOTTOM)

	SITE ID	DATE 3/14/11	DATE 3/15/11	DATE 3/16/11	DATE 4/11/11	DATE 4/12/11
PRE-PROFILE	**PS R**	2H,2L	2H,2L	2H,2L	NS	NS
PRE-PROFILE	**PS M**	2H,2L	2H,2L	2H,2L	NS	NS
PRE-PROFILE	**OPR4 A**	2H,2L	2H,2L	2H,2L	2X	2X
PRE-PROFILE	**OPR4 B**	2H,2L	2H,2L	2H,2L	NS	NS
PRE-PROFILE	**BECY 1.5 A**	2H,2L	2H,2L	2H,2L	2X	2X
PRE-PROFILE	**BECY 1.5 B**	2H,2L	2H,2L	2H,2L	NS	NS
PRE-PROFILE	**PBR 9**	2X	2X	2X-Before flush	NS	NS
PRE-PROFILE	**SC-13**	2X	2X	2X Before flush	2X	2X
	SC-14	NS	NS	NS	2X	2X
	SAMPLER	BC/LAB	TOWN/USCB	TOWN/USCB	BC/USCB	BC/USCB

	SITE ID	DATE 3/16/11	DATE 3/17/11	DATE 3/18/11	DATE 4/12/11	DATE 4/13/11	DATE 4/14/11	DATE 4/21/11
FLUSH	**PS**	PM: 2X	AM:2X PM:2X	AM:2X PM:2X	NS	NS	NS	NS
FLUSH	**OPR4**	PM: 2X	AM:2X PM:2X	AM:2X PM:2X	2X	2x	2x	2x
FLUSH	**BECY 1.5**	PM: 2X	AM:2X PM:2X	AM:2X PM:2X	2X	2x	2x	2x
FLUSH	**PBR 9**	PM: 2X	AM:2X PM:2X	AM:2X PM:2X	NS	NS	NS	NS
FLUSH	**SC-13**	PM: 2X	AM:2X PM:2X	AM:2X PM:2X	Until bolus is caught	2x	2x	2x
FLUSH	**SC-14**	NS	NS	NS	2x	2x	2x	2x

	SITE ID	DATE 3/19/11	DATE 3/20/11	DATE 3/21/11	DATE 4/21/11	DATE 4/25/11
POST-PROFILE	**PS R**	2H,2L	2H,2L	2H,2L	NS	NS
POST-PROFILE	**PS M**	2H,2L	2H,2L	2H,2L	NS	NS
POST-PROFILE	**OPR4 A**	2H,2L	2H,2L	2H,2L	2X	2X
POST-PROFILE	**OPR4 B**	2H,2L	2H,2L	2H,2L	NS	NS
POST-PROFILE	**BECY 1.5 A**	2H,2L	2H,2L	2H,2L	2X	2X
POST-PROFILE	**BECY 1.5 B**	2H,2L	2H,2L	2H,2L	NS	NS

	SITE ID	DATE 3/19/11	DATE 3/20/11	DATE 3/21/11	DATE 4/21/11	DATE 4/25/11
POST-PROFILE	**PBR 9**	2X	2X	2X	NS	NS
POST-PROFILE	**SC-13**	2X	2X	2X	2X	2X
POST-PROFILE	**SC-14**	NS	NS	NS	2X	2X
	SAMPLER	TOWN/USCB	TOWN/USCB	BC/USCB	BC/USCB	BC/USCB

APPENDIX 2: Fecal Concentrations for BJSWA ASR3 3/14-3/21

------ Pre-profile ------ During flush ----- Post-profile

Col. Date	Site ID	MPN Fecal	Site ID	MPN Fecal	Site ID	MPN Fecal	Site ID	MPN Fecal	Site ID	MPN Fecal	Site ID	MPN Fecal
3/14/11	PS031411H#1R	10	PS031411L#1R	<1	OPR4031411H#1A	4332	OPR4031411L#1A	6896	BECY1.5031411H#1A	2053	BECY1.5031411L#1A	1720
3/14/11	PS031411H#2R	5	PS031411L#2R	1	OPR4031411H#2A	6017	OPR4031411L#2A	4286	BECY1.5031411H#2A	2176	BECY1.5031411L#2A	2092
3/14/11	PS031411H#1M	3	PS031411L#1M	<1	OPR4031411H#1B	3434	OPR4031411L#1B	5226	BECY1.5031411H#1B	2053	BECY1.5031411L#1B	1632
3/14/11	PS031411H#2M	2	PS031411L#2M	<1	OPR4031411H#2B	4604	OPR4031411L#2B	3450	BECY1.5031411H#2B	1724	BECY1.5031411L#2B	1666
3/14/11	PBR9031411#1	995	SC13031411#1	1120								
3/14/11	PBR9031411#2	1180	SC13031411#2	687								
3/15/11	PS031511H#1R	12	PS031511L#1R	10	OPR4031511H#1A	2755	OPR4031511L#1A	2828	BECY1.5031511H#1A	2481	BECY1.5031511L#1A	1812
3/15/11	PS031511H#2R	23	PS031511L#2R	5	OPR4031511H#2A	3255	OPR4031511L#2A	2238	BECY1.5031511H#2A	2359	BECY1.5031511L#2A	2152
3/15/11	PS031511H#1M	9	PS031511L#1M	10	OPR4031511H#1B	8664	OPR4031511L#1B	2492	BECY1.5031511H#1B	1664	BECY1.5031511L#1B	2238
3/15/11	PS031511H#2M	10	PS031511L#2M	43	OPR4031511H#2B	2064	OPR4031511L#2B	7218	BECY1.5031511H#2B	2755	BECY1.5031511L#2B	1626
3/15/11	PBR9031511#1	1935	SC13031511#1	579								
3/15/11	PBR9031511#2	2282	SC13031511#2	517								
3/16/11	PS031611H#1R	276	PS031611L#1R	60	OPR4031611H#1A	3968	OPR4031611L#1A	8704	BECY1.5031611H#1A	1576	BECY1.5031611L#1A	8212
3/16/11	PS031611H#2R	214	PS031611L#2R	175	OPR4031611H#2A	3784	OPR4031611L#2A	9768	BECY1.5031611H#2A	1918	BECY1.5031611L#2A	5206
3/16/11	PS031611H#1M	31	PS031611L#1M	78	OPR4031611H#1B	7701	OPR4031611L#1B	10950	BECY1.5031611H#1B	2064	BECY1.5031611L#1B	4356
3/16/11	PS031611H#2M	39	PS031611L#2M	103	OPR4031611H#2B	7701	OPR4031611L#2B	9222	BECY1.5031611H#2B	2613	BECY1.5031611L#2B	1262
3/16/11	PBR9031611#1	12997	SC13031611#1	164								
3/16/11	PBR9031611#2	12033	SC13031611#2	231								
3/16/11			PS031611#1PM	76			OPR4031611#1PM	24420			BECY1.5031611#1PM	25994
3/16/11			PS031611#2PM	98			OPR4031611#2PM	24196			BECY1.5031611#2PM	17328
3/16/11			PBR9031611#1PM	350			SC13031611#1PM	20				
3/16/11			PBR9031611#2PM	407			SC13031611#2PM	20				
3/17/11	PS031711#1AM	12	PS031711#1PM	6	OPR4031711#1AM	291	OPR4031711#1PM	93	BECY1.5031711#1AM	240	BECY1.5031711#1PM	109
3/17/11	PS031711#2AM	22	PS031711#2PM	3	OPR4031711#2AM	370	OPR4031711#2PM	88	BECY1.5031711#2AM	253	BECY1.5031711#2PM	176
3/17/11	PBR9031711#1AM	770	PBR9031711#1PM	326	SC13031711#1AM	84	SC13031711#1PM	980				
3/17/11	PBR9031711#2AM	821	PBR9031711#2PM	256	SC13031711#2AM	147	SC13031711#2PM	711				
3/18/11	PS031811#1AM	46	PS031811#1PM	4	OPR4031811#1AM	210	OPR4031811#1PM	93	BECY1.5031811#1AM	236	BECY1.5031811#1PM	117
3/18/11	PS031811#2AM	47	PS031811#2PM	2	OPR4031811#2AM	187	OPR4031811#2PM	112	BECY1.5031811#2AM	202	BECY1.5031811#2PM	150

3/18/11	PBR9031811#1AM	>2420	PBR9031811#1PM	210	SC13031811#1AM	31	SC13031811#1PM	1120				
3/18/11	PBR9031811#2AM	2176	PBR9031811#2PM	162	SC13031811#2AM	93	SC13031811#2PM	980				
3/19/11	PS031911H#1R	12	PS031911L#1R	34	OPR4031911H#1A	2827	OPR4031911L#1A	1842	BECY1.5031911H#1A	3106	BECY1.5031911L#1A	3466
3/19/11	PS031911H#2R	14	PS031911L#2R	39	OPR4031911H#2A	1540	OPR4031911L#2A	2599	BECY1.5031911H#2A	3106	BECY1.5031911L#2A	4839
3/19/11	PS031911H#1M	19	PS031911L#1M	16	OPR4031911H#1B	2092	OPR4031911L#1B	2827	BECY1.5031911H#1B	3973	BECY1.5031911L#1B	3106
3/19/11	PS031911H#2M	19	PS031911L#2M	59	OPR4031911H#2B	2240	OPR4031911L#2B	1961	BECY1.5031911H#2B	3973	BECY1.5031911L#2B	2599
3/19/11	PBR9031911#1	3635	SC13031911#1	27								
3/19/11	PBR9031911#2	2053	SC13031911#2	25								
3/20/11	PS032011H#1R	85	PS032011L#1R	221	OPR4032011H#1A	2176	OPR4032011L#1A	2586	BECY1.5032011H#1A	8665	BECY1.5032011L#1A	9932
3/20/11	PS032011H#2R	82	PS032011L#2R	275	OPR4032011H#2A	2738	OPR4032011L#2A	2738	BECY1.5032011H#2A	4332	BECY1.5032011L#2A	6499
3/20/11	PS032011H#1M	218	PS032011L#1M	91	OPR4032011H#1B	3635	OPR4032011L#1B	2053	BECY1.5032011H#1B	4604	BECY1.5032011L#1B	5600
3/20/11	PS032011H#2M	46	PS032011L#2M	240	OPR4032011H#2B	2738	OPR4032011L#2B	2053	BECY1.5032011H#2B	4082	BECY1.5032011L#2B	5231
3/20/11	PBR9032011#1	1298	SC13032011#1	26								
3/20/11	PBR9032011#2	1350	SC13032011#2	17								
3/21/11	PS032111H#1R	12	PS032111L#1R	9	OPR4032111H#1A	808	OPR4032111L#1A	1827	BECY1.5032111H#1A	2285	BECY1.5032111L#1A	4902
3/21/11	PS032111H#2R	10	PS032111L#2R	9	OPR4032111H#2A	995	OPR4032111L#2A	2176	BECY1.5032111H#2A	1984	BECY1.5032111L#2A	2624
3/21/11	PS032111H#1M	5	PS032111L#1M	10	OPR4032111H#1B	829	OPR4032111L#1B	6017	BECY1.5032111H#1B	2306	BECY1.5032111L#1B	5231
3/21/11	PS032111H#2M	11	PS032111L#2M	10	OPR4032111H#2B	1007	OPR4032111L#2B	265	BECY1.5032111H#2B	1937	BECY1.5032111L#2B	9932
3/21/11	PBR9032111#1	7068	SC13032111#1	35								
3/21/11	PBR9032111#2	12098	SC13032111#2	38								

APPENDIX 3: High and Low sample comparisons for sites PS, OPR4, BECY1.5

------ Pre-profile ----- Post-profile

Col. Date	Site ID PS	MPN Fecal	Site ID	MPN Fecal	Site ID	MPN Fecal	Site ID	MPN Fecal	Site ID	MPN Fecal	Site ID	MPN Fecal
3/14/11	*PS031411H#1R*	*10*	*PS031411L#1R*	*<1*	*OPR4031411H#1A*	*4332*	*OPR4031411L#1A*	*6896*	*BECY1.5031411H#1A*	*2053*	*BECY1.5031411L#1A*	*1720*
3/14/11	*PS031411H#2R*	*5*	*PS031411L#2R*	*1*	*OPR4031411H#2A*	*6017*	*OPR4031411L#2A*	*4286*	*BECY1.5031411H#2A*	*2176*	*BECY1.5031411L#2A*	*2092*
3/14/11	*PS031411H#1M*	*3*	*PS031411L#1M*	*<1*	*OPR4031411H#1B*	*3434*	*OPR4031411L#1B*	*5226*	*BECY1.5031411H#1B*	*2053*	*BECY1.5031411L#1B*	*1632*
3/14/11	*PS031411H#2M*	*2*	*PS031411L#2M*	*<1*	*OPR4031411H#2B*	*4604*	*OPR4031411L#2B*	*3450*	*BECY1.5031411H#2B*	*1724*	*BECY1.5031411L#2B*	*1666*
3/15/11	*PS031511H#1R*	*12*	*PS031511L#1R*	*10*	*OPR4031511H#1A*	*2755*	*OPR4031511L#1A*	*2828*	*BECY1.5031511H#1A*	*2481*	*BECY1.5031511L#1A*	*1812*
3/15/11	*PS031511H#2R*	*23*	*PS031511L#2R*	*5*	*OPR4031511H#2A*	*3255*	*OPR4031511L#2A*	*2238*	*BECY1.5031511H#2A*	*2359*	*BECY1.5031511L#2A*	*2152*
3/15/11	*PS031511H#1M*	*9*	*PS031511L#1M*	*10*	*OPR4031511H#1B*	*8664*	*OPR4031511L#1B*	*2492*	*BECY1.5031511H#1B*	*1664*	*BECY1.5031511L#1B*	*2238*
3/15/11	*PS031511H#2M*	*10*	*PS031511L#2M*	*43*	*OPR4031511H#2B*	*2064*	*OPR4031511L#2B*	*7218*	*BECY1.5031511H#2B*	*2755*	*BECY1.5031511L#2B*	*1626*
3/16/11	*PS031611H#1R*	*276*	*PS031611L#1R*	*60*	*OPR4031611H#1A*	*3968*	*OPR4031611L#1A*	*8704*	*BECY1.5031611H#1A*	*1576*	*BECY1.5031611L#1A*	*8212*
3/16/11	*PS031611H#2R*	*214*	*PS031611L#2R*	*175*	*OPR4031611H#2A*	*3784*	*OPR4031611L#2A*	*9768*	*BECY1.5031611H#2A*	*1918*	*BECY1.5031611L#2A*	*5206*
3/16/11	*PS031611H#1M*	*31*	*PS031611L#1M*	*78*	*OPR4031611H#1B*	*7701*	*OPR4031611L#1B*	*10950*	*BECY1.5031611H#1B*	*2064*	*BECY1.5031611L#1B*	*4356*
3/16/11	*PS031611H#2M*	*39*	*PS031611L#2M*	*103*	*OPR4031611H#2B*	*7701*	*OPR4031611L#2B*	*9222*	*BECY1.5031611H#2B*	*2613*	*BECY1.5031611L#2B*	*1262*
3/19/11	*PS031911H#1R*	*12*	*PS031911L#1R*	*34*	*OPR4031911H#1A*	*2827*	*OPR4031911L#1A*	*1842*	*BECY1.5031911H#1A*	*3106*	*BECY1.5031911L#1A*	*3466*
3/19/11	*PS031911H#2R*	*14*	*PS031911L#2R*	*39*	*OPR4031911H#2A*	*1540*	*OPR4031911L#2A*	*2599*	*BECY1.5031911H#2A*	*3106*	*BECY1.5031911L#2A*	*4839*
3/19/11	*PS031911H#1M*	*19*	*PS031911L#1M*	*16*	*OPR4031911H#1B*	*2092*	*OPR4031911L#1B*	*2827*	*BECY1.5031911H#1B*	*3973*	*BECY1.5031911L#1B*	*3106*
3/19/11	*PS031911H#2M*	*19*	*PS031911L#2M*	*59*	*OPR4031911H#2B*	*2240*	*OPR4031911L#2B*	*1961*	*BECY1.5031911H#2B*	*3973*	*BECY1.5031911L#2B*	*2599*
3/20/11	*PS032011H#1R*	*85*	*PS032011L#1R*	*221*	*OPR4032011H#1A*	*2176*	*OPR4032011L#1A*	*2586*	*BECY1.5032011H#1A*	*8665*	*BECY1.5032011L#1A*	*9932*
3/20/11	*PS032011H#2R*	*82*	*PS032011L#2R*	*275*	*OPR4032011H#2A*	*2738*	*OPR4032011L#2A*	*2738*	*BECY1.5032011H#2A*	*4332*	*BECY1.5032011L#2A*	*6499*
3/20/11	*PS032011H#1M*	*218*	*PS032011L#1M*	*91*	*OPR4032011H#1B*	*3635*	*OPR4032011L#1B*	*2053*	*BECY1.5032011H#1B*	*4604*	*BECY1.5032011L#1B*	*5600*
3/20/11	*PS032011H#2M*	*46*	*PS032011L#2M*	*240*	*OPR4032011H#2B*	*2738*	*OPR4032011L#2B*	*2053*	*BECY1.5032011H#2B*	*4082*	*BECY1.5032011L#2B*	*5231*
3/21/11	*PS032111H#1R*	*12*	*PS032111L#1R*	*9*	*OPR4032111H#1A*	*808*	*OPR4032111L#1A*	*1827*	*BECY1.5032111H#1A*	*2285*	*BECY1.5032111L#1A*	*4902*
3/21/11	*PS032111H#2R*	*10*	*PS032111L#2R*	*9*	*OPR4032111H#2A*	*995*	*OPR4032111L#2A*	*2176*	*BECY1.5032111H#2A*	*1984*	*BECY1.5032111L#2A*	*2624*
3/21/11	*PS032111H#1M*	*5*	*PS032111L#1M*	*10*	*OPR4032111H#1B*	*829*	*OPR4032111L#1B*	*6017*	*BECY1.5032111H#1B*	*2306*	*BECY1.5032111L#1B*	*5231*
3/21/11	*PS032111H#2M*	*11*	*PS032111L#2M*	*10*	*OPR4032111H#2B*	*1007*	*OPR4032111L#2B*	*265*	*BECY1.5032111H#2B*	*1937*	*BECY1.5032111L#2B*	*9932*

APPENDIX 4: Fecal Concentrations for BJSWA ASR3 4/11-4/25

------ Pre-profile ------ During flush ----- Post-profile

Col. Date	Site ID	MPN Fecal	Site ID	MPN Fecal	Site ID	MPN Fecal	Site ID	MPN Fecal
4/11/11	*SC14041111#1*	*731*	*OPR4041111#1*	*8665*	*SC13041111#1*	*>2420*	*BECY1.5041111#1*	*418*
4/11/11	*SC14041111#2*	*731*	*OPR4041111#2*	*7068*	*SC13041111#2*	*>2420*	*BECY1.5041111#2*	*711*
4/12/11	*SC14041211#1*	*560*	*OPR4041211#1*	*7766*	*SC13041211#1*	*553*	*BECY1.5041211#1*	*467*
4/12/11	*SC14041211#2*	*522*	*OPR4041211#2*	*5600*	*SC13041211#2*	*420*	*BECY1.5041211#2*	*431*
4/12/11	SC14041211#1PM	399	OPR4041211#1PM	11588	SC13041211#1PM	298	BECY1.5041211#1PM	12976
4/12/11	SC14041211#2PM	754	OPR4041211#2PM	8704	SC13041211#2PM	389	BECY1.5041211#2PM	8704
4/13/11	S14041311#1AM	690	OPR4041311#1AM	166	SC13041211#3PM	211	BECY1.5041311#1AM	219
4/13/11	SC14041311#2AM	472	OPR4041311#2AM	147	S13041311#1AM	821	BECY1.5041311#2AM	204
4/13/11	SC14041311#1PM	456	OPR4041311#1PM	172	SC13041311#2AM	821	BECY1.5041311#1PM	326
4/13/11	SC14041311#2PM	394	OPR4041311#2PM	249	SC13041311#1PM	381	BECY1.5041311#2PM	345
4/14/11	SC14041411#1AM	545	OPR4041411#1AM	128	SC13041311#2PM	335	BECY1.5041411#1AM	236
4/14/11	SC14041411#2AM	626	OPR4041411#2AM	129	SC13041411#1AM	260	BECY1.5041411#2AM	158
4/14/11	SC14041411#1PM	315	OPR4041411#1PM	185	SC13041411#2AM	345	BECY1.5041411#1PM	228
4/14/11	SC14041411#2PM	403	OPR4041411#2PM	192	SC13041411#1PM	403	BECY1.5041411#2PM	261
4/21/11	*SC14042111#1*	*1095*	*OPR4042111#1*	*255*	*SC13042111#1*	*221*	*BECY1.5042111#1*	*499*
4/21/11	*SC14042111#2*	*1226*	*OPR4042111#2*	*214*	*SC13042111#2*	*210*	*BECY1.5042111#2*	*615*
4/25/11	*SC14042511#1*	*922*	*OPR4042511#1*	*>4839*	*SC13042511#1*	*922*	*BECY1.5042511#1*	*2827*
4/25/11	*SC14042511#2*	*922*	*OPR4042511#2*	*>4839*	*SC13042511#2*	*690*	*BECY1.5042511#2*	*2827*