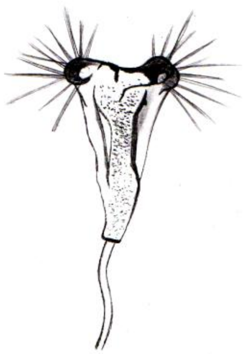
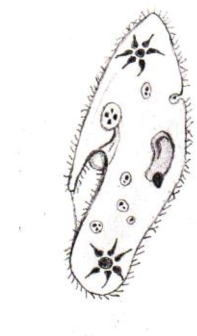


Comprehensive Aerated Stabilization Basin Evaluation

Pulp and Paper Mill

Southeastern United States



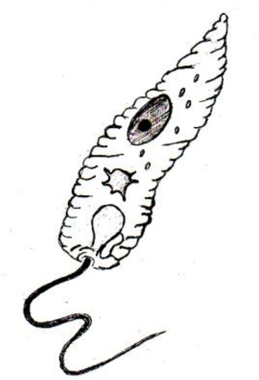
Conducted by:

Michael H. Foster

Beth Guidotti

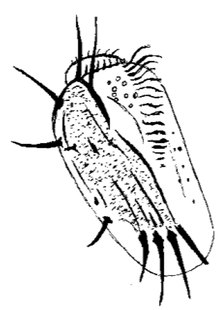
Todd Talley

Christopher Agosta



Environmental Business Specialists, LLC

Mandeville, LA



Study dates:

January 10 – February 15, 2006

Environmental
Business Specialists, LLC

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Executive Summary

The mill operates an integrated Kraft mill producing both coated and uncoated fine paper, as well as market pulp. The wastewater treatment system typically treats 22 – 26 MGD with an influent BOD concentration of 125 – 250 mg/l. The treatment system consists of two aerated basins, referred to as Pond 1 and Pond 2, and a settling basin, referred to as the Stabilization Basin. In late 2005, the mill contacted Mike Foster of Environmental Business Specialists (EBS) regarding increasing TSS in the effluent over the past five years particularly in the winter months. A review of the data showed that TSS levels had dramatically increased over the past two years (2004 and 2005), particularly in the winter months.

The purpose of this study was to investigate the causes of the increased TSS, with the basic premise being that the root cause was a loss of overall efficiency in Pond 1 (supported by the BOD data analysis.) Adequate time under aeration and adequate nutrient supply results in a healthier microbial mass, which in turn results in higher initial oxygen uptake rates, and more rapid soluble BOD conversion. This leads to faster floc formation, better settling solids and a lower supernatant TSS.

Beginning on January 11, EBS initiated a comprehensive evaluation of the ASB consisting of (a) a lithium tracer study to evaluate retention times and flow patterns; (b) an ASB performance profile for multiple parameters; (c) a nutrient balance; and (d) a treatability study utilizing respirometry to evaluate the benefits of supplemental nutrient addition, supplemental bioaugmentation, and increased retention time. The report presents the findings for each of these project areas along with recommendations for treatment system improvements.

This study and subsequent conversations revealed several factors contributing to the loss of performance observed over the recent years. These include:

- ***An increase in flow to the system of 15-20% -*** In addition to flow increases over the past few years, by comparison to others mills of a similar production capacity, this mill has historically a high water user.
- ***Significant volume loss in the system (>30%), due to sludge buildup*** – The previous survey found that current (2004) volumes in Pond 1 and Pond 2 were less than original.
- ***Poor flow pattern in the ASB by design –*** The influent line is located directly across from the barrier opening creating a high degree of short-circuiting.
- ***Elimination of nitrogen addition to the system –*** It is apparent that the system is nitrogen limited at least some of the time. Since bacterial reproduction decreases at lower temperatures, the problem manifests itself more so in the winter months.

The report concludes with several recommendations for system performance improvement, including:

- ***Evaluate water conservation options in the mill*** – Any reduction in flow will significantly improve the performance of the system by increasing retention time.
- ***Increase hydraulic retention time by recovering lost volume*** – Dredging the pond(s) may improve system performance, but is expensive and logistically difficult.

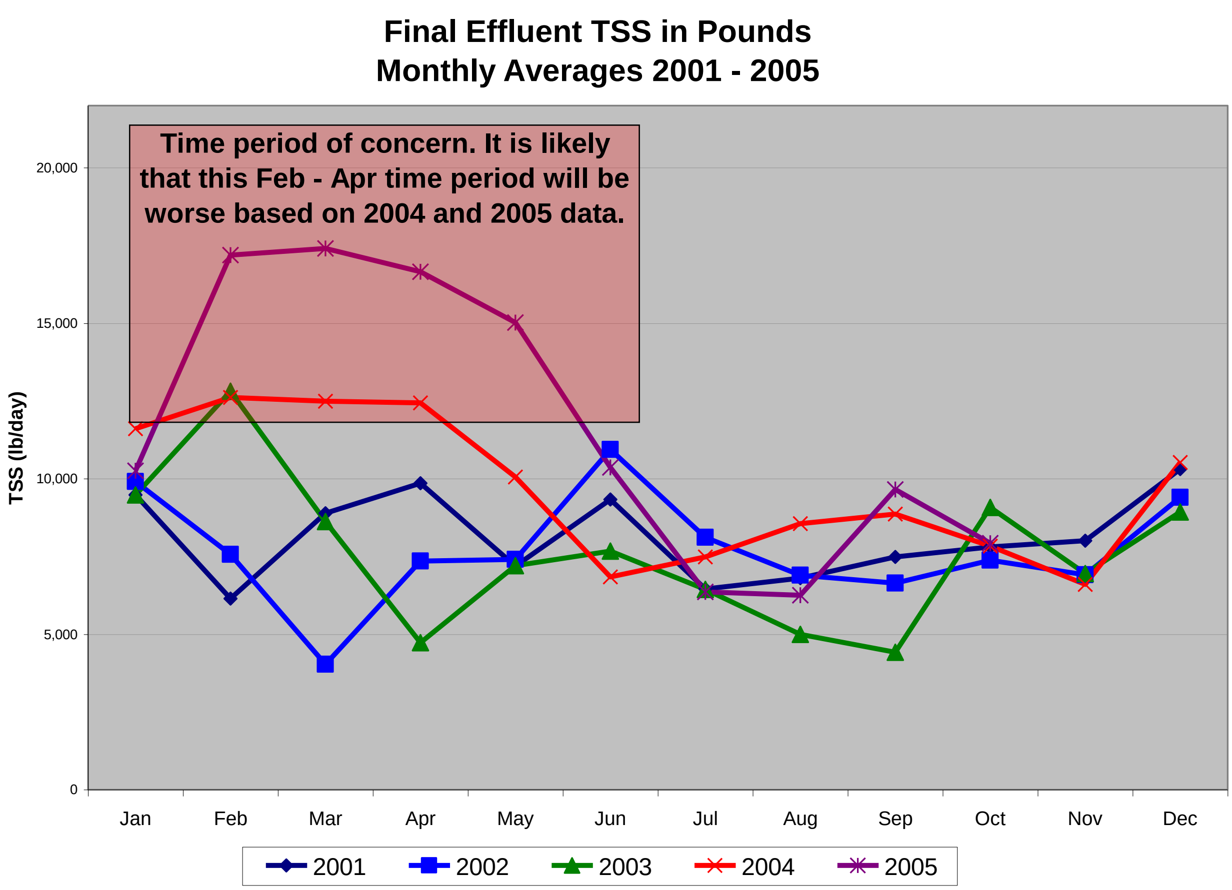
- ***Improve utilization of existing volume by adding baffle curtains to create more plug flow*** – This option offers both improved BOD conversion in the in the pre-barrier area and energy savings via aerator optimization (aerators utilized for BOD removal only.)
- ***Implement supplemental nitrogen addition with or without bio-augmentation*** – While the impact may not be as great as with other options, this is a low capital cost option that can be implemented quickly at any time.

Each of these options is discussed in greater detail in the report.

Introduction

The mill operates an integrated Kraft mill producing both coated and uncoated fine paper, as well as market pulp. The wastewater treatment system typically treats 22 – 26 MGD with an influent BOD concentration of 125 – 250 mg/l. The treatment system consists of two aerated basins, referred to as Pond 1 and Pond 2, and a settling basin, referred to as the Stabilization Basin. In late 2005, the mill contacted Mike Foster of Environmental Business Specialists (EBS) with concerns regarding increasing TSS in the effluent over the past five years particularly in the winter months. A review of the data showed that TSS levels had dramatically increased over the past two years (2004 and 2005). Figure 1 shows average effluent TSS concentrations each month from 2001 through 2005. During the winter months the data show significantly higher TSS concentrations in 2005 and 2004.

Figure 1



Further review of the BOD data suggested that the BOD conversion efficiency in the ASB had deteriorated over the time period. Figure 2 shows the actual BOD vales along with calculated soluble BOD values for Pond 1 for the period 2001 through 2005. Figure 3 shows the BOD trend for the pre-barrier area in 2004 and 2005, where the majority of BOD conversion should occur. These data suggest that soluble BOD conversion in the pre-barrier area is has deteriorated, particularly since 2004.

Figure 2

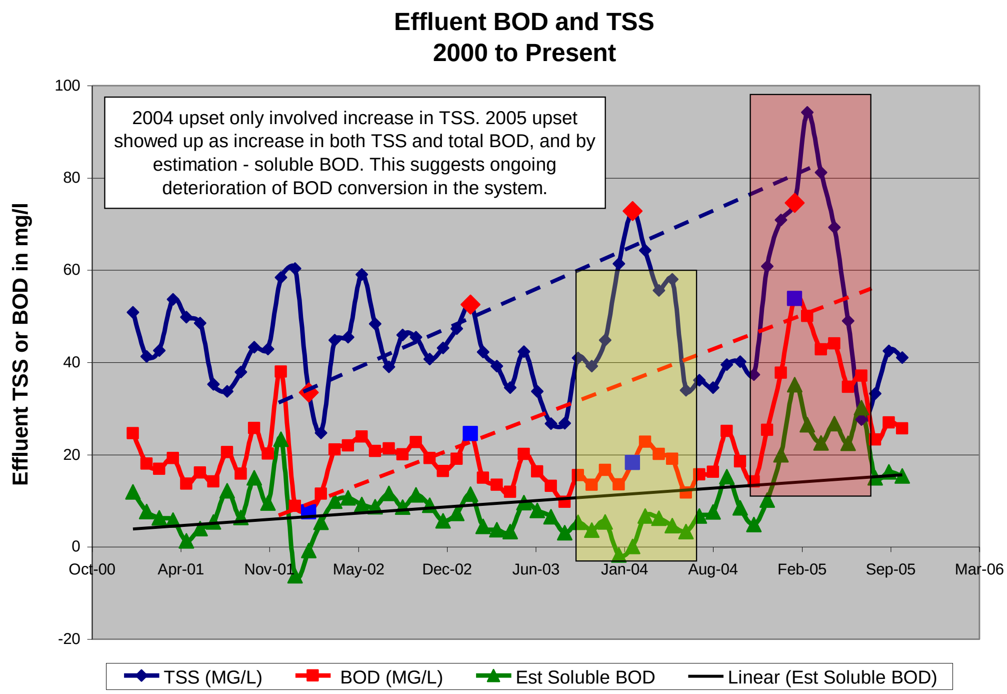
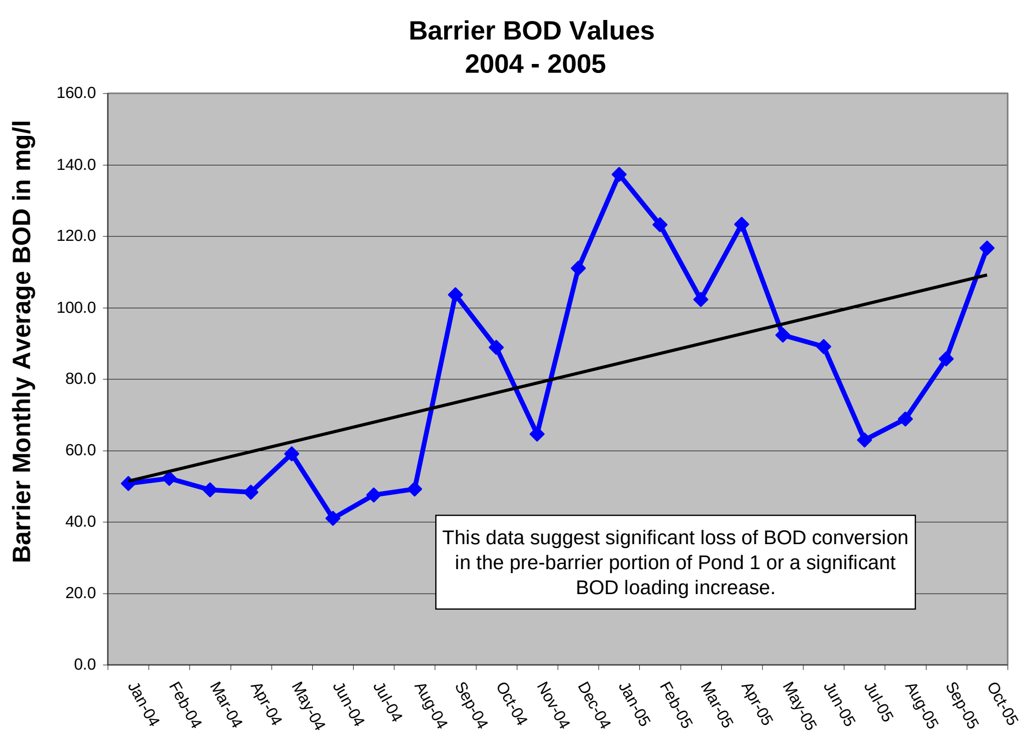
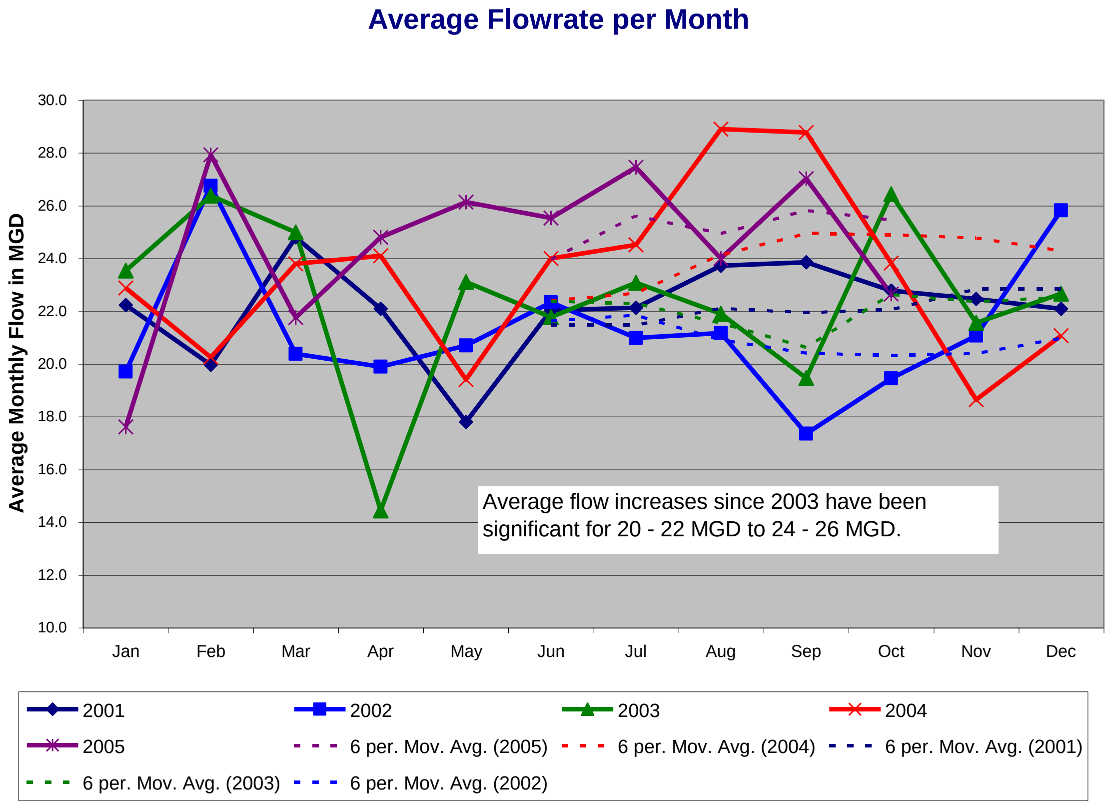


Figure 3



Lastly, the data show a significant increase in flow to the wastewater treatment system. Increases in flow reduce hydraulic retention time, which reduces the BOD removal efficiency. Reductions in hydraulic retention time are particularly problematic during the colder months of the year and further reduce the BOD removal efficiency. Figure 4 shows the average monthly effluent flow rates for 2001 – 2005.

Figure 4



The purpose of this study was to investigate the causes of the increased TSS, with the basic premise being that the root cause was a loss of overall efficiency in Pond 1 (supported by the BOD data analysis.) Adequate time under aeration and adequate nutrient supply results in a healthier microbial mass, which in turn results in higher initial oxygen uptake rates, and more rapid soluble BOD conversion. This leads to faster floc formation, better settling solids and a lower supernatant TSS.

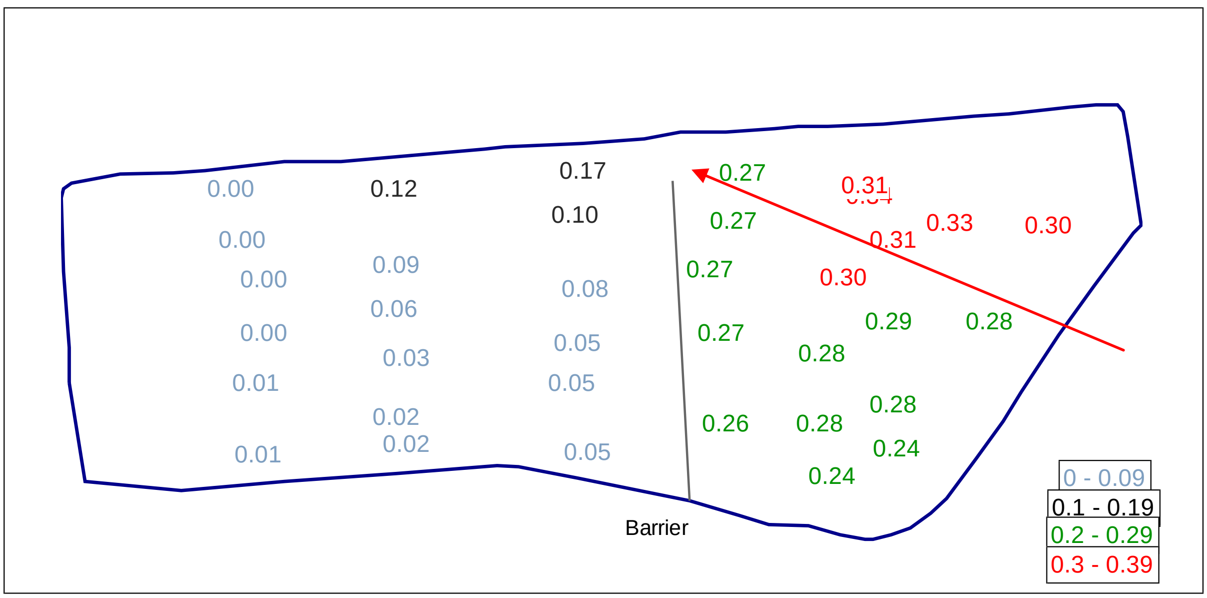
Beginning on January 11, EBS initiated a comprehensive evaluation of the ASB consisting of (a) a lithium tracer study to evaluate retention times and flow patterns; (b) an ASB performance profile for multiple parameters; (c) a nutrient balance; and (d) a treatability study utilizing respirometry to evaluate the benefits of supplemental nutrient addition, supplemental bioaugmentation, and increased retention time. The report presents the findings for each of these project areas along with recommendations for treatment system improvements.

Lithium Tracer Study

On January 11, EBS initiated a lithium tracer study to determine retention times in the ASB and settling ponds. Four drums of lithium chloride (146 pounds of Li) were added to the primary clarifier flume. Profile samples were taken at 36 locations throughout the ASB at four hours and twenty-four hours after lithium addition. Continuous samplers were set up at the barrier and the ASB Outlet and composite samples were used for Pond 2 and Pond 3. About 300 samples were collected over the next four weeks. These samples were analyzed for lithium concentration by an outside laboratory with extensive experience in lithium analyses in pulp and paper ASBs.

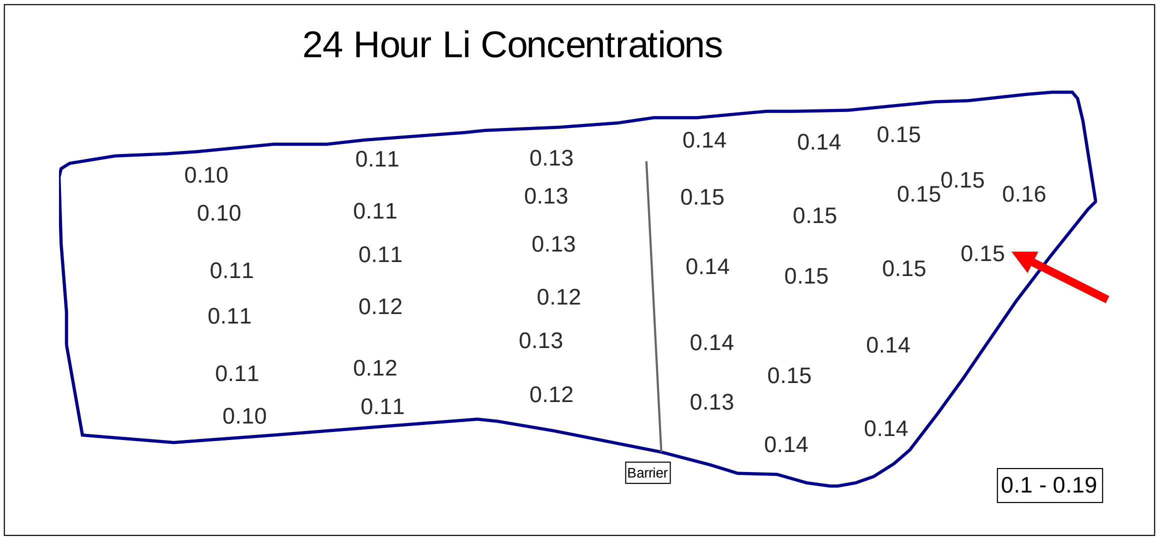
The four hour basin profile indicates that lithium was detected past the barrier, but that most of the lithium is still in the front section of the ASB. The lithium concentrations on the side of the pre-barrier area toward the opening were 25 – 30% higher than in the area away from the opening indicating that while the area is fairly well mixed, a significant portion of the lithium (and wastewater) shot straight across the pre-barrier area. Figure 5 shows the lithium concentration at the thirty-six ASB locations four hours after the tracer was added.

Figure 5 – Lithium Profile at 4 Hours



The 24-hour lithium profile showed that the concentrations are evenly spread throughout the pre-curtained area and a significant portion of the lithium (32%) had already reached the post-barrier section of Pond 1. At twenty-for hours measurable lithium concentrations were observed at the outlet of Pond 1. The results of the 24 hour profile are shown in Figure 6.

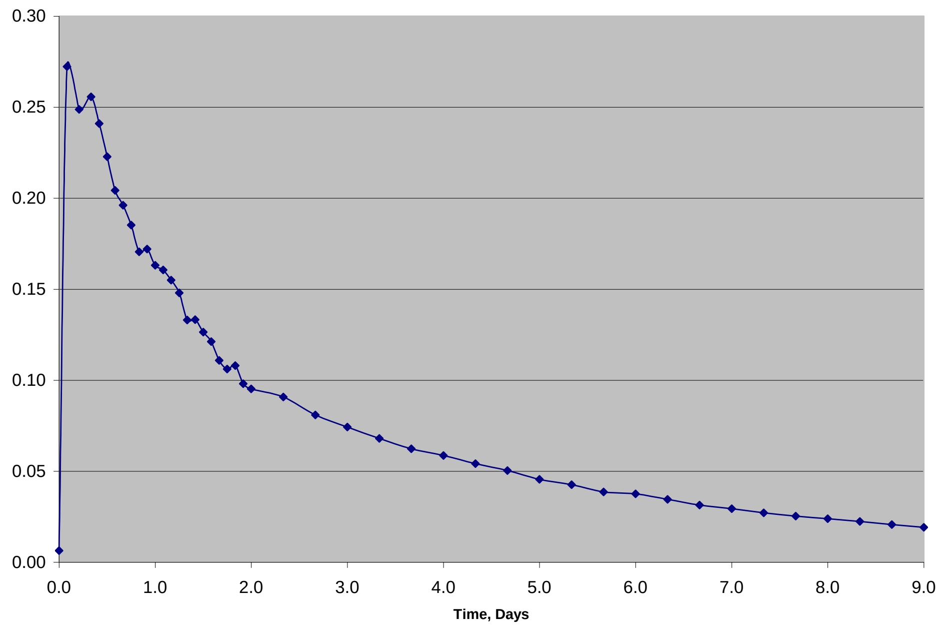
Figure 6 – Lithium Profile at 24 Hours



Retention Time Study

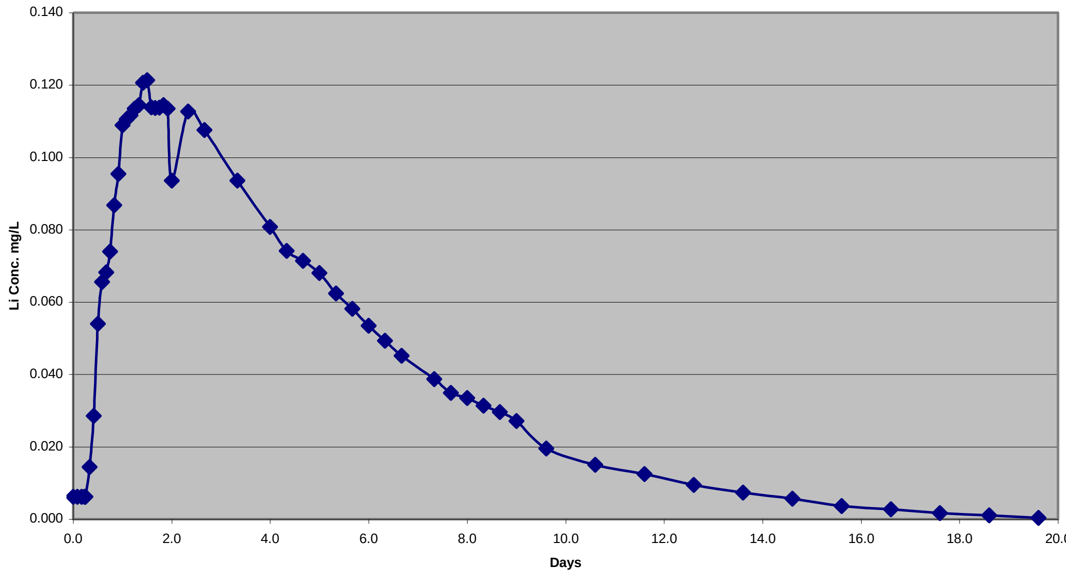
The lithium concentrations throughout the system were monitored over time and theoretical retention times calculated based on NCASI calculations. The lithium concentrations at the Barrier were monitored with an automatic grab sampler for nine days. Figure 7 shows the concentration at each sampling time. Based on these data a retention time of 2.73 days was calculated with 98% recovery of the lithium.

Figure 7 - Li Concentration at the Barrier



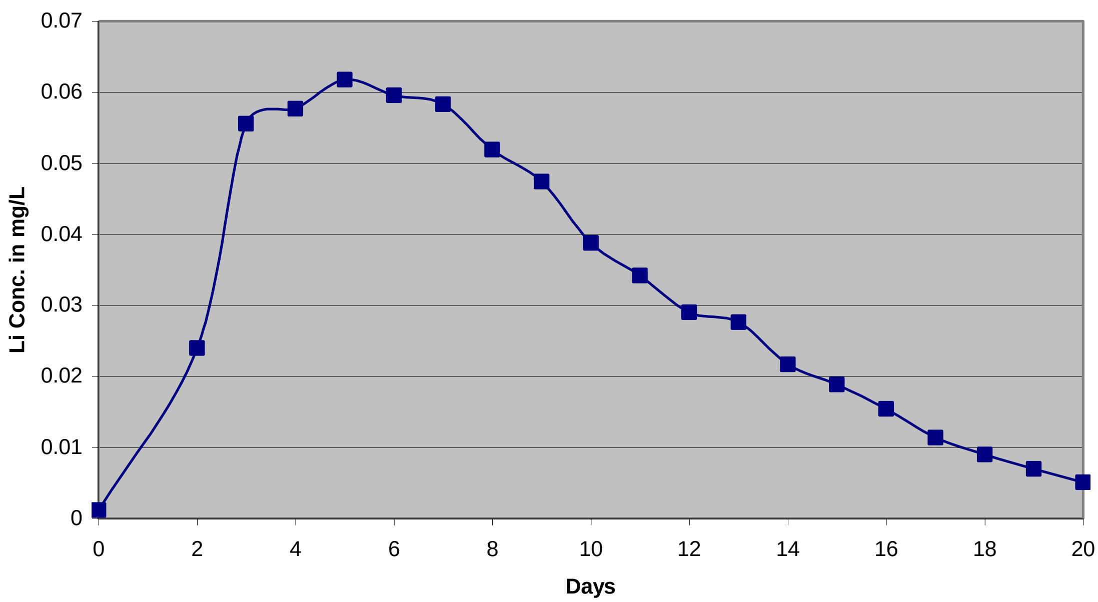
Lithium concentrations at the Pond 1 outlet were monitored with an automatic grab sampler for twenty days. Figure 11 shows the concentration over this twenty day period. A retention time of 3.89 days was calculated based on this data. Total lithium recovery was 98%.

Figure 8 – Li Concentration at Pond 1 Effluent



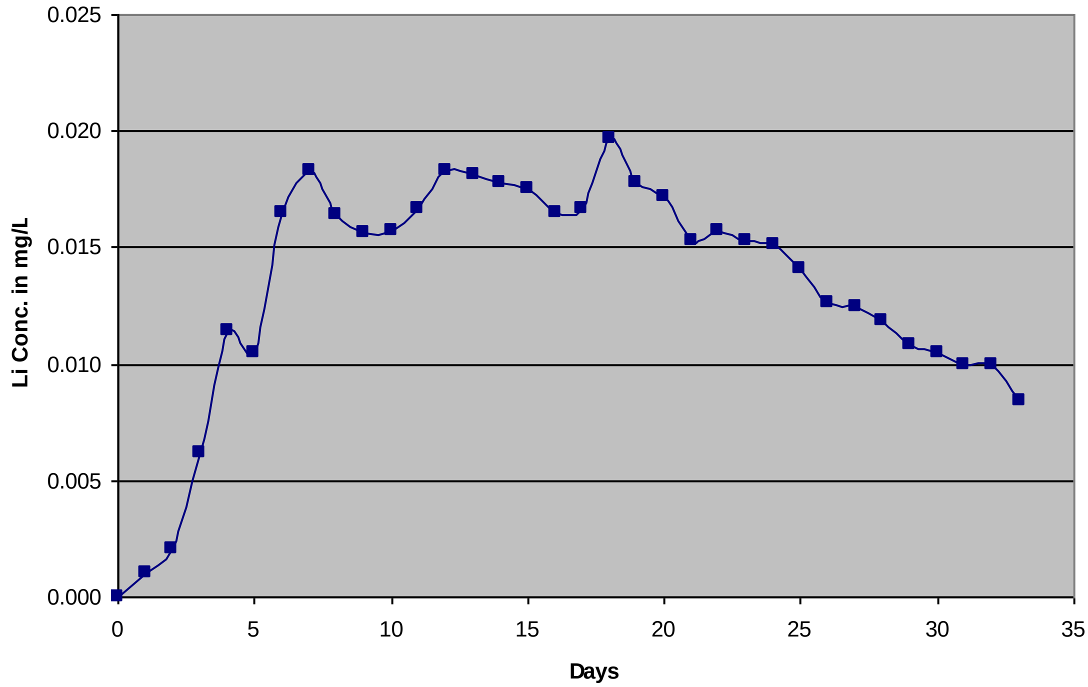
Lithium concentrations at the outlet of Pond 2 were collected for 20 days with a lithium recovery of 94% and a calculated mean retention time of 8.27 days.

Figure 9 - Lithium Concentrations – Pond 2



Lithium concentrations were measured in the Stabilization Pond effluent for 33 days. Lithium recovery was 64% with a calculated mean retention time of 17.2 days. The low lithium recovery relative to the other ponds indicates that the actual retention time of the system including the stabilization pond is greater than the calculated 17.2 days. However, the fact that measurable lithium showed up at the final outfall after only five or six days indicates significant short-circuiting in the final settling pond.

Figure 10 - Lithium Concentrations at Final Effluent



The data were analyzed using methods discussed in NCASI Technical Bulletin 408 and compared with original design data and current operating volumes based on the Dummer Engineering survey conducted in 2004. Table 1 summarizes the retention time data for the system.

Though the calculated retention times are close to the theoretical retention times, the time for the first appearance of tracer at each location indicates short circuiting. The NCASI calculation weighs the time at the end of the curve more heavily giving more impact to dead spots in the system than short circuiting.

The Morrill Index is a ratio of the 90% recovery time to the 10% recovery time. A Morrill Index of 1 indicates pure plug flow and an index of 22 hours indicates complete mix. A Morrill index above 22 would suggest short circuiting in conjunction with a basin approaching complete mix.

Table 1 – Summary of Retention Time Data

	Barrier	ASB Outlet	Pond 2	Final Effluent
Average Flow	26.2 mgd	25.1 mgd	25.1 mgd	25.1 mgd
Estimated Volume by Dummer Sludge Profile (MM gal)	55.7	75.9	87.6	471.8
Theoretical Retention Time Under Aeration	2.12 days	5.23 days	8.72 days	27.5 days
First Appearance of Tracer	2 hours	8 hours	24 hours	120 hours
10% Recovery	0.25 days	1.17 days	2.75 days	5.75 days
50% Recovery	2.0 days	3.79 days	7.08 days	16.5 days
90% Recovery	6.67 days	9.58 days	16.6 days	28.5 days
Retention Time - NCASI Calculation	2.73 days	4.79 days	8.25 days	17.2 days
% of Theoretical Retention Time	127%	92%	95%	63%
Morrill Index	27	8.2	6.0	5.0

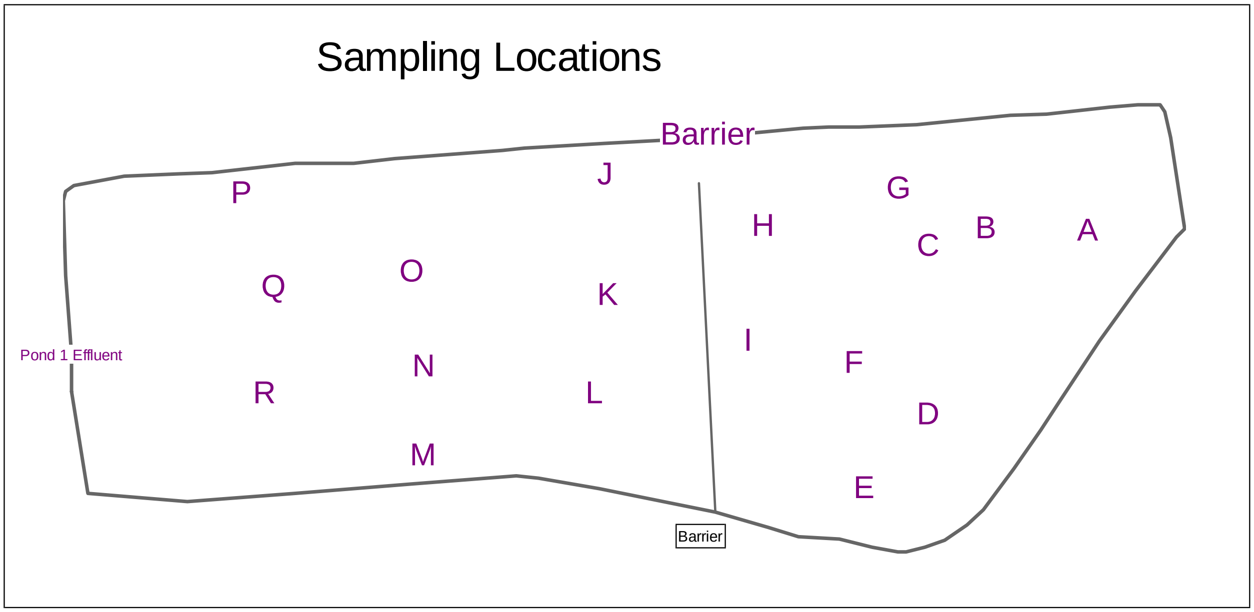
ASB Performance Profile Study

Samples were also taken throughout the pond for a profile study per the diagram in Figure 11. These samples were analyzed for: BOD, soluble BOD, TSS, pH, Total COD, Soluble COD, Nitrogen, Phosphorous, and DOUR. These results are summarized on Table 2 and plotted at the sample locations following the summary.

Table 2 – Sample Profile Analytical Results

Sample	BOD_5	$SBOD_5$	TSS	pH	TCOD	SCOD	N	N Probe	P	DOUR
Influent Composte from Previous Day	280		162	9.9	958	699		4.9	4.9	
A		51	166	7.23	515	260	0.12		2.8	3.9
B	**56**	33	174	7.21	536	270	0.06		2.8	3.4
C		39	170	7.24	520	269	0.06		3.4	4.6
D		75	156	7.23	541	257	0.08		3.6	3.6
E	**77**	72	158	7.34	537	287	0.08		3.1	5.5
F		33	168	7.25	537	274	0.04		3.7	4.0
G		33	158	7.21	531	266	0.08		3.1	4.1
H	**63**	33	164	7.23	540	278	0.04		3.3	4.0
I		30	164	7.23	540	264	0.06		3.4	5.5
Barrier	**57**	30	162	7.28	517	260	0.02	0.08	3.4	4.3
J		29	139	7.19	527	254	0.06		3.5	4.1
K		20	109	7.11	409	229	0.00		3.7	2.3
L		20	109	7.08	406	216	0.00		3.9	2.9
M		20	101	7.16	380	210	0.00		4.2	2.2
N	**43**	20	103	7.16	435	209	0.00		4.1	1.8
O		15	112	7.16	426	225	0.00		3.9	2.2
P		14	79	7.28	333	201	0.54		4.0	1.0
Q	**27**	14	79	7.25	341	221	0.36		4.2	0.9
R		14	91	7.13	362	215	0.38		4.4	1.2
Pond 1 Effluent	**27**	15	92	7.32	351	219	0.48	0.82	4.7	0.8
Pond 2 Effluent	**22.5**	8	56	7.23	300	197	2.6	2.37	3.9	0.6

Figure 11 – Sample Locations in the ASB



The ammonia profile for Pond 1 (Figure 12) indicates ammonia deficiency throughout the pre-barrier section as well as much of the remainder of Pond 1. The ammonia concentrations increase near the outlet of Pond 1 due to benthic feed back or possibly some slowly degradable organic amine compounds.

Figure 12 – Ammonia Profile in the ASB

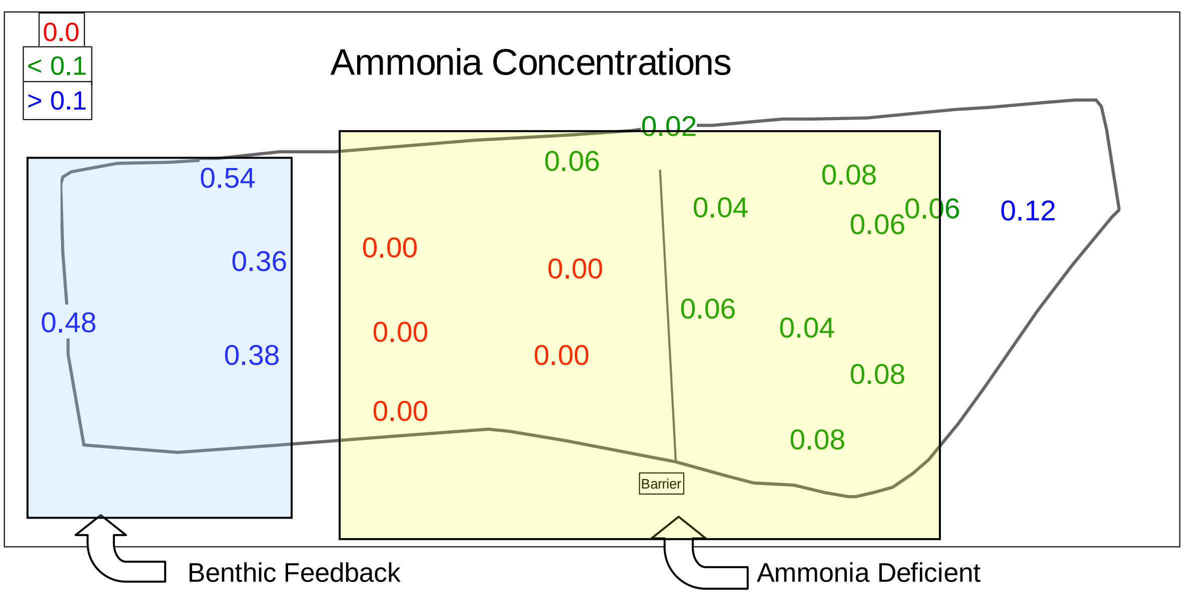
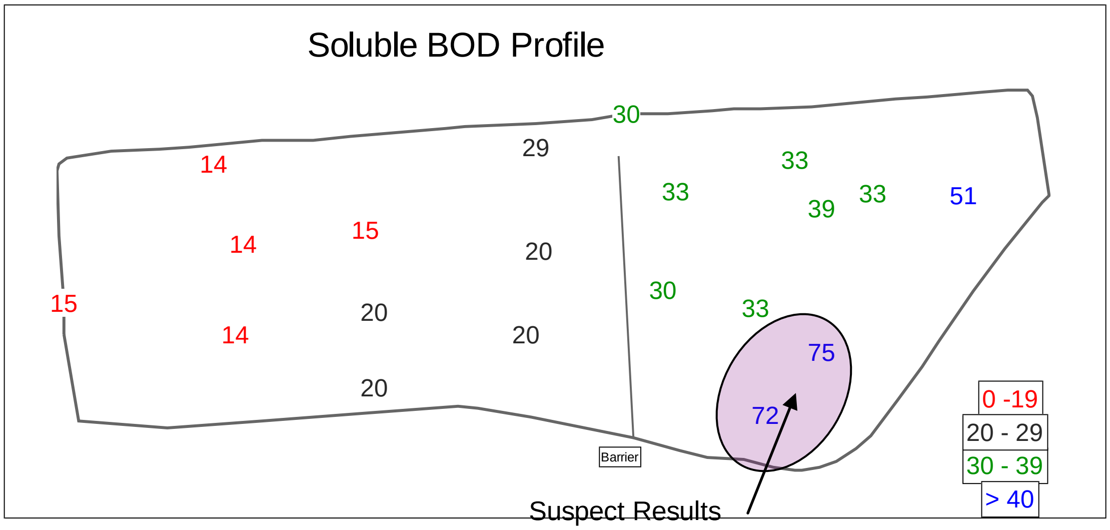


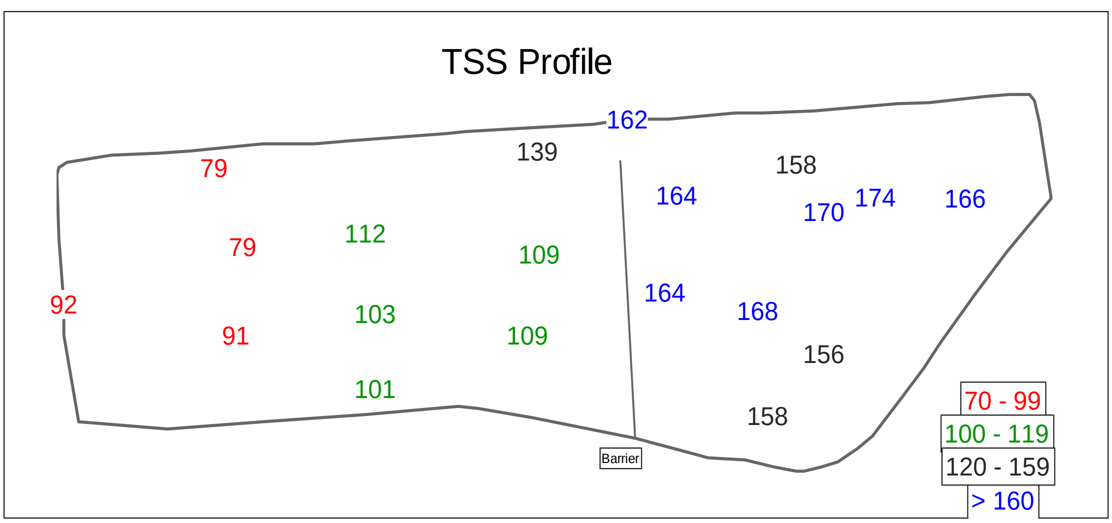
Figure 13 shows the soluble BOD profile. The respirometry study indicated that improved BOD results can be obtained with four days of aeration.

Figure 13 - Soluble BOD Profile in the ASB



The TSS profile also shows relatively good mixing in the pre-barrier area, though the area away from the barrier opening had lower TSS levels, indicating some settling is occurring in that area. Significant settling occurs after the barrier as would be expected due to the reduced amount of aeration and mixing in this area.

Figure 14 - TSS Profile in Pond 1



Dissolved oxygen uptake rate (DOUR) is a measure of biological activity of a sample and is akin to a five minute BOD test. Higher DOUR values indicate more biological activity due to more remaining food (BOD). The DOUR profile indicates good biological activity throughout the pre-barrier area with the most of the remaining BOD stabilization occurring in the second half of Pond 1.

Figure 15 - DOUR Profile in Pond 1

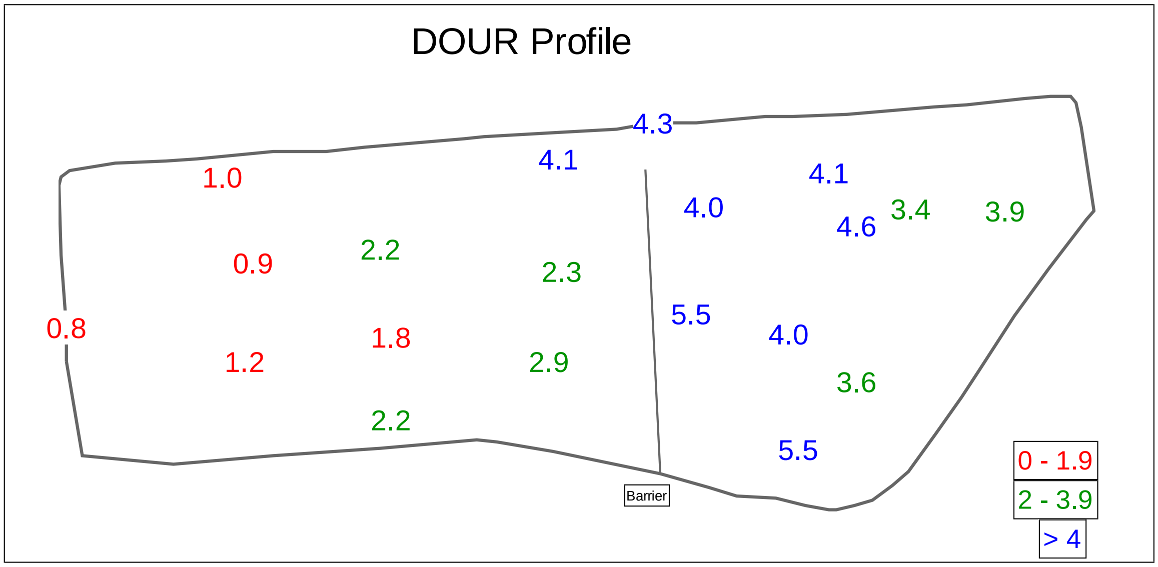


Figure 16 – Temperature Profile in the ASB

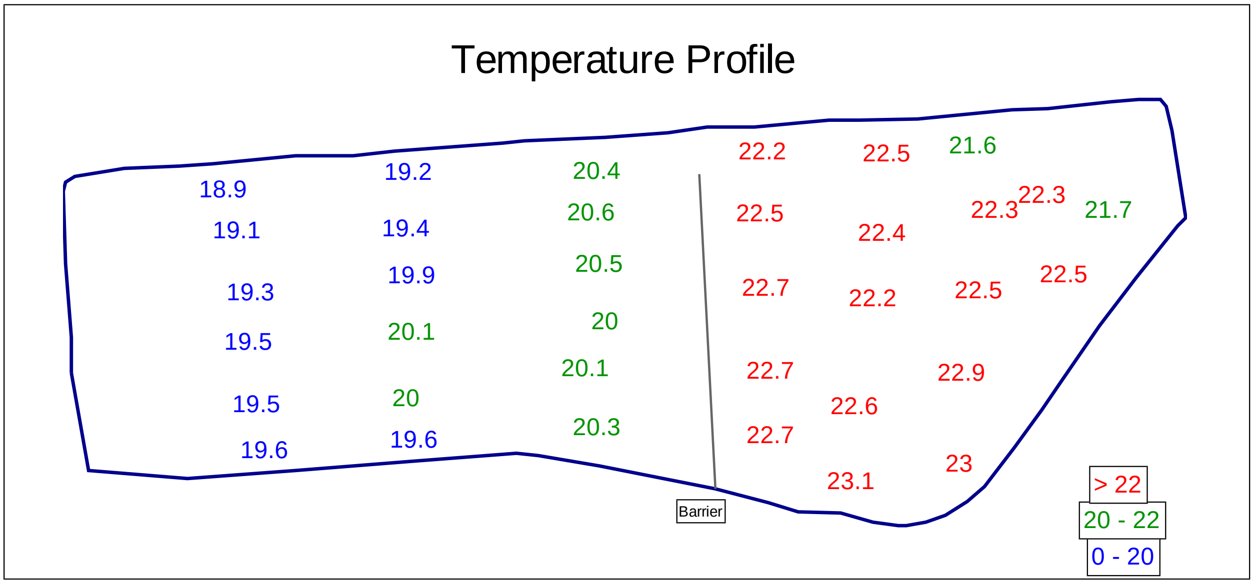
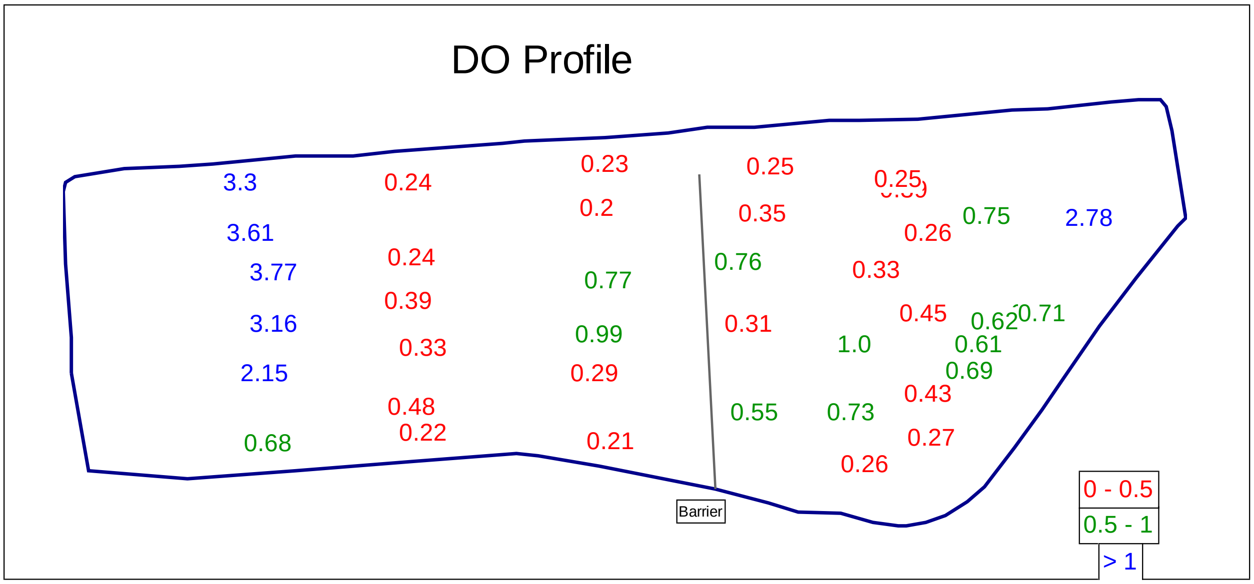


Figure 17 – Dissolved Oxygen Profile in the ASB



While the dissolved oxygen readings were low in many areas, one must take into consideration that most of the readings were taken a safe distance from operating aerators. With the high mixing energy found in the pre-barriers area, one can assume that the bacteria have access to more dissolved oxygen than the profile suggests. The elevated dissolved oxygen levels at the end of Pond 1 would also indicate adequate dissolved oxygen availability earlier in the pond.

Nutrient Balance

Operating experience in the pulp and paper industry shows the importance of having sufficient amounts of nitrogen and phosphorus. While it is possible for bacteria to consume BOD without nutrients, the synthesis of new cells requires nitrogen and phosphorus in the proper amounts. The rule of thumb for biological wastewater treatment is to provide in influent ratio of 100:5:1 (BOD:N:P), though an ASB can often operate at ratios approaching 100:2.5:0.5. Table 3 shows the nutrient balance across the ASB for a three day period. Note that nitrogen in the form of ammonia is readily accessible. TKN (Total Kjeldahl Nitrogen) includes organic nitrogen that is not immediately accessible for cell development. Phosphorus in the form of soluble ortho-phosphate is readily available for cell development.

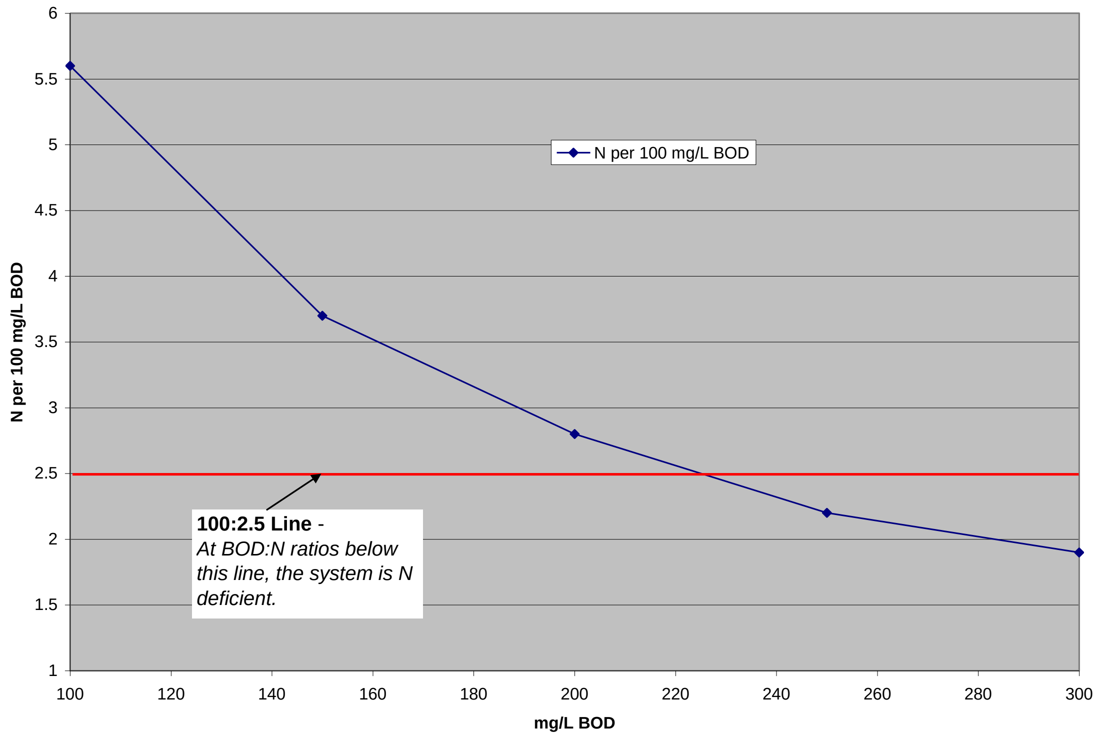
Respirometry work on nutrients for this system was conducted in 2002 and presented at the 2003 TAPPI Environmental Conference. The findings of that study showed the addition of supplemental nitrogen enhanced biological activity and BOD removal. However, based on residual analyses that showed adequate ammonia residuals throughout the system, the mill discontinued ammonia addition some time in 2004.

Table 3 – Three Day Composite Profile

Sample	Date	pH	BOD_5	TSS	TCOD	SCOD	TKN	Soluble TKN	Ammonia	Total P	Soluble o-PO4
Influent Composite	1/9	7.10	165	172	493	318	10.40	3.90	4.90	7.95	4.9
Influent Composite	1/10	9.91	280	300	944	669	5.88	4.67	2.50	8.12	2.0
Influent Composite	1/11	8.00	271	144	755	600	8.40	7.28	8.20	11.00	5.5
Influent Composite	1/12	8.13	207	160	692	555	10.10	7.00	6.90	29.00	3.8
Barrier Composite	1/10	7.45	57.0	148	416	217	9.80	1.40	0.02	8.02	3.8
Barrier Composite	1/11	7.49	62.5	192	485	317	8.96	1.68	0.03	6.94	3.2
Barrier Composite	1/12	7.53	52.5	150	469	251	8.40	1.44	0.02	8.07	3.3
Pond 1 Composite	1/10	7.54	30.0	73	297	187	7.00	4.48	1.38	8.85	3.8
Pond 1 Composite	1/11	7.55	36.0	98	488	192	9.52	1.68	0.68	5.78	2.7
Pond 1 Composite	1/12	7.56	34.0	117	530	276	8.68	2.24	0.25	13.30	3.2

Figure 18 shows a graph of the 100 mg/L BOD to nitrogen ratio (BOD:N) at a nitrogen concentration of 5.6 ppm vs. BOD concentrations from 100 to 300 mg/L. This nitrogen concentration is an average of the influent nitrogen concentrations in Table 3. The graph shows that at higher BOD concentrations the system is nitrogen deficient.

Figure 18 – Nutrient Ratios per 100 mg/L BOD



Respirometry Study

The respirometer (See Figure 19) is a laboratory scale system which allows for running up to sixteen different samples simultaneously under varying conditions. The system monitors the dissolved oxygen uptake during the test and after the test the various ‘final products’ can be tested and comparisons in operating performance measured.

Figure 19 - Sixteen Cell Challenge Respirometer

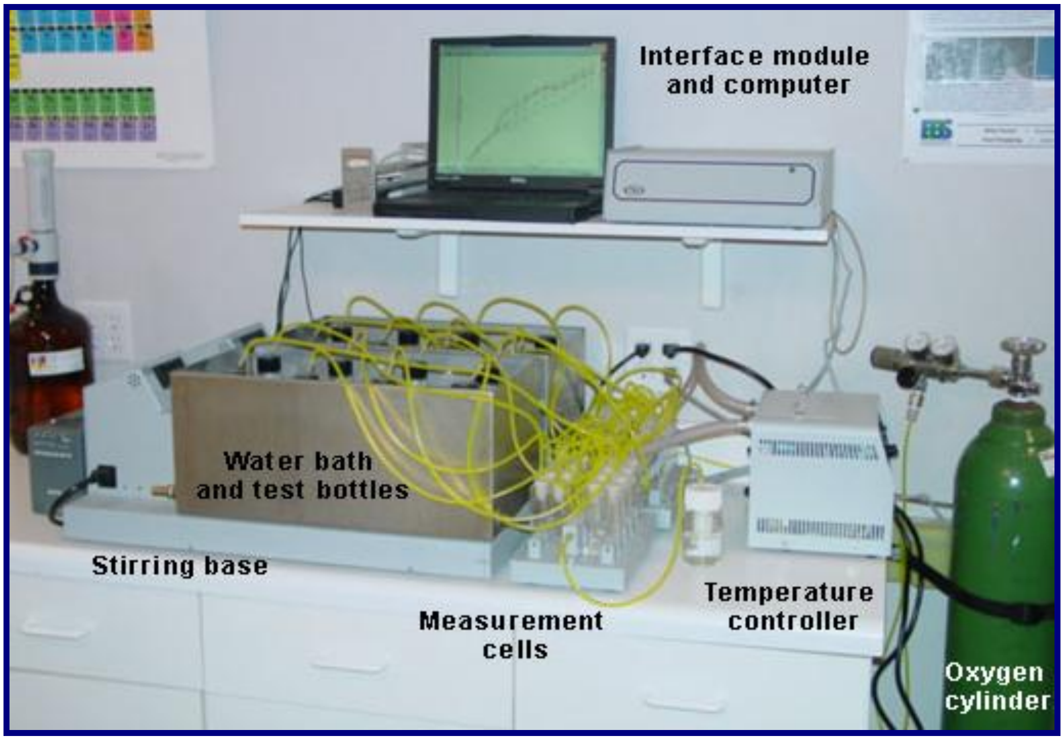
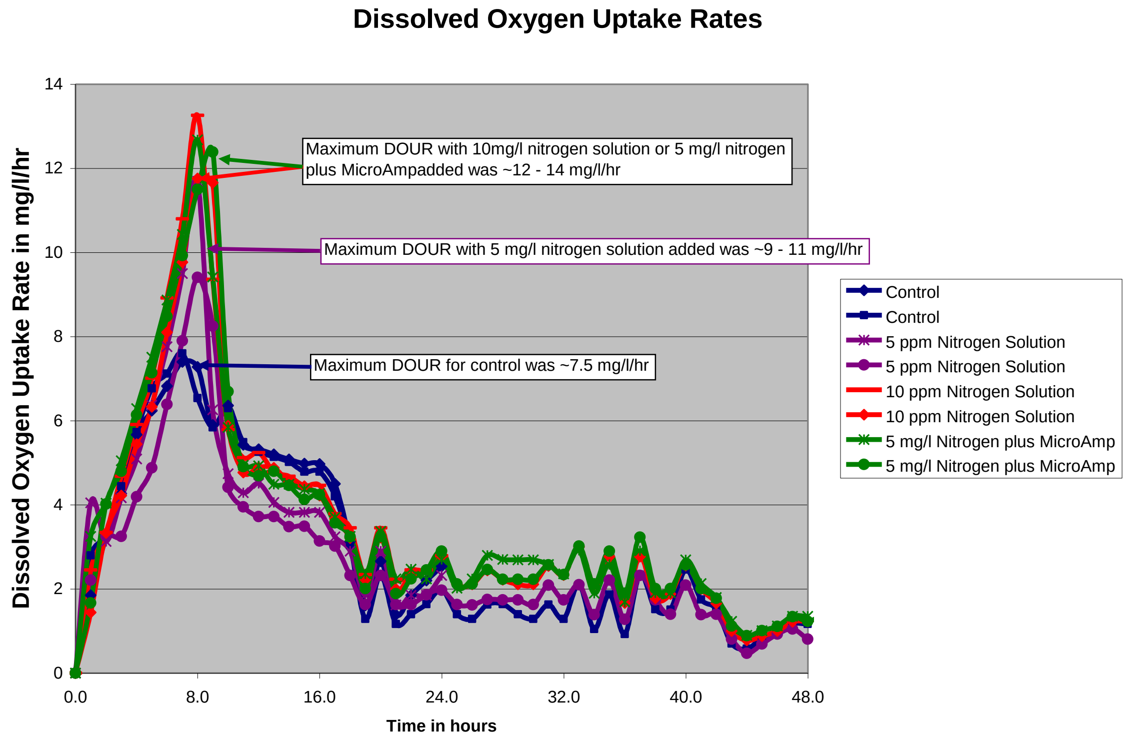


Figure 20 shows the oxygen uptake for samples of the ASB influent. The samples were spiked with different levels of nutrient and bacteria from the EBS MicroAmp. The MicroAmp is an on-site bioaugmentation system capable of producing large quantities of commercial bacterial cultures and adding them semi-continuously into the aeration basin (see Figure 27).

Figure 20



Figures 21-23 show various analytical results of the study at 24, 48, 72 and 89 hours. Figure 21 shows the bacterial counts for the study at selected intervals. Nitrogen addition and bacterial addition provide higher bacteria counts sooner, therefore increasing the number of "workers" available for BOD conversion.

Figure 21

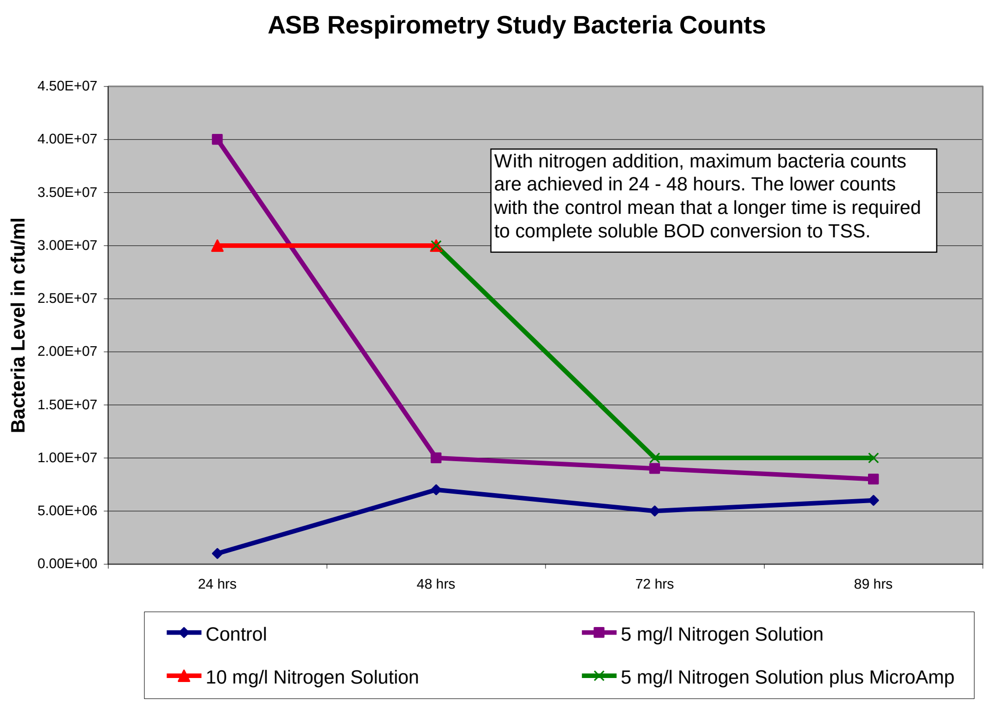


Figure 22 shows the soluble BOD concentrations at several different intervals during the study. The control took 72 hours to achieve complete soluble BOD conversion, while the nutrient spiked samples reached minimum BOD levels in 48 hours or less. These results strongly suggest that nutrient addition would facilitate more rapid BOD conversion and would allow more time for solids settling.

Figure 22

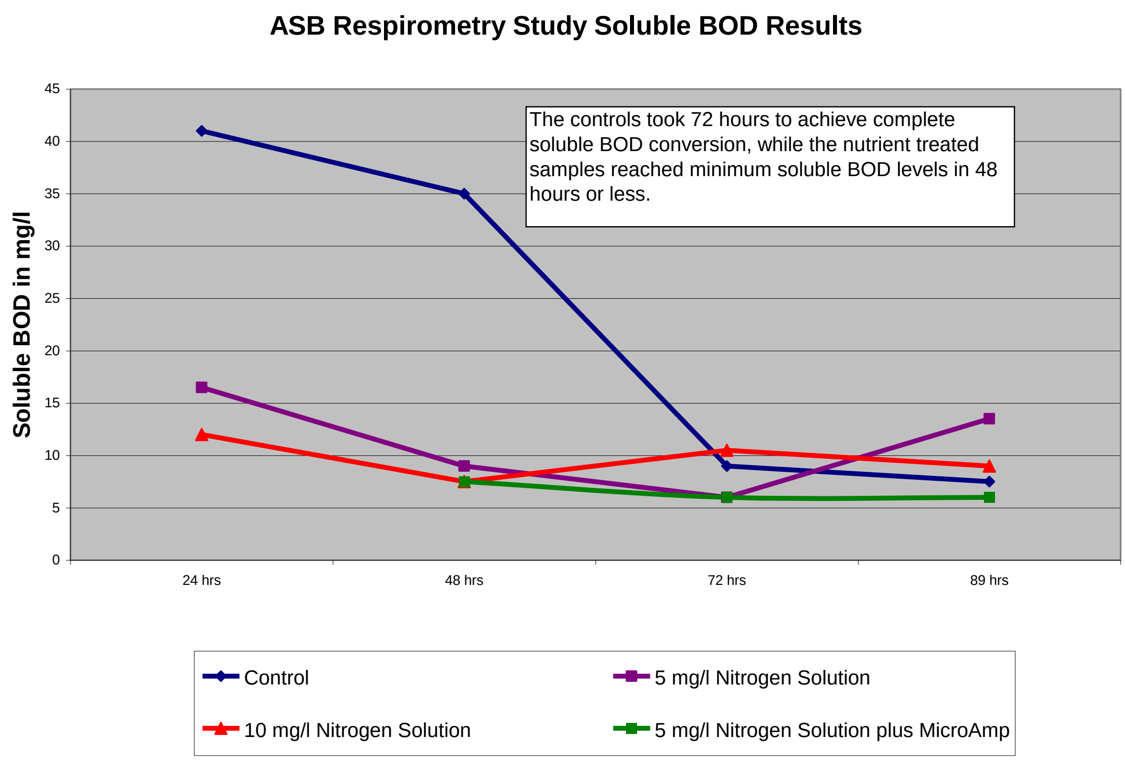
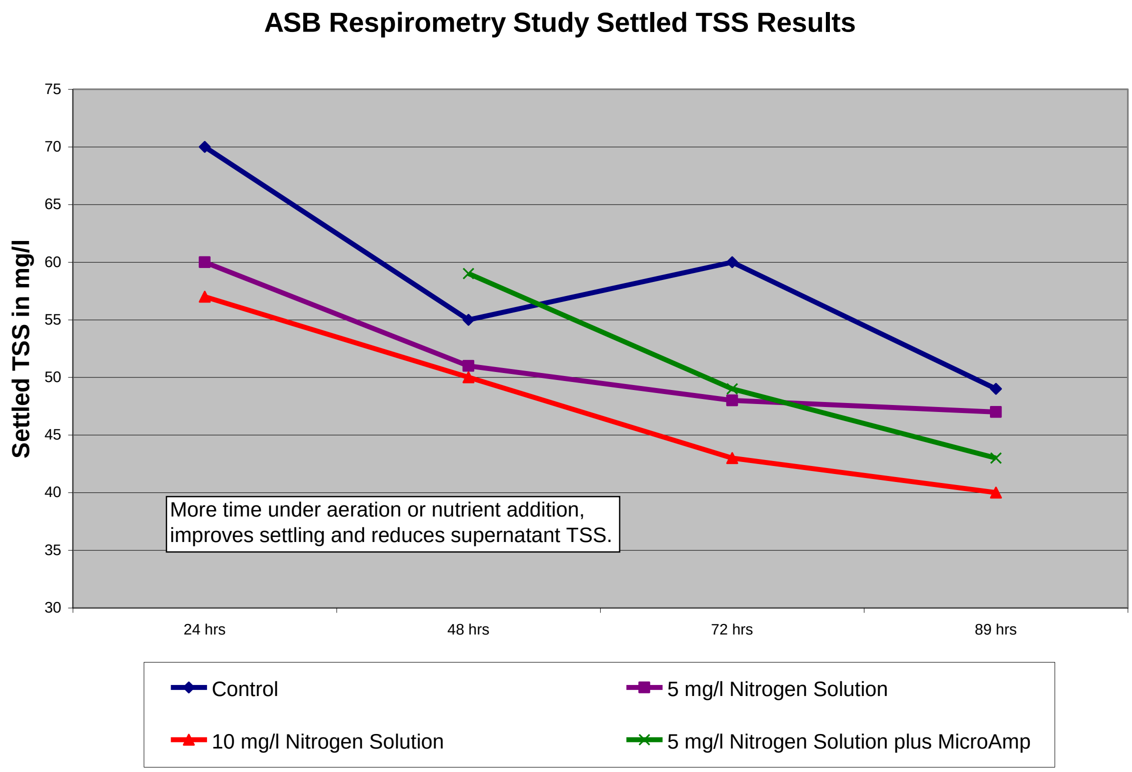


Figure 23 shows the TSS at several different intervals during the test. The control takes longer to settle and the final TSS levels are higher. This data provides additional support to the premise that faster BOD conversion reduces effluent or supernatant TSS.

Figure 23



Aerator Layout and Depth Survey

GPS reading were taken around the perimeter of the ponds. Figure 24 shows the layout of the three ponds.

Figure 24 – Pond Layout

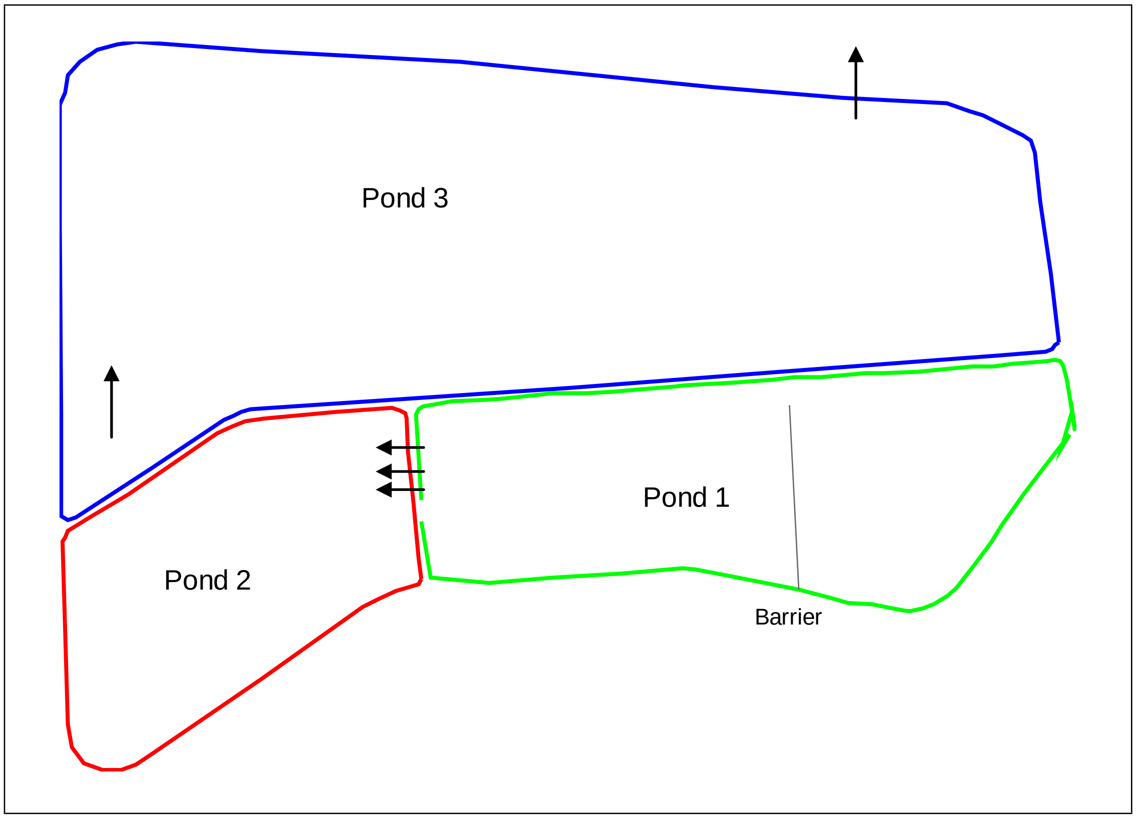


Figure 25 shows the placement of the aerators in the pond. (The mixers were not mapped.)

Figure 25 – Aerator Locations

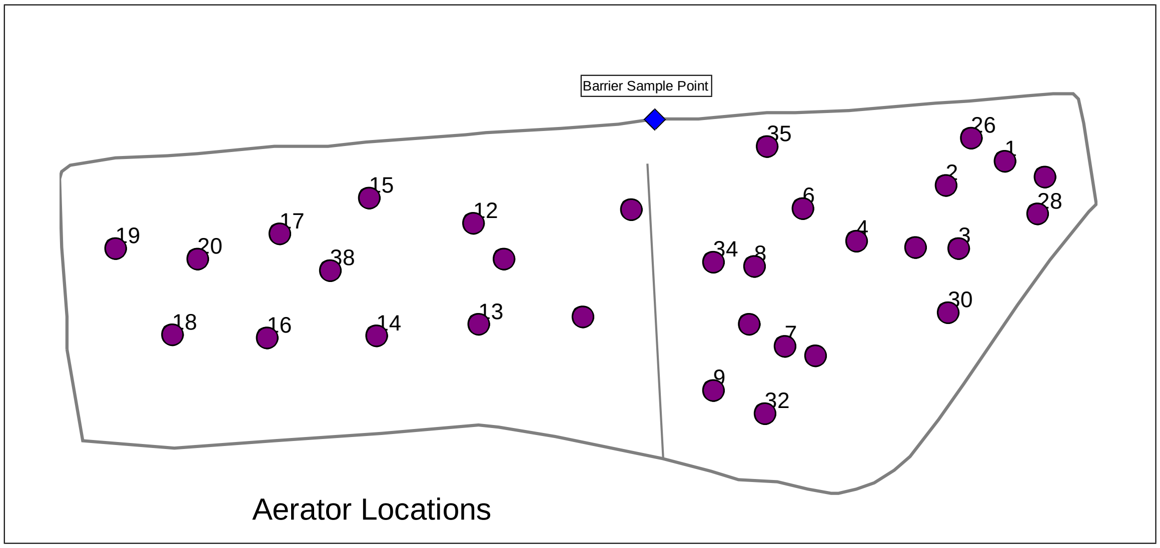
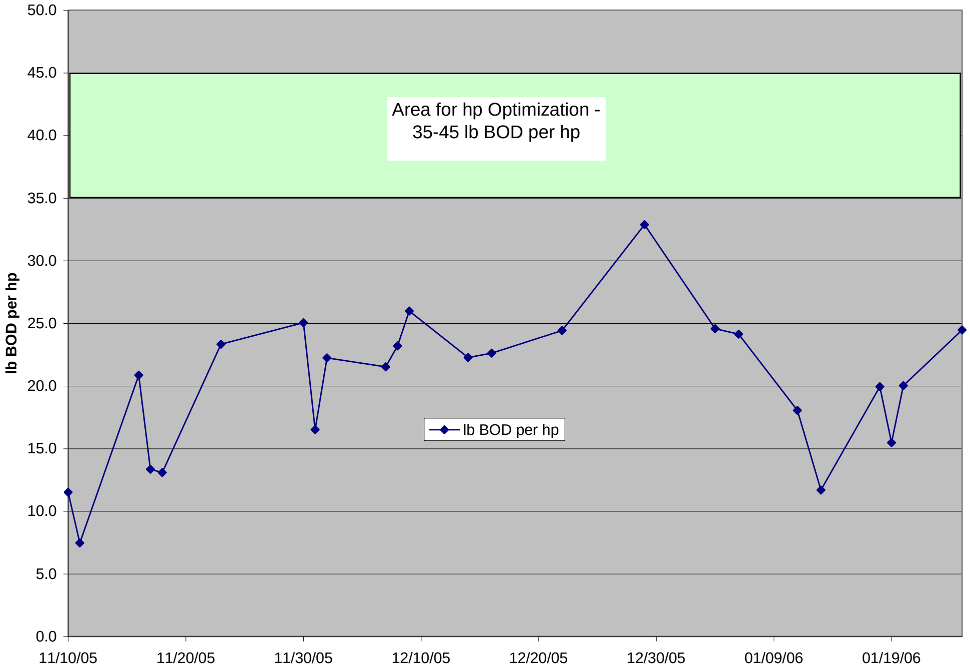


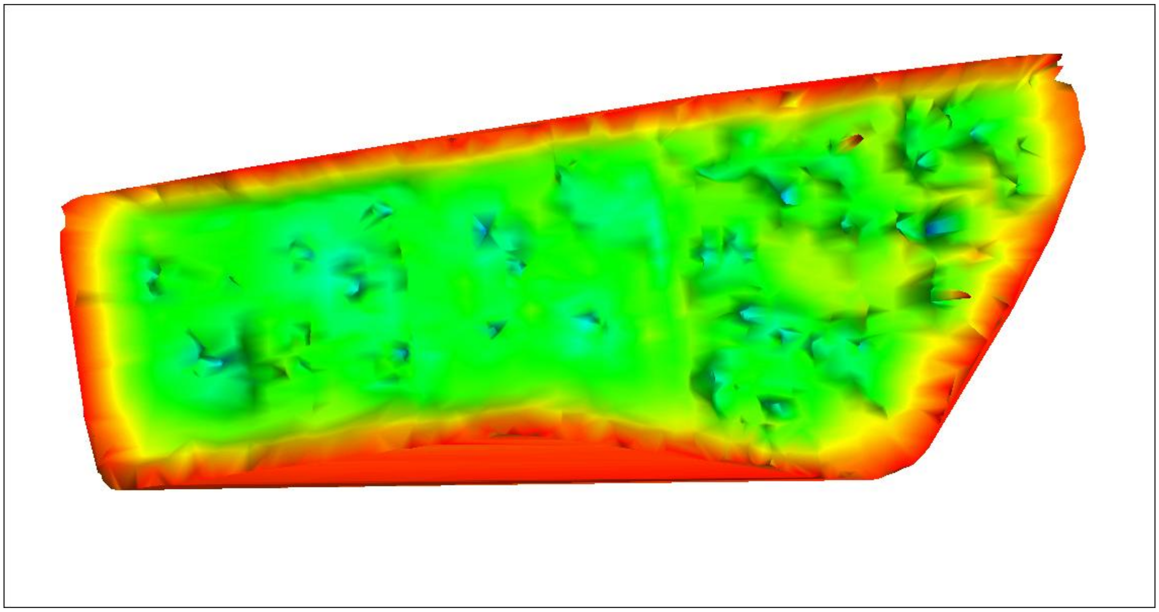
Figure 26 shows a graph of total lbs BOD coming into the system per hp used by the aerators for November 2005 through January 2006. Optimal aerator power use is 35 to 45 hp per lb of BOD removed. These results indicate that significant amounts of aeration energy is being used for mixing rather than BOD removal and support the assertion that baffle curtain installation offers potential energy savings as well as performance improvement.

Figure 26 – lb BOD per hp



The raw data from the survey completed in 2004 by a local surveying & engineering services company. was utilized to determine the effective volume of the ponds. Using 3-D graphing software this data was color-mapped for Pond 1. See Figure 27 below and the full size drawing attached to this report (Figure 29).

Figure 27 – Color mapped ASB Depths based on Previous Survey



Summary and Conclusions

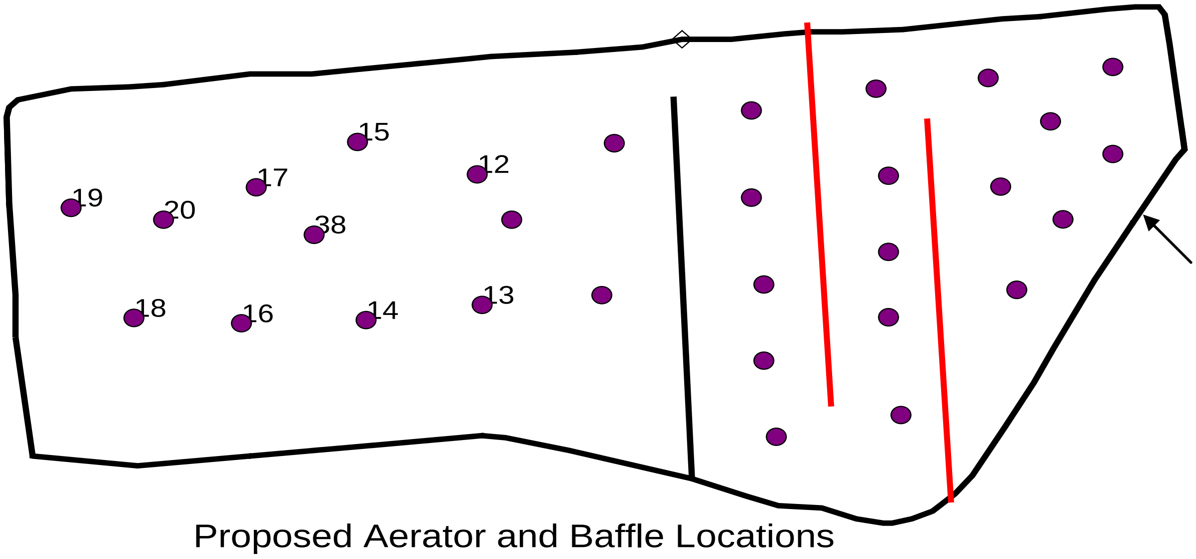
This study and subsequent conversations revealed several factors contributing to the loss of performance observed over the recent years. These include:

- ***An increase in flow to the system of 15-20% -*** By comparison to others mills of a similar production capacity, this mill has historically a high water user. In recent years the water usage has further increased, which reduces treatment times and effective treatment capacity.
- ***Significant volume loss in the system (>30%), due to sludge buildup*** – The Dummer survey found that current (2004) volumes in Pond 1 and Pond 2 were less than original. This is a fact of life for ASB systems. By design solids settle in quiescent areas and solids removal will eventually be required. Because dredging ASBs is an expensive and logistically difficult proposition, mills tend to avoid it as long as possible.
- ***Poor flow pattern in the ASB by design –*** The influent line is located directly across from the barrier opening creating a high degree of short-circuiting. This design flaw is aggravated further by in the increase in flow and decrease in effective volume. Since solids tend to settle in the areas with less flow, the resulting velocity increase occurs in the area of short-circuiting.
- ***Elimination of nitrogen addition to the system –*** It is apparent that the system is nitrogen limited at least some of the time. Since bacterial reproduction decreases at lower temperatures, the problem manifests itself more in the winter months, resulting in nutrient deficiency under high loading and/or lower ambient temperatures. This problem has gone undetected due to the use of the Nessler test for ammonia, which has a high bias in water samples with a brown or yellow background color.

Options for System Performance Improvements

- ***Evaluate water conservation options in the mill*** – Any reduction in flow will significantly improve the performance of the system by increasing retention time. There are likely several areas within the mill where water conservation opportunities exist, but this was beyond the scope of this project.
- ***Increase hydraulic retention time by recovering lost volume*** – Dredging the pond(s) may improve system performance, but is expensive and logistically difficult. Dredging will also not alter the basic problem of short-circuiting due to the layout of the influent line and barrier opening.
- ***Improve utilization of existing volume by adding baffle curtains to create more plug flow*** – This option offers both improved BOD conversion in the in the pre-barrier area and energy savings via aerator optimization (aerators utilized for BOD removal only.) By installing baffles to modify the flow patterns, aerators will be used primarily for aeration rather than also providing adequate energy to maintain complete mix. This will allow fewer aerators to be employed to achieve the same level or greater BOD conversion. The baffles will also increase water velocity in the pre-barrier area and potentially remove some of the sludge from this area without dredging. The cost of baffles from JPS is approximately $150 per linear foot installed. Lead-time for the baffles is usually two or three months and installation takes less than two weeks. (Figure 28 shows the proposed baffle layout.)
- ***Implement supplemental nitrogen addition with or without bioaugmentation*** – While the impact may not be as great as with other options, this is a low capital cost option that can be implemented quickly at any time. EBS currently supplies nutrients to twenty mills in the United States and would be happy to assist the mill in re-instituting nitrogen addition. We have also developed a new bioaugmentation technology called the MicroAmp, (see Figure 29) which is an on-site bacterial production unit capable of adding the equivalent of 500 – 2000 pounds per day of dry bacteria.

Figure 28 – Proposed Baffle Curtain Locations



Additional Recommendations and Future Work

- We are attempting to utilize the NCASI ASB Model to verify the impact of these recommendations. This is a learning experience for us and we are still working on this. Worst case, Beth and I and attending a workshop on the ASB Model at the June NCASI meeting in Charleston and we will get assistance at that time. The model also asks for information, such as ultimate BOD, that is not readily available, and must be approximated. Additional data is also required under various operating conditions (loading, ambient temperature, and etc.) to 'calibrate' the model.
- Our work found problems with the use of the Nessler test for ammonia. We have already suggested a switch to another method (Hach Salycilate), which has been implemented.
- The DOUR profile indicated that DOUR may be a useful tool for monitoring this system. By monitoring DOUR at the Barrier, Pond 1 Outlet and Pond 2 Outlet, mill personnel can determine how effectively BOD is being converted throughout the system.
- At a minimum, another sludge depth study should be conducted later this year. If some of the other recommendations, particularly baffle installation, are implemented a scaled down version of this entire study would be in order.

Figure 29 - Color mapped ASB Depths based on Dummer Survey

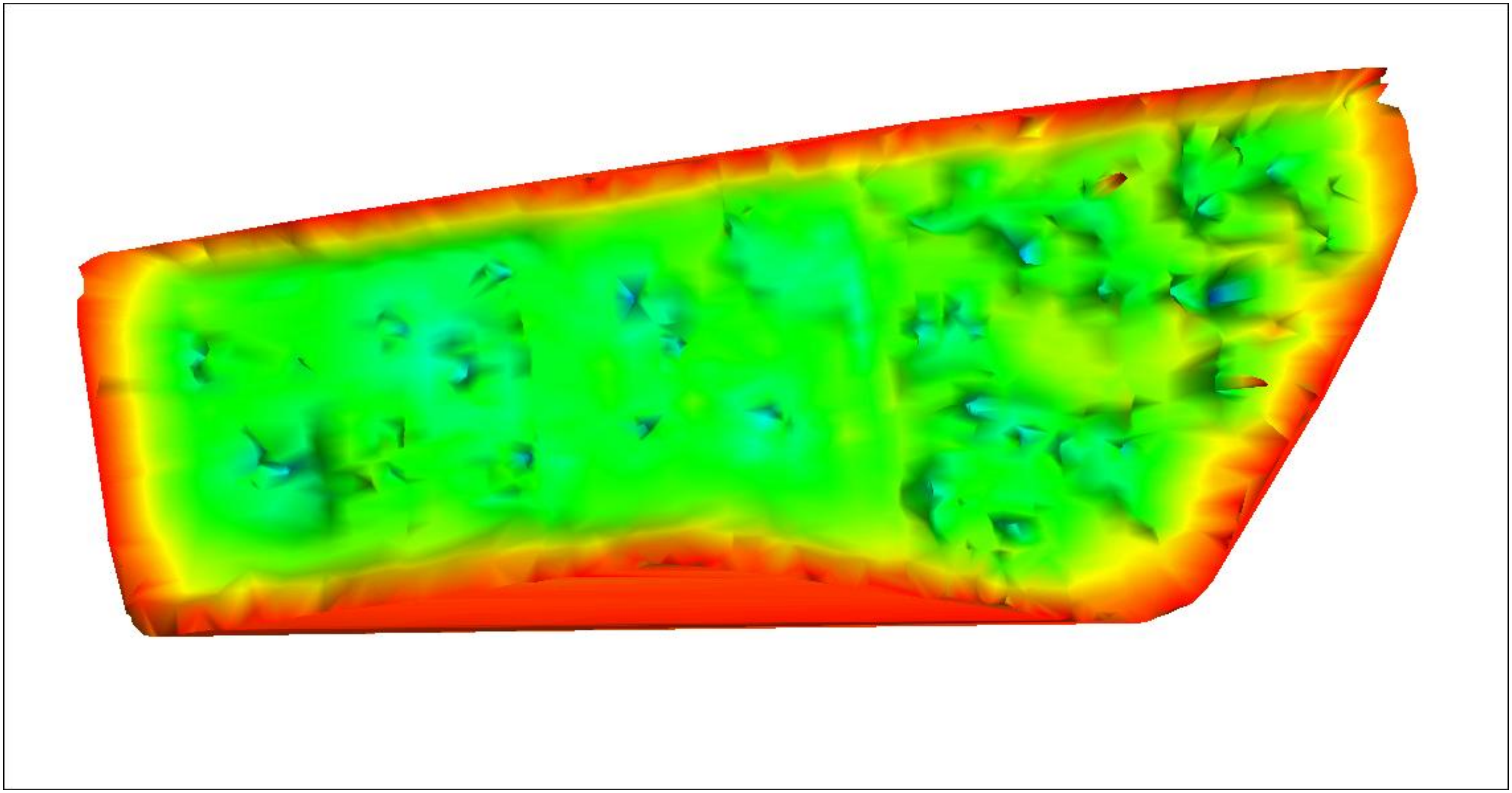


Figure 29 – The EBS MicroAmp Unit