



FINAL

**DeVries Dairy
Bion NMS Nutrient and Atmospheric
Emission Quantification Project
Analytical Approach Details and Results**

**James Morris, Ph.D., P.E. – Chief Technology Officer
Jere Northrop, Ph.D. – Senior Technical Director
George Bloom, P.E. – Chief Engineer**

Accepted by:

**DeVries Dairy Nutrient Discharge
and
Atmospheric Emission Review Team**

December 22, 2004



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December 22, 2004

Dr. James Morris
Chief Technology Officer
Bion Environmental Technologies, Inc.
32 Stoneridge Circle
Standish, ME 04084

Subject: DeVries Dairy Bion NMS Nutrient and Atmospheric Emission Quantification Project –
Review of Protocols, Protocol Implementation, Analytical Approach and Results

Dear Dr. Morris:

Per our agreement, Camp Dresser & McKee, Inc. (CDM) has coordinated and participated in the following efforts associated with the above referenced project:

Reviews of conceptual approach to, and protocols for, nutrient and emission quantification;

Limited observations of protocol implementation;

Reviews of analytical results from protocol implementation.

This letter summarizes our findings and efforts with respect to each of the above efforts, as well as the limitations of such efforts. Team members for the project, their roles, affiliations and project focus are presented in Table 1. Note that advisors commented only on the proposed protocols for the project.

Review approaches and findings are summarized below.

Protocol Review

Draft protocols produced by Bion were circulated among the review team and advisors. Bion revised the document to reflect comments received via discussions with the reviewers and advisors.

Some reviewers provided written comments on the revised protocols – specifically on the acceptability of the procedures with respect to project goals. Where specific comments were provided – both on the emissions and nutrient protocols – reviewers found the revised protocols to be “acceptable.”



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Table 1. Project Review and Advisory Team

Team Member	Affiliation	Site Observation	Nutrient Conversion Review	Emission Review
Reviewers				
Lynne H. Moss, P.E., DEE Coordinator/Reviewer	CDM	X		X
Mark Gould, P.E, DEE	CDM	X		X
Clyde Burnett, P.E., DEE	CDM	X	X	
Richard Nicolai, PhD, P.E.	South Dakota State Univ.			X
Richard Stowell, PhD	Univ. of Nebraska - Lincoln			X
William Clarkson, PhD, P.E.	Oklahoma State Univ. - Tulsa		X	
Kevin Young, P.E.	J.R. Wauford & Co.		X	
Advisors				
Raymond Loehr, PhD.	Univ. of Texas		X	
Ron Heavner	USDA/NRCS/CED			X

Sampling Observations

A total of three visits were made to the site for observation purposes. The first visit included two representatives from the Texas Commission on Environmental Quality (TCEQ), who came to view the system and emission protocol implementation.



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Date of the visits and brief summaries of each visit are as follows:

April 22, 2004

Participants included:

Review Team – Lynne Moss, Clyde Burnett

TCEQ – John Smith (Emission Measurement Support Program, Compliance Support Division), Anna Rodriguez (Air Permits Division)

Ms. Moss observed both nutrient and emission protocols, while Mr. Burnett focused on the implementation of nutrient protocols. They observed that the protocols were correctly followed, and that appropriate care was given to sampling procedures and chain of custody requirements.

TCEQ representatives observed emission testing. Mr. Smith specifically commented on sampling procedures, noting that “the sampling techniques I observed were, in my opinion, valid and appropriate” (see letters from TCEQ in Attachment A).

During the visit, Ms. Moss noted that, while most parameters subjected to both in-situ measurements and laboratory analyses seems to be in relative agreement, there was a large discrepancy between hydrogen sulfide (H₂S) in-situ and lab results. Consequently, it was agreed that at her next visit, she would bring an alternative device for in-situ measurements.

May 27, 2004

Only Ms. Moss visited the site on this day. The objectives of her visit were two-fold: (1) to continue observations of emission and nutrient protocol implementation and, (2) to perform supplemental H₂S testing.

Her observations of protocol implementation mirrored those of the previous visit.

For H₂S sampling, she brought an Interscan Portable Analyzer. Additional detail on this equipment and sample results can be found in the DeVries Dairy *Bion NMS Nutrient and Atmospheric Emission Quantification Project Analytical Approach Details and Results*, hereinafter referred to as the Project Report. The “Interscan” measurements were comparable to those obtained in-situ by Bion staff using Draeger colorimetric tubes. Consequently, Ms. Moss recommended that greater confidence be placed in the in-situ measurements for H₂S, as opposed to laboratory results. (In response, the most conservative in-situ measurements were used in the subsequent emission analysis.)



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June 29, 2004

The primary purpose of this visit, by Review Team members Lynne Moss and Mark Gould, was to gather full-scale H₂S emission data from the NMS system for comparison to results from the pilot operation. Toward that end, the reviewers brought a flux chamber and appurtenant equipment to the site and, based upon the NMS system configuration, worked with Bion to identify appropriate sampling points on the surface of the NMS basins. The approach developed and results are discussed in the Project Report.

In sum, at no time during the field visits did the Review Team determine that protocols were not being appropriately and carefully followed. Moreover, when potential problems arose with the protocols (for example, concerns regarding the accuracy of laboratory analyses for H₂S), procedures to remedy those problems (or improve data collection) were developed by Bion staff with concurrence from the Review Team leader.

Analytical Results Review

At the conclusion of the field study, Bion staff compiled the data collected and computed nutrient loadings to and from the NMS system, as well as emission rates from the process. A draft Project Report was issued that included sample calculations, a CD containing all calculations made for the project, and conclusions drawn from the pilot operation.

The draft Project Report was disseminated to all review team members for review and comment in August 2004, and written comments on the document were received from all reviewers over a several month period.

Comments indicate that the team generally found the draft Project Report to be of high caliber. The comments of one reviewer appear to echo the sentiments of other reviewers – that, generally, “this report is found to be of excellent quality with respect to the acceptability of the sampling and data analysis protocols, as well as the calculations and summarized results.”

Comments from the individual reviewers did not “overlap” (which would indicate a general and more serious concern regarding an element of the report). The sole exception to this was use of emission data collected from non-NMS system components. The paucity of data collected from these locations, as opposed to measurements related to the NMS process, limits the ability to draw useful conclusions from the information gathered (as noted in the Project Report). Moreover, as questions have been raised regarding the accuracy of H₂S laboratory analysis of samples from these locations, in particular, we recommend that non-NMS process measurements be viewed with caution, if not skepticism.



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All comments were satisfactorily addressed in the final Project Report, which was issued on December 22, 2004.

In sum, and based upon the reviewer comments, the computational approach presented in the draft Project Report and corresponding Master Spreadsheet is believed to be acceptable, and the values derived from the approach are acceptable as well.

The above findings do not give or imply an endorsement or recommendation by the Review Team (corporately or by any individual member thereof) of the technology, process or system evaluated. Rather, this review sought to validate that the protocols and approach for emission estimates and nutrient quantification were acceptable and, in our opinion, that goal was achieved.

Sincerely,

A handwritten signature in black ink, appearing to read 'Lynne H. Moss', with a vertical red line to its right.

Lynne H. Moss, P.E., DEE
Principal
Camp Dresser & McKee Inc.

ATTACHMENT A

Kathleen Hartnett White, *Chairman*
R. B. "Ralph" Marquez, *Commissioner*
Larry R. Soward, *Commissioner*



RECEIVED AUG 24 2004

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Protecting Texas by Reducing and Preventing Pollution

August 9, 2004

MS LYNNE H MOSS PE DEE
CAMP DRESSER AND McKEE
12357 A RIATA TRACE PARKWAY STE 210
AUSTIN TX 78727

Re: Sampling Observations at the DeVries Dairy Site

Dear Ms. Moss:

I traveled to the DeVries Dairy near Dublin, Texas to observe emission estimation methods for the Bion NMS Waste Management System on April 22, 2004. The Bion March 30, 2004 Project Overview documents the procedure used to create a system which would allow for a reasonable simulation of a full scale operations and facilitate measuring emissions. It also describes the methods used for measuring emissions. It was understood that these measurements were for general information purposes and no attempt was made to meet the stringent requirements of demonstration of compliance with a TCEQ air permit utilizing EPA source (stack) sampling methods. The purpose was to use containment and air handling techniques to gather data which would allow models to be constructed. Some samples were collected from the ambient air and in these cases the effort was made to sample at locations which would yield the highest available concentration.

The Bion personnel were very familiar with the equipment and measurement techniques and the data was collected with due diligence towards gathering the best possible samples that conditions would allow. The sampling equipment was in good working order and the reagents (sampling tubes and chips) were properly stored and handled. The vent sampling locations were well situated and I do not believe any sample dilution occurred. I have not reviewed the results but the sampling techniques I observed were, in my opinion, valid and appropriate.

If you have any questions please contact me at (512) 239-1676 or josmith@tceq.state.tx.us

Sincerely,

A handwritten signature in cursive script that reads "John R. Smith".

John R. Smith
Emission Measurement Support Program
Compliance Support Division

Kathleen Hartnett White, *Chairman*
R. B. "Ralph" Marquez, *Commissioner*
Larry R. Soward, *Commissioner*
Glenn Shankle, *Executive Director*



RECEIVED SEP 08 2004

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Protecting Texas by Reducing and Preventing Pollution

August 31, 2004

Ms. Lynne H. Moss, P.E., DEE
Principal
CDM
12357-A Riata Trace Parkway, Suite 210
Austin, Texas 78727

Re: Devries Dairy Testing
Dairy
Dublin, Erath County

Dear Ms. Moss:

After touring the Devries Dairy in Dublin, Erath County and viewing the wastewater treatment system on April 22, 2004, it is my opinion that the system still allows the dairy operation to meet the requirements of the air standard permit in Chapter 321. Should the company choose to discontinue coverage under the air standard permit and seek authorization for the dairy under an individual air quality permit in Chapter 116, the wastewater treatment system appears to meet current Best Available Control Technology.

Please understand that additional technical review of the system may cause this opinion to change but based on what was seen in April, there do not appear to be any authorization issues associated with the wastewater treatment system in place.

If you have any questions, please contact me at (512) 239-1307, or write to the Texas Commission on Environmental Quality, Office of Permitting, Remediation, and Registration, Air Permits Division (MC-163), P.O. Box 13087, Austin, Texas 78711-3087.

Sincerely,


Anna M. Rodriguez
Air Permits Division

AMR/ssl

cc: Mr. Tony L. Walker, Air Section Manager, Region 4 - Fort Worth

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MEMORANDUM



DATE: August 11, 2004
TO: DeVries Dairy Nutrient Discharge and
Atmospheric Emission Review Team
FROM: James Morris, Ph.D., P.E. – Chief Technology Officer
Jere Northrop, Ph.D. – Senior Technical Director
George Bloom, P.E. – Chief Engineer
**RE: DeVries Dairy Bion NMS Nutrient and Atmospheric Emission
Quantification Project - Analytical Approach Details and Results.**



1. SUMMARY AND REVIEW TEAM CHARGE

The review team is to report that:

- 1) the protocols were reviewed and found acceptable as refined;
- 2) through site visit direct observations by the team leader, consultants to the team leader and regulatory personnel, the protocols were followed, including proper monitoring component installations and sampling;
- 3) the computations used as detailed in this analytical approach document and executed in the analysis spreadsheet are acceptable (not ideal or the way that may have been preferred, but appropriate to obtain an acceptable result); and
- 4) the values derived from this approach, as summarized in Table 1.1 below, are an acceptable result of the approach.

Individual review team members are not required to review and deem acceptable all results and computations presented but rather concentrate on their specific areas of expertise as detailed in the "Verification / Review of DeVries operating results" memorandum to the review team dated March 26, 2004. Again, members are to focus in depth particularly on their areas of expertise. Each team member will detail the general and specific qualifications, caveats, and limitations, if any, upon which their acceptance depends and these shall be presented in the review report. The protocols and review team memorandum are included in the appendix to this document.

The review team is not responsible for the further use of the values in Table 1.1. Further analysis, discussions, potential process response, fundamental mechanisms, explanations for

data behavior, comparisons to other processes or technologies, conclusions drawn from these results or any other extensions from the values accepted by the review team are not part of the review requested. The review team will be clearly cited as having accepted only the protocols (methods, materials and approach included) and the direct results summarized in the Table 1.1 below. **It shall be made very clear that no form of endorsement or technology recommendation has been given or implied by the review team corporately or by any individual member thereof.**

Only the information contained in Table 1.1 below and the approach detailed herein to determine these values are to be reviewed.

TABLE 1.1 – SUMMARY OF BION NMS PROJECT RESULTS

Nutrients		
Average for the nutrient study period from 12/10/03 to 5/17/04		
	lb P/day	lb N/day
Load	180	1,529
Effluent discharge	162 (95% particulate solids)	720 (56% particulate solids)
Coarse solids removed	24	169
Fine solids removed	5	34
	180 in to 191 out Closure of ±3%	606 N ₂ (by mass balance difference)
<p>Given the final effluent, if an additional solids separation process (centrifuge, filtration, etc.) were to be fed this stream and a total phosphorous removal of 70% and a total nitrogen removal of 45% were obtained, a total of 79% Total-P removal and 74% Total-N removal would result for the entire system with this additional step.</p>		
System Air Emissions		
Total System Average Emissions for the period from 4/20/04 to 7/15/04		
Parameter	lb/day	lb/KLAW-year
Methane: CH₄	147.32	27.49 (21.74 since 6/11/04)
Hydrogen sulfide: H₂S	2.17 ^a	0.40 ^a (0.23 since 6/11/04)
Ammonia: NH₃	0.81	0.15
Nitrogen oxides: NO_x (NO ₂ standard)	0.062 ^b	0.012 ^b
NMOC: (C ₅ H ₁₂ pentane standard)	0.10 ^b	0.020 ^b
Carbon dioxide: CO₂	3,319	621
<p>^a - Parallel system H₂S emission rate analyses were executed on two operating days. This project's air emission tank approach appears to provide a very similar (±36%), conservatively high, valuation of H₂S mass air emission rates compared to the Flux-Chamber approach. ^b - Note that all measurements for NO_x and NMOC were non-detect.</p>		
Area Air Emissions		
<p>Limited sampling appears to indicate that additional mass emissions of the six air parameters, does occur in areas of the dairy outside of the system's active reactor volume, <u>but</u> these sources appear to be insignificant. This appears to be particularly true for NMOC and NO_x based on the universal non-detects measured for these two parameters.</p>		

NOTICE

A team of seven independent engineering waste management experts including both nutrient management and atmospheric emission specialists actively advised, amended and accepted the monitoring / sampling system design and protocols for data collection. On-site verification of the installation and adherence to the sampling protocols was performed by two team members and two regulatory agency air emission specialists. The review team then performed a detailed audit of the data collected, the computations and analysis of the data, and the results obtained. Additional advice and participation was provided by governmental agency and regulatory personnel. Acceptance of the protocols, sampling, data collection, data analysis and the results reviewed does not give or imply an endorsement or recommendation of the technology, process or system used, by the review team corporately or by any individual member thereof.

1.1 Overall Approach

The nutrient and air emission protocols have been performed. Results from these protocols have been collected and used to obtain the summary results presented in Table 1.1. These results were derived from the data as presented in the Master Spreadsheet. The data and computations are presented as related results or as specific parameters in individual worksheets within the Master Spreadsheet. Within this document are sections detailing each worksheet's organization and computations. Complete units, conversions and example computations are provided for all significant parameters. In many of the sections, a specific parameter and /or system operating date is selected to represent a general case for the computations and is presented as an example with step by step example calculations referring to the specific location in the worksheet under consideration. Use of this document is intended to be hand-in-hand with the Master Spreadsheet during review.

This is not a stand-alone document but a companion piece to be used directly with the Master Spreadsheet and within the context of the sampling protocols. It is written for use by the review team during the review process such that a thorough rigorous review may be accomplished with as little effort and as efficiently as possible.

There are charts or graphs of data on some of the worksheets of the Master Spreadsheet. **The graphs are NOT part of the review required.** They are made available to allow some overview of the parameters plotted and are not intended to portray any conclusions.

1.2 General Methodology

The general purpose of this document is to present the data collected by applying the nutrient and air emissions protocols and the computations applied to obtain the results reported in Table 1.1 above. In so doing, the aim has been to provide the reviewer with a straightforward, methodical, rigorous and transparent guide through the computations to the extent possible. The central desire is to provide the simplest, most efficient yet complete guide to the project results.

1.2.1 Two time periods are considered for these analyses.

The 159 day period from 12/10/03 to 5/17/04 for nutrient considerations. This period is chosen for two primary reasons. First this period represents slow biological activity during the coldest operation period of the year. While the average system mixed liquor or bioreactor liquid temperature for all operating days through 7/15/04 is 20.0 °C, this period's average is 16.7 °C. For 81 of the 159 day period the temperature averaged only 13.3 °C with several days below 11 °C. Thus, the nutrient conversions and results observed during this period will likely reflect a conservative low system response to loadings. A period of system acclimation and operating shakedown ending with consistent operation had been completed prior to the beginning of this period.

The 86 day period of 4/20/04 to 7/15/04 for atmospheric emissions considerations. Two major factors determined the choice for this period of testing. First the installation,

commissioning and steady operation of all air emission program components was required before testing was initiated. Secondly, this period represents relatively high system mixed liquor operating temperatures. The average system liquid temperature for the period was 26.6 °C with several days approaching 31 °C. These warm conditions have a number of aspects that lead to potentially increasing the amount of atmospheric emissions for the six parameters addressed. At warmer temperatures gas solubility is decreased, aeration oxygen transfer reduced, stripping of gases and potential for anaerobic activity increased; all of which lead to an expected higher rate of emissions. Thus, the results obtained should represent a conservative high emissions response by the system

1.3 Organization and Conventions

Raw field and laboratory data are organized into broad topics of system flows, dairy and load generation, N & P discharge, solids removed and air emissions in the master analysis Excel spreadsheet. This data is then analyzed to determine system mass loading and discharge of nutrients, mass generation of nutrients in solids produced, and the mass emission rates for the six atmospheric discharge parameters.

Individual data and computational areas are contained in separate worksheets or tabs on the analysis spreadsheet. **Note: Alpha-numeric characters in [brackets] refer to cells, columns or rows in the worksheet location under discussion.** For example on the “CH₄” tab or worksheet the ventilation flow rate through the anaerobic tank’s headspace of 20.62 ft³/min on 5/20/04 appears in [G22], for the same date the pounds of methane generated from the anaerobic zone of the entire system on a per thousand pounds of contributing cows’ live animal weight per year of 22.43 lb CH₄/KLAW-yr is provided in [M22].

The example calculations provided in this document cite the specific worksheet cell address. The result obtained may vary slightly from the numerical amount obtained using a handheld calculator but the result should equal the spreadsheet cell value referenced. The difference is due to rounding.

All animal weight units are converted into a 1,000 pound live animal weight or KLAW basis for internal consistency and consistency with regulatory and published environmental impact baseline figures.

2. SYSTEM DISCHARGE FLOW OR FLOW ANALYSIS

2.1 General Approach

The Bion NMS reactor is located within a preexisting lagoon having a total volume of 5,200,000 gallons. Floating baffles, securely sealed and anchored to the bottom and sides of the lagoon, enclose the reactor’s 1,100,000 gallons liquid volume or mixed liquor, which is physically located inside the preexisting lagoon. It is estimated that the slack present in these baffles allows the contained volume to vary by 30,000 to 40,000 gallons as a buffer between short-term differences in inflow and outflow. Recycle flush water is pumped from the mixed

liquor and returns by gravity with the added volume of manure, bedding and wasted feed from dairy housing to the Houle contact, mix sump. Milk-house wash water, spilled drinking water and runoff from minor rain events (less than 0.25 inches over three hours or more) generated

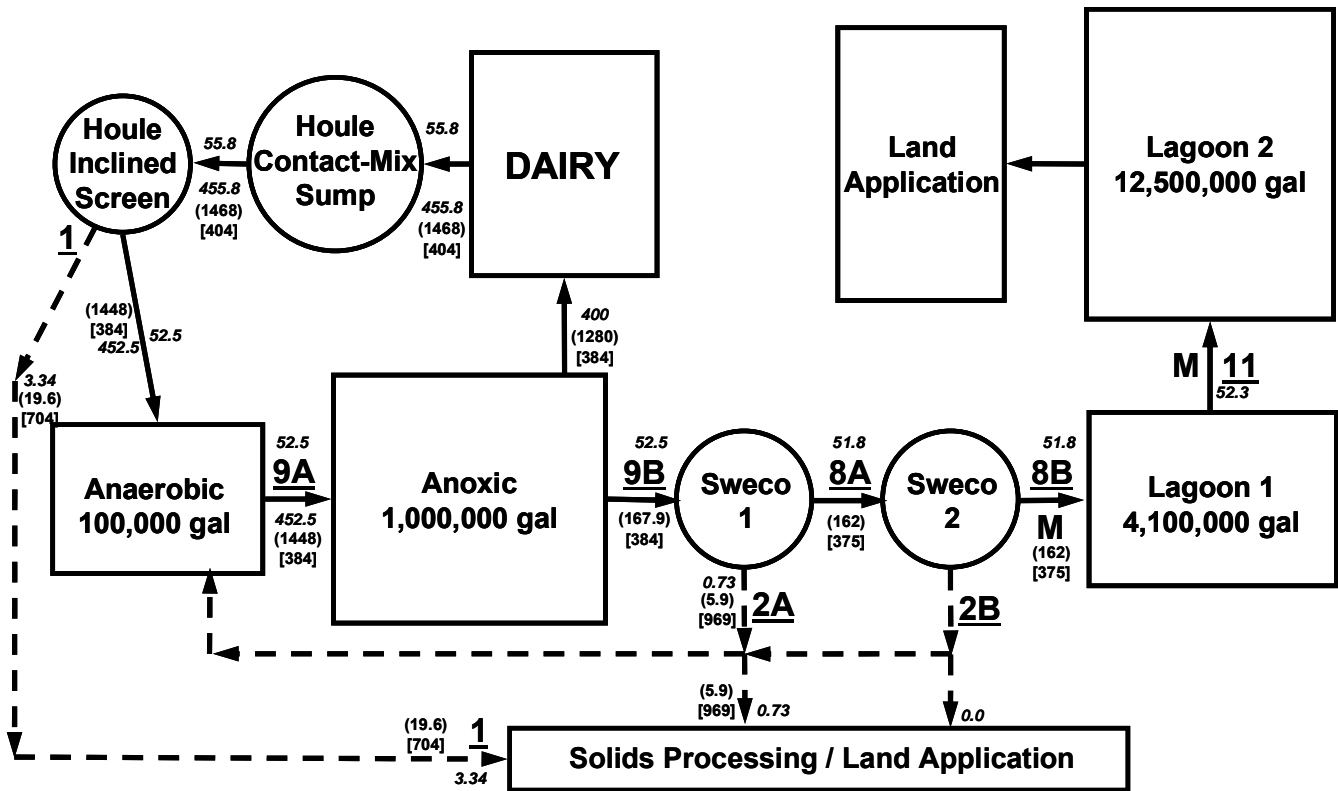


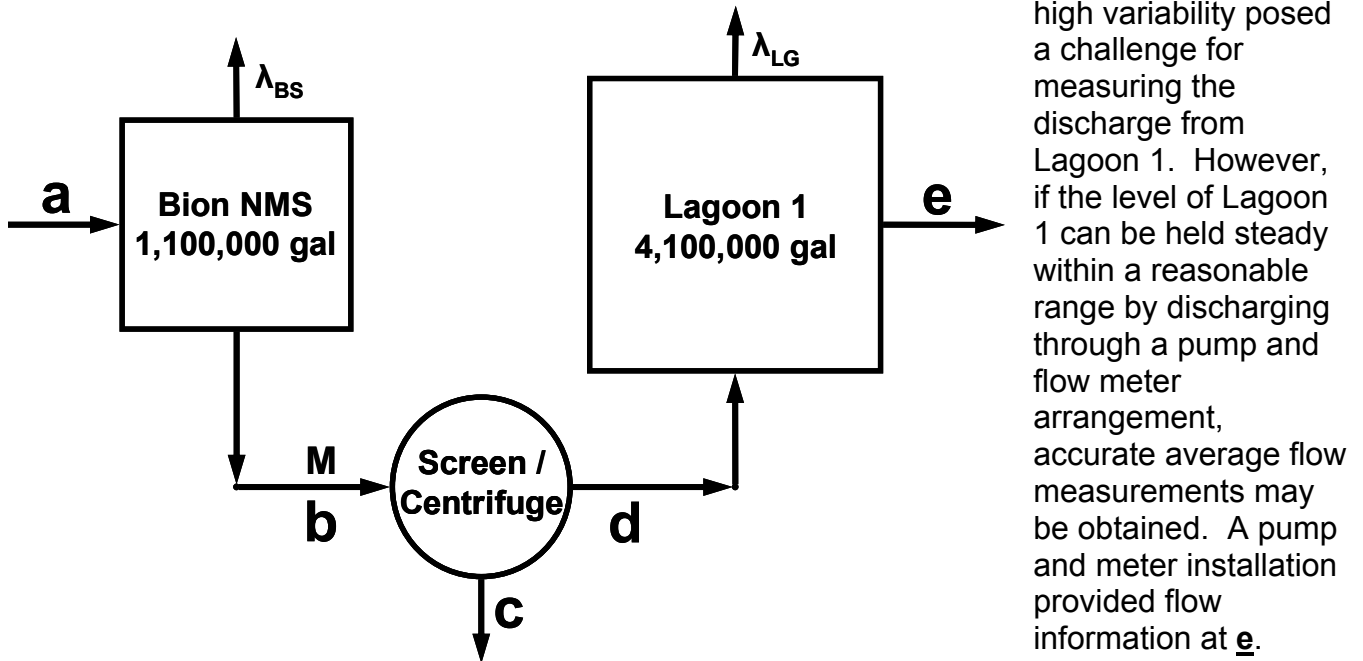
Figure 1.1. Process flow diagram for DeVries Dairy Bion Nutrient Management System. Also shown are selected system sampling points (i.e. **8B**) and flow meter locations - **M** (from the Nutrient Sampling Protocol), and example *net forward flows over total flows with recycle* in thousands of gallons per day, example (phosphorous mass rates) in pounds of phosphorous per day, and [total phosphorous concentration] in mg Tot-P/L.

by the dairy also flow by gravity to this sump (please refer to Figure 1.1). All of these inflows are generated from multiple sources within the four barns and milk-house of the dairy. Large rain events overflow the sump to the outside of the baffle enclosed volume and thus bypassing the Bion NMS reactors. However, these major rain events do flow into Lagoon 1 and exit via the lagoon one discharge pump and meter except for extreme events which overflow to Lagoon 2. It is the net excess of rainfall over evaporation for the surface of Lagoon 1 outside of the Bion process volume that accounts for the greater discharge shown at sample point 11 compared to 8B.

Recycled process flush water and influent wastes are discharged to the Houle contact chamber/mix sump where the mixture is vigorously mixed, pumped over the Houle inclined plane static screen and enters the 100,000 gallon bioreactor anaerobic zone by gravity. Mixed liquor is withdrawn from the complete mix anoxic zone and pumped through either screens or a screen – centrifuge combination. Figure 1.2 is a simplified representation of the flows through the system. The flow at **a** is the net forward flow (less recycle), an average of 52.5

kgpd on Figure 1.1. This flow is balanced by the flow pumped through the screen / centrifuge. Effluent from the screen / centrifuge is discharged outside the reactor volume into Lagoon 1. If the screen / centrifuge discharge **d** is not balanced relative to the net inflow **a**, the difference will be forced past the baffles into or out of the mixed liquor volume once the buffer volume is exceeded. It is not possible to measure **a** directly at this installation.

Lagoon 1 has an overflow spillway so that volume added to the lagoon less evaporation, and including precipitation onto the lagoon and surrounding embankments and direct catchment area, are displaced by gravity. The low average flows, in the range of 36 gpm, coupled with



high variability posed a challenge for measuring the discharge from Lagoon 1. However, if the level of Lagoon 1 can be held steady within a reasonable range by discharging through a pump and flow meter arrangement, accurate average flow measurements may be obtained. A pump and meter installation provided flow information at **e**. Since the pump acted on a small float difference to maintain

1 Figure 1.2 Bion NMS Flow Relationships.

near constant system volume, the short term volume measurements were quite variable (driven mostly by wind action) but long term averages should be accurate. All flow meters were periodically calibrated.

Even in cool periods evaporation can represent a significant daily volume loss from open lagoon surfaces in Central Texas. A weather observing station is operated by Texas A&M in Stephenville, Texas less than 5 miles from the system. They report the Class A Pan Evaporation measured daily on their internet web site. This value in inches is multiplied by the local small lake and pond factor of 0.7 to arrive at the calculated evaporative losses from the system and Lagoon 1. An on-site recording rain gauge continuously monitored by the dairy was used to determine precipitation additions to Lagoon 1.

These daily values were used by the operators to determine the pump rate to the screens / centrifuge and was checked against the totalized flow measured and is the Bion NMS discharge rate **d** on Figure 1.2 and the long term average of 51.8 kgpd on Figure 1.1 at **8B**.

If $\underline{\lambda}$ = evaporation – precipitation for combined surfaces of the Bion system and Lagoon 1 = $\lambda_{BS} + \lambda_{LG}$, then the flow measured through the Lagoon 1 effluent pump at \underline{e} (Figure 1.2) plus $\underline{\lambda}_{LG}$ equals the amount discharged from the system to Lagoon 1 at \underline{d} or $\underline{8B}$ on Figure 1.1. Since $\underline{d} = \underline{b} - \underline{c}$:

$$\underline{b} - \underline{c} = \underline{e} + \lambda_{LG}$$

This relationship was used by the system operators to daily adjust the metered pump rate to the screen / centrifuge. In any event the long term average of $\underline{e} + \underline{\lambda}$ represents the system discharge at $\underline{8B}$ on Figure 1.1 or \underline{d} on Figure 1.2. This is the basis for all system discharge values reported and that used for mass discharge calculations.

2.2 Example Calculations:

Data and calculations to determine systems flows are in the “Flow Analysis” worksheet. May 13, 2004 or row [193] will be used for the example calculations.

2.2.1 Lagoon 1 Discharge

Column [D] contains the totalizer reading from the Lagoon 1 effluent discharge pump meter.

Column [E] records the daily amount of pumped discharge as the difference between consecutive daily readings.

For 5/13/2004: 11,060,111 gal [D193] – 11,045,244 gal [D192] = **14,867 gpd** [E193]

There are 13 missing values out of the 245 operating days addressed caused by discharge pump maintenance needs. The actual differences were averaged and this resulted in constant readings for consecutive days.

2.2.2 Evaporation

The values recorded in column [F] are the Class A Pan Evaporation measured daily at the weather observing station operated by Texas A&M, with the following exceptions:

- Zero values reported during cold weather are due to the presence of ice on the pan surface. The surface of Lagoon 1 never had any ice formation and the complete mix Bion NMS basin mixed liquor temperature remained above 10 C, therefore when zero was reported on cold days a value of 0.05 inches was placed in column [F].
- Zero values recorded on days with measurable precipitation were left at zero.

The combined water surface area of the Bion NMS and Lagoon 1 is 2.2 acres or 95,832 ft². An inch of evaporation from this surface equals:

$$(95,833 \text{ ft}^2)(\text{ft}/12 \text{ inch})(7.48 \text{ gal}/\text{ft}^3) = \mathbf{59,735.28 \text{ gal}/\text{inch}} \text{ [R11]}$$

Evaporation from the system is determined by applying the local small lake and pond evaporation factor [L4]:

$$(0.7 \text{ local factor})(59,735.28 \text{ gal/inch})(0.23 \text{ inch}) = \mathbf{9,617 \text{ gpd}} \text{ [G193]}$$

Precipitation additions are determined by accounting for rainfall onto the water surface and the banks and drainage area which is 2.42 acres giving 65,708.81 gal/inch [R12]:

$$(0.01 \text{ inch})(65,708.81 \text{ gal/inch}) = \mathbf{657 \text{ gpd}} \text{ [I193]}$$

The net discharge from the Bion NMS is thus:

$$(14,867 \text{ gpd}) + (9,617 \text{ gpd}) - (657 \text{ gpd}) = \mathbf{23,827 \text{ gpd}} \text{ [J193]}$$

2.2.3 System Discharge

Operations at a dairy are very stable. Though flows generated by such a facility do vary from day to day, they are not reflected by the very large variations seen at the Lagoon 1 discharge. However, long term averages can provide reasonable measures of flow discharged. The hydraulic detention time of the system for the nutrient study period of 12/10/03 to 5/17/04 was approximately 21 days. Therefore, flow values are averaged over a 21-day period. Before applying the running 21-day averaging, 18 of the 148 flow figures for the nutrient study period were deleted from the raw data in column [J] according to the following criteria: 1) days when substantial system bypass occurred due to major rainfall events or equipment maintenance, 2) negative values and 3) values greater than the average by more than two standard deviations, (a statistical criteria for outliers). The same approach was applied to the entire data set from 11/14/03 to 7/15/04. The edited data appears in column [J] and reflects measured normal daily discharge flows. Thus, the long term average over the entire nutrient study period reflects the normal average discharge flow from the system, 51,822 gpd [J274].

The value of 33,454 gpd in [K193] is the flow average for that day and the previous 20 days, (or cells [J173] through [J193]). This includes six edited blank cells, in this case, that are not factored into the average for that 21-day period.

Thus, the normal system average flow for the edited raw data of 51,822 gpd [J274] does not equal the 21-day average of 53,760 gpd [K274] for the same period. The data gaps created by editing the normal flow data causes this lack of data set closure or agreement. The data set must be adjusted to reflect the normal total flow for the period using the edited raw data. The small adjustment is obtained by multiplying the individual daily 21-day average flows by the ratio of the normal flow average and the 21-day average. Therefore, each cell in column [J] is multiplied by $[J274]/[K274]$ or $51,822/53,760$ to obtain the normalized 21-day flow values reported in column [N] for nutrient study period of 12/10/03 to 5/17/04.

This is a minor adjustment since the two averages are only $\pm 3.7\%$ apart and this is well within the expected accuracy of the meter, evaporation and precipitation measurements. Once normalized in this way the total flow for the period, totaled daily 21-day average flows for the

period, and the average of the 21-day daily flows for the period can all be used to determine the mass discharge of nutrients for the nutrient study period.

These 21-day average values should provide a reasonable measure of net system discharge at sampling point 8B from a process discharge standpoint, since the system retention time was indeed approximately 21 days for the period.

The same approach was used to obtain normalized 21-day average flows for the entire period from 11/14/03 to 7/15/04 and Lagoon 1 discharge for 12/10/03 to 5/17/04.

The average discharge rate for the nutrient sampling period of 12/10/03 to 5/17/04 is **51,822 gpd** [J274].

3. TOTAL NUTRIENT DISCHARGE PHOSPHOROUS & NITROGEN FROM THE BION NMS

3.1 General Approach for Phosphorous and Nitrogen

As detailed above, the 159 days from 12/10/03 to 5/17/04 is the base period for all nutrient considerations. The data collected over this entire period will provide a reasonable measure of the mass of nutrients discharged by the process. Stated another way, the average concentrations of nutrient parameters multiplied by the average discharge flow for the period will determine a reasonable figure for the average mass discharge for each parameter for the 159 day period.

As was the case with system discharge flows, daily discharge values based on 21-day running average adjusted to the normal discharge raw parameter analyses will also be determined. These normalized 21-day average numbers can then be considered as the parameter concentration and mass discharge variation as seen by the system over the period. Their use is to portray the variation experienced by the system over the nutrient study period. These individual daily values are not required to determine the average mass discharges, which is the average concentration multiplied by the average discharge rate for each parameter for the period.

Please note that the approach, calculations and examples for phosphorous and nitrogen are nearly identical. The examples and approach descriptions are given for ease of review and completeness.

3.2 System Phosphorous Discharge or P Discharge

Example computations provided below for March 30, 2004 will be for row [119] of the P-Discharge worksheet.

Column [D] is the normalized 21-day average discharge from the "Flow Analysis" worksheet column [N]. On 3/30/04 the normalized 21-day average discharge flow equaled 55,035-gpd as shown in cell [D119].

The raw laboratory discharge concentration data is entered in columns [E, F, G] for total phosphorous or Tot-P, particulate phosphorous or Part-P and soluble phosphorous or Sol-P respectively as sampled at monitoring point 8B in Figure 1.1. On 3/30/04 the Tot-P, Part-P and Sol-P concentrations at sampling location 8B equaled 395 mg/L [E119], 386 mg/L [F119] and 9 mg/L [G119], respectively.

3.2.1 The 21-day running average for the three P parameters are determined as follows.

For the first sampling cycle the average concentration value of the initial two samples is entered for each operating day within the cycle. On the next sampling day the average of three samples is used. On the 21st day from the first sampling day and thereafter, a 25 day bracket was used for the running averages from four sampling days during each successive sampling cycle. This 25-day bracket was used because sample days were not always exactly 21 days apart but if a 25-day bracket was used for the averages it would include the four sampling days representative of the 21-day period. This technique was used for all three P concentration parameters (and all three nitrogen concentration parameters in the next section as well). The 21-day average concentration values obtained in this way appear in columns [H, I, J].

For the 3/30/04 example shown on row [119]:

21-Day average Tot-P: $(338 + 359 + 366 + 395 \text{ mg Tot-P/L})/4 = \mathbf{365 \text{ mg Tot-P/L}}$ [H119]

21-Day average Part-P: $(324 + 347 + 360 + 386 \text{ mg Part-P/L})/4 = \mathbf{354 \text{ mg Part-P/L}}$ [I119]

21-Day average Sol-P: $(14 + 12 + 7 + 9 \text{ mg Sol-P/L})/4 = \mathbf{10 \text{ mg Sol-P/L}}$ [J119]

3.2.2 The normalized 21-day running average for the three P parameters are determined as follows:

The normal operating day raw data averages for the three concentration parameters differs slightly from the average for the 21-day averages. To allow daily 21-day averages to be considered as components of the total mass discharge for the period, these values are adjusted in the same manner as the 21-day average discharge flow values in the previous section.

This is a minor adjustment since the two averages are only $\pm 0.8\%$, $\pm 1.1\%$, and $\pm 1.1\%$ apart for Tot-P, Part-P and Sol-P respectively. This is well within the expected accuracy of the analyses. This treatment is parallel to the daily value calculation for the discharge flows. Note that these daily values are only used to determine system operation variation. The average concentration times the average discharge flow for the period determines the average mass discharge rate for the period.

The normalized **total phosphorous** value for the 3/30/04 example in [K119] of 368 mg Tot-P/L is obtained by multiplying [H119] by the ratio of [E171]/[H171] or raw normal average by 21-day average to obtain the normalized average:

$$(365 \text{ mg Tot-P/L})(381 \text{ mg Tot-P/L})/(378 \text{ mg Tot-P/L}) = \mathbf{368 \text{ mg Tot-P/L}} \text{ [K119]}$$

The **particulate phosphorous** normalized example in [L119] of 358 mg Part-P/L is obtained by multiplying [I119] by the ratio of [F171]/[I171] or raw normal average by 21-day average to obtain the normalized average:

$$(354 \text{ mg Part-P/L})(360 \text{ mg Part-P/L})/(356 \text{ mg Part-P/L}) = \mathbf{358 \text{ mg Part-P/L}} \text{ [L119]}$$

Soluble phosphorous normalized value in [M119] of 10 mg Sol-P/L is obtained by multiplying [J119] by the ratio of [G171]/[J171] or raw normal average by 21-day average to obtain the normalized average:

$$(10 \text{ mg Sol-P/L})(22 \text{ mg Sol-P/L})/(22 \text{ mg Sol-P/L}) = \mathbf{10 \text{ mg Sol-P/L}} \text{ [M119]}$$

3.2.3 The mass discharged from the system of the three P parameters are determined as follows:

The average mass of phosphorous discharged daily from the system over the nutrient study period is equal to the average discharge flow rate multiplied by the average concentration.

Average flow for the nutrient study period was determined to be 51,822 gpd [J274] on the Flow Analysis worksheet. The average raw data concentrations during normal operating sampling for the three P parameters of 381 mg Tot-P/L, 360 mg Part-P/L and 22 mg Sol-P/L were determined in cells [E171], [F171], and [G171] respectively. Therefore their average daily mass discharge for the study period is determined as follows:

$$(51,822 \text{ gal/day})(381 \text{ mg Tot-P/L})(3.7854\text{L/gal})(\text{lb}/454,000 \text{ mg}) = \mathbf{162 \text{ lb Tot-P/day}} \text{ [N171]}$$

$$(51,822 \text{ gal/day})(360 \text{ mg Part-P/L})(3.7854\text{L/gal})(\text{lb}/454,000 \text{ mg}) = \mathbf{153 \text{ lb Part-P/day}} \text{ [O171]}$$

$$(51,822 \text{ gal/day})(22 \text{ mg Sol-P/L})(3.7854\text{L/gal})(\text{lb}/454,000 \text{ mg}) = \mathbf{9 \text{ lb Sol-P/day}} \text{ [P171]}$$

3.2.4 Phosphorous load to the system and removal considerations

Phosphorous load to the system is transferred from the Herd P loading values determined in column [W] of the BNMS Herd & Load worksheet to column [Q]. On 3/30/04 the Herd P load to the system equaled 182.8 lb Tot-P/day [Q119] = [W167] on the BNMS Herd & Load worksheet. These loading values are then used with the Part-P [O] and Sol-P [P] system mass discharge data to determine the percent of the influent load [Q] load remaining in the system effluent as soluble (column [R]) and particulate (column [S]) forms. The 4.6 lb Sol-P/day in soluble form represents 2.5% of the average 182.8 lb P/day load to the system that day. All phosphorous loaded to the system other than this remaining 4.6 lb Sol-P/day has been

removed as coarse solids, removed as fine solids or has either remained as particulate through the system or has been converted to particulate phosphorous in the effluent. The 97.5% particulate to 2.5% soluble P ratio in the system effluent is the result of the biological conversion of soluble P to particulate form while retaining the unconverted particulate P loaded as particulate P. Effluent P in the particulate form may be captured and removed more readily by effluent polishing unit processes.

3.2.5 Nutrient Study Phosphorous Summary

A summary of the average effluent phosphorous discharged from the system over the 159 day nutrient study period 12/10/04 to 5/17/04 as processed by the Bion NMS process is detailed in Table 3.1. The value for the particulate phosphorous or Part-P discharged is particularly significant as this material is subject to ready removal by further unit operations or processes (centrifuges, filtration, etc.). If, for example, a unit process capable of removing 70% of the Tot-P discharged were installed, such as the centrifuge trialed at the dairy, of the average discharge amount of 162 lb Tot-P/day, 113 lb Tot-P/day would be removed as solids separated from the effluent. In Table 3.2 it may be seen that combined with the removals observed for coarse and fine screening, additional effluent polishing with a centrifuge would result in potential system total phosphorus removals of 79%.

Table 3.1. Average System Liquid Effluent P Discharge for Nutrient Study

Parameter	Discharge lb P/day [cell]
Total Phosphorous	162 [N171]
Particulate Phosphorous	153 [O171]
Soluble Phosphorous	9 [P171]
% Particulate Phosphorous	95 % [s171]

Table 3.2. Projected Average Total Phosphorous Removal for Nutrient Study

Removal Path	lb P / day	Load portion, %
Coarse Screenings	24^a	13
Fine Screenings	5^b	3
Effluent Separation	113	63
Total Removal	142	79
System Load	180^c	100

^a From Coarse Solids Data Analysis worksheet, cell [O305].

^b From Fine Solids Data Analysis worksheet, cell [O305].

^c From BNMS Herd & Load worksheet, cell [W287].

3.3 System Nitrogen Discharge or N Discharge

For total nitrogen discharged computations the amount present as NO₂-N and NO₃-N are not significant. Over the nutrient study period all 19 samples analyzed for NO₂-N were non-detect and the concentration measure for NO₃-N was non-detect for 16 out of a total of 25 samples. For the 9 samples in which NO₃-N was measured the range was from 0.3 to 2.5 mg NO₃-N/L with an average of 1.2 mg NO₃-N/L for all nine positive samples. The average for TKN during the nutrient study was always in the range of from 1,500 to 2,000 mg TKN/L. Thus, being insignificant NO₂-N and NO₃-N were not considered. As was expected, during start-up substantial NO₃-N was measured with values being from an initial concentration of around 250 NO₃-N /L then decreasing to 40 mg NO₃-N /L over a period of several weeks, although NO₂-N was not detected.

Please note that the approach, calculations and examples for phosphorous and nitrogen are nearly identical. The examples and approach descriptions are given for ease of review and completeness.

Example computations provided below for March 30, 2004 will be for row [119] of the N-Discharge worksheet.

Column [D] is the normalized 21-day average discharge from the "Flow Analysis" worksheet column [N]. On 3/30/04 the normalized 21-day average discharge flow equaled 55,035 gpd as shown in cell [D119].

The raw laboratory discharge concentration data is entered in columns [E, F, G] for total nitrogen or Tot-N, particulate nitrogen or Part-N and soluble nitrogen or Sol-N respectively as sampled at monitoring point 8B in Figure 1.1. On 3/30/04 the Tot-N, Part-N and Sol-N concentrations at sampling location 8B equaled 1,634 mg/L [E119], 926 mg/l [F119] and 708 mg/l [G119], respectively.

3.3.1 The 21-day running average for the three N parameters are determined as follows.

For the first sampling cycle the average concentration value of the initial two samples is entered for each operating day within the cycle. On the next sampling day the average of three samples is used. On the 21st day from the first sampling day and thereafter, a 25 day bracket was used for the running averages from four sampling days during each successive sampling cycle. This 25-day bracket was used because sample days were not always exactly 21 days apart but if a 25-day bracket was used for the averages it would include the four sampling days representative of the 21-day period. This technique was used for all three N concentration parameters (and all three phosphorous concentration parameters in the previous section as well). The 21-day average concentration values obtained in this way appear in columns [H, I, J].

For the 3/30/04 example shown on row [119]:

$$\begin{aligned} \text{21-Day average Tot-N: } & (1,571 + 1,711 + 1,642 + 1,634 \text{ mg Tot-N/L})/4 = \\ & = \mathbf{1,640 \text{ mg Tot-N/L}} \text{ [H119]} \end{aligned}$$

$$\text{21-Day average Part-N: } (852 + 849 + 908 + 926 \text{ mg Part-N/L})/4 = \mathbf{884 \text{ mg Part-N/L}} \text{ [I119]}$$

$$\text{21-Day average Sol-N: } (719 + 862 + 734 + 708 \text{ mg Sol-N/L})/4 = \mathbf{756 \text{ mg Sol-N/L}} \text{ [J119]}$$

3.3.2 The normalized 21-day running average for the three N parameters are determined as follows:

The normal operating day concentration raw data averages for the three concentration parameters differs slightly from the average for the 21-day averages. To allow daily 21-day averages to be considered as components of the total mass discharge for the period, these values are adjusted in the same manner as the 21-day average discharge flow values in the flow discharge section.

This is a minor adjustment since the two averages are only $\pm 0.7\%$, $\pm 0.4\%$, and $\pm 2.1\%$ apart for Tot-N, Part-N and Sol-N respectively. This is well within the expected accuracy of the analyses. This treatment is parallel to the daily value calculation for the discharge flows. Note that these daily values are only used to determine system operation variation. The average concentration times the average discharge flow for the period determines the average mass discharge rate for the period.

The normalized **total nitrogen** value for the 3/30/04 example in [K119] of 1,651 mg Tot-N/L is obtained by multiplying [H119] by the ratio of [E171]/[H171] or raw normal average by 21-day average to obtain the normalized average:

$$(1,640 \text{ mg Tot-N/L})(1,675 \text{ mg Tot-N/L})/(1,664 \text{ mg Tot-N/L}) = \mathbf{1,651 \text{ mg Tot-N/L}} \text{ [K119]}$$

The **particulate nitrogen** normalized example in [L119] of 880 mg Sol-N/L is obtained by multiplying [I119] by the ratio of [F171]/[I171] or raw normal average by 21-day average to obtain the normalized average:

$$(884 \text{ mg Part-N/L})(943 \text{ mg Part-N/L})/(947 \text{ mg Part-N/L}) = \mathbf{880 \text{ mg Part-N/L}} \text{ [L119]}$$

Soluble nitrogen normalized value in [M119] of 772 mg Sol-P/L is obtained by multiplying [J119] by the ratio of [G171]/[J171] or raw normal average by 21-day average to obtain the normalized average:

$$(756 \text{ mg Sol-N/L})(732 \text{ mg Sol-N/L})/(717 \text{ mg Sol-N/L}) = \mathbf{772 \text{ mg Sol-N/L}} \text{ [M119]}$$

3.3.3 The mass discharged from the system of the three N parameters are determined as follows:

The average mass of nitrogen discharged daily from the system over the nutrient study period is equal to the average discharge flow rate multiplied by the average concentration.

Average flow for the nutrient study period was determined to be 51,822 gpd [J274] on the Flow Analysis worksheet. The average raw data concentration during normal operating sampling for the three N parameters of 1,675 mg Tot-N/L, 943 mg Part-N/L and 732 mg Sol-N/L were determined in cells [E171], [F171], and [G171] respectively. Therefore their average daily mass discharge for the study period is determined as follows:

$$(51,822 \text{ gal/day})(1,675 \text{ mg Tot-N/L})(3.7854\text{L/gal})(\text{lb}/454,000 \text{ mg}) = \mathbf{720 \text{ lb Tot-N/day}} \text{ [N171]}$$

$$(51,822 \text{ gal/day})(943 \text{ mg Part-N/L})(3.7854\text{L/gal})(\text{lb}/454,000 \text{ mg}) = \mathbf{404 \text{ lb Part-N/day}} \text{ [O171]}$$

$$(51,822 \text{ gal/day})(732 \text{ mg Sol-N/L})(3.7854\text{L/gal})(\text{lb}/454,000 \text{ mg}) = \mathbf{316 \text{ lb Sol-N/day}} \text{ [P171]}$$

3.3.4 Nitrogen load to the system and removal considerations

Nitrogen load to the system is transferred from the Herd N loading values determined in column [Z] of the BNMS Herd & Load worksheet to column [Q]. On 3/30/04 the Herd N load to the system equaled 1,561.0 lb Tot-N/day [Q119] = [Z167] on the BNMS Herd & Load worksheet. These loading values are then used with the Part-N column [O] and Sol-N column [P] system mass discharge data to determine the percent of the influent load [Q] load remaining in the system effluent as soluble (column [R]) and particulate (column [S]) forms. The 354.4 lb Sol-N/day in soluble form represents 22.7% of the average 1,561.0 lb N/day load to the system. All nitrogen loaded to the system other than this remaining 354.4 lb Sol-N/day has been removed as coarse solids, removed as fine solids or has either remained as particulate through the system, has been converted to particulate nitrogen in the effluent or has been converted to and removed as nitrogen gas. Effluent N in the particulate form may be captured and removed more readily by effluent polishing unit processes.

3.3.5 Nutrient Study Nitrogen Summary

A summary of the average effluent nitrogen discharged from the system over the 159 day nutrient study period 12/10/04 to 5/17/04 as processed by the Bion NMS process is detailed in Table 3.3. By mass balance the difference between the N load to the system and all N discharges as separated solids and effluent discharge must be equal to the amount converted to and discharged as nitrogen gas. Thus, if the average discharge of 720 lb N/day [N171] in the effluent is added to the average N removed as coarse screenings at 169 lb N/day (Coarse Solids Data Analysis worksheet, cell [P305]) and of fine screenings at 34 lb N/day (Fine Solids Data Analysis worksheet, cell [P305]) a total discharge of 923 lb N/day is obtained. These measured discharges are 606 lb N/day short of the N load to the system. Therefore, by conservation of mass and mass balance the 606 lb N/day difference must be leaving the system as atmospheric discharge. From the NH₃ emissions worksheet an average of 0.81 lb NH₃/day [L135] was emitted to the atmosphere during the air emissions study. Converting this to nitrogen mass equivalents (14 N/17 NH₃) results in an average nitrogen mass discharge of 0.67 lb NH₃-N/day. If a similar discharge was assumed for the nutrient discharge period only 0.11% or 1,100 ppm of nitrogen mass discharged to the atmosphere would be as ammonia nitrogen or NH₃-N.

The value for the particulate nitrogen or Part-N discharged is particularly significant as this material is subject to ready removal by further unit operations or processes (centrifuges, filtration, etc.). If, for example, a unit process capable of removing 45% of the Tot-N discharged were installed, such as the centrifuge trialed at the dairy, of the average discharge amount of 720 lb Tot-N/day, 324 lb Tot-N/day would be removed as solids separated from the effluent. In Table 3.4 it may be seen that combined with the removals observed for coarse screening, fine screening and gaseous nitrogen discharges, additional effluent polishing with a centrifuge would result in a potential system total nitrogen removals of 74%.

Table 3.3. Average System Liquid Effluent P Discharge for Nutrient Study

Parameter	Discharge lb N/day [cell]
Total Nitrogen	720 [N171]
Particulate Nitrogen	404 [O171]
Soluble Nitrogen	316 [P171]
% Particulate Nitrogen	56 %

Table 3.4. Projected Average Total Nitrogen Removal for Nutrient Study with Effluent Treatment to 45% Tot-N Removal

Removal Path	lb N / day	Load portion, %
Coarse Screenings	169 ^a	11
Fine Screenings	34 ^b	2
Effluent Separation	324	21
Nitrogen Gas	605 ^c	40
Ammonia Gas	0.6	0.04
Total Removal	1133	74
Effluent Discharge	396^d	26
System Load	1,529^e	100

^a Coarse Solids Data Analysis worksheet, cell [P305].

^b Fine Solids Data Analysis worksheet, cell [P305].

^c By mass balance difference.

^d 720 lb Tot-N/day (effluent discharge) - 324 lb Tot-N/day (45% separation) =
= 396 lb Tot-N/day (treated effluent)

^e BNMS Herd & Load worksheet, cell [Z287].

4. HERD SERVED BY BION NMS AND RESULTING LOAD OR BNMS HERD & LOAD

Nutrient loads from cleaning agents and all other sources have been considered and found to be insignificant by two or more orders of magnitude.

The worksheet or tab labeled “BNMS Herd & Load” provides information on the herd served by the Bion NMS and the nutrient load generated by dairy operations. Since the system operates on a 21-day horizon, and since system loads are driven by cow numbers and milk production, all the milker and dry matter intake and milk production values are converted to 21-day running averages and normalized to the raw data averages as detailed elsewhere. Information on daily cow numbers, dry matter intake of rations fed, milk production and the nutrient composition of the ration are all carefully monitored by the dairy operations manager using comprehensive spreadsheet and model driven management tools. The values for these parameters were obtained directly from those dairy operations records.

Column [F] details the daily number of cows milked. The average ration dry matter intake per milk cow is presented in column [G]. Average daily milk production per milk cow is recorded in column [H]. Columns [I, J, K] are the 21-day running average for the number of milkers, dry matter intake and daily milk production respectively. Columns [L, M, N] are the 21-day averages normalized for the entire operations period from 11/21/03 to 7/16/04 and likewise columns [O, P, Q] are normalized for the nutrient study period from 12/10/03 to 5/17/04.

Non-milker manure load and bedding load is a constant for the operation. The average number of heifers and dry cow served by the system remains essentially constant according to dairy records and observation checks during the study period. The total of 432 animals in this category have an average weight of 867 pounds. Thus, they are equivalent to 274 milkers [J7] as defined at 1,365 pounds each. These 274 non-milkers contribute approximately 30% of their manure to the flush lanes as they are held in an area with feed lanes adjacent to the flush lane but open to the corals outside the barn where they are free to move at will. Flows from the open corals by-pass the Bion NMS during rain events and thus do not contribute load to the system. Thus, the Non-Milker manure contribution is equivalent to 82.2 cows [R] as is their equivalent weight contribution to the total herd being served.

4.1 Example calculations will be presented for 3/30/04 or row [167].

The number of normalized 21-day average milkers between the data sets covering the nutrient study period in column [L] compared to the values normalized to the entire data set available from 11/21/03 to 7/17/04 varies by $\pm 0.6\%$. The larger data set is thus used for the primary considerations of air emissions per thousand pound live animal weight served (KLAW) and for nutrient load generation by the dairy served.

Thus, the **cow equivalent served daily** is:

$$(1,280 \text{ milkers, cows [L167]}) + (82.2 \text{ non-milkers, cows [R167]}) = \\ = \mathbf{1,362 \text{ total herd served, cows [S167]}}$$

The **total herd weight served** by the system is then in thousand pounds live animal weight or KLAW is:

$$(1,362 \text{ cows [S167]}) (1,365 \text{ lb/cow [J6]}) (\text{KLAW}/1,000 \text{ lb}) = \mathbf{1,859 \text{ KLAW [T167]}}$$

4.2 Nutrient contribution from milkers

Nutrients fed the milking herd are closely monitored by the dairy, as is milk production. Nutrients fed, less nutrients stored in the animals, minus nutrients leaving in milk is equal to the mass excreted in manure (urine + feces = manure). The variation in average weight per milker in the herd is insignificant. Therefore, nutrients stored in milkers body mass may be ignored. Thus, since the total weight variation per milker of a production herd is insignificant, all P fed and all N fed either becomes manure load to the system or leaves the dairy as the amount removed in milk. The DeVries Dairy has very accurate numbers for dry matter intake (rations consumed by the cows or DMI), the nutrient content of that ration and of course milk production. If an allowance is made for the minor amount of feed spillage that also contributes to system load, on the order of 5% (Steve Martin animal nutritionist for DeVries Dairy – conversation 11/26/03), then this approach provides a good determination of system load. This approach is recommended by Lorimor, Jeff, et al. (2000), “Manure Characteristics – Manure Management System Series,” MidWest Plan Service, Ames Iowa, MWPS-18 Section 1, pp 19, 23.

4.2.1 Phosphorous contributed by milkers ration input:

Knowing the total number of milk cows [L167], the ration intake per cow [M167], the P content of that ration [F6] and an allowance for ration spilt that becomes part of the nutrient load to the system [J5], the P contributed to the system by ration input [U167] may be calculated as follows.

$$(1,280 \text{ milkers, cows [L167]})(52.2 \text{ lb DMI/cow-d [M167]})(0.0038 \text{ P/DMI [F6]})(1.05 \text{ spillage [J5]}) \\ = \mathbf{268 \text{ lb P/day [U167]}}$$

4.2.2 Phosphorous leaving site in fluid milk:

The phosphorous leaving in milk produced [V167] is equal to the number of milkers [L167] times the average milk production rate per milker [N167] times the P content of the milk [F8].

$$(1,280 \text{ milkers, cows [L167]})(73.7 \text{ lb milk/cow-d [N167]})(0.001 \text{ P/milk [F8]}) = \\ = \mathbf{94.3 \text{ lb P/day [V167]}}$$

4.2.3 Nitrogen contributed by milkers ration input:

Knowing the total number of milk cows [L167], the ration intake per cow [M167], the N content of that ration [F7] and an allowance for ration spilt that becomes part of the nutrient load to the system [J5], the N contributed to the system by ration input [X167] may be calculated as follows.

$$(1,280 \text{ milkers, cows [L167]})(52.2 \text{ lb DMI/cow-d [M167]})(0.0275 \text{ N/DMI [F6]})(1.05 \text{ spillage [J5]}) \\ = \mathbf{1,926 \text{ lb N/day [X167]}}$$

4.2.4 Nitrogen leaving site in fluid milk:

The nitrogen leaving in milk produced [Y167] is equal to the number of milkers [L167] times the average milk production rate per milker [N167] times the N content of the milk [F9].

$$(1,280 \text{ milkers, cows}) [L167](73.7 \text{ lb milk/cow-d} [N167])(0.005 \text{ N/milk} [F8]) = \\ = \mathbf{471 \text{ lb P/day} [Y167]}$$

4.3 Nutrient contribution from non-milkers & bedding

Non-milkers contribute nutrients through manure not accounted for when considering the milker ration and milk production from milkers in the herd. Though their numbers remain relatively small at 82.2 out of an average of 1,310 total cows or 6.3%, and though they produce manure at rates substantially lower than lactating production milkers, their input is significant.

The manure load from non-milkers is determined using the proposed ASAE manure standard as this represents the most up-to-date data reflecting current dairy rations and practices. (ASAE (2003). "Manure Production and Characteristics – Standard ASAE D384.1," proposed standard dated and issued for review on September 2, 2003.) The manure nutrient production rates for dry cows and heifers are lower by about 51% for N and about 38% for P when compared to higher manure nutrient production rates for an actively milked lactating cow. Both are the same on a per-pound of live animal weight basis. For example the total nutrient production from two 675 pound heifers or three 450 pound heifers equals the output from one 1,350 pound dry (non-milking) milk cow.

0.0661 lb P/1,400 lb cow or 0.0472 lb P/ KLAW [AF8] for heifers and dry cows

0.503 lb N/1,400 lb cow or 0.359 lb N /KLAW [AF9] for heifers and dry

4.3.1 Non-milker manure nutrient load is determined as follows:

The number of non-milker (82.2 cows) equivalent cows (cow at 1.365 Klb), times the weight of an equivalent cow (1.365 Klb) determines the total weight of the non-milkers contributing to the system. This total weight of contributing non-milkers is then multiplied by the manure nutrient rate per KLAW to obtain the nutrient rate contributed to the system.

For phosphorous:

$$(82.2 \text{ non-milkers, cows} [AF7])(1.365 \text{ KLAW/cow} [AF4])(0.0472 \text{ lb P/KLAW-d non-milker} [AF8]) \\ = \mathbf{5.30 \text{ lb P/day non-milker manure load} [AF11]}$$

For nitrogen:

$$82.2 \text{ non-milkers, cows} [AF7])(1.365 \text{ KLAW/cow} [AF4])(0.359 \text{ lb N/KLAW-d non-milker} [AF9]) = \\ = \mathbf{40.28 \text{ lb N/day non-milker manure load} [AF12]}$$

4.3.2 Nutrient Load from Bedding:

Over the entire study period a constant eight loads of gin trash per week at an average of 4,920 lb/load was used by the dairy. All bedding was removed to the flush lanes and thus directly contributed to the system load. Thus, an average of 5,623 lb bedding/day [AF18] enters the system.

Five bedding samples have been analyzed over the study period. Each sample represented a composite taken from four or more locations within the bedding stockpile and blended before submitting for analysis. The average bedding nutrient composition was 888 mg P/kg [AG22] and 14,500 mg N/kg [AG21] all on a dry weight basis. The average dry solids content of the bedding samples was 80.5% [AG23] or 0.805 dry weight bedding per wet weight bedding. The bedding nutrient load may be computed as follows:

For phosphorous:

$$(888 \text{ mg P/kg dry bedding [AG22]})(\text{Kg}/1,000,000 \text{ mg})(5,623 \text{ lb wet bedding/d [AF18]}) \\ (0.805 \text{ bed dry/bed wet [AG23]}/100) = \mathbf{4.0 \text{ lb P/day [AG27]}}$$

For nitrogen:

$$(14,500 \text{ mg P/kg dry bedding [AG22]})(\text{Kg}/1,000,000 \text{ mg})(5,623 \text{ lb wet bedding/d [AF18]}) \\ (0.805 \text{ bed dry/bed wet [AG23]}/100) = \mathbf{65.6 \text{ lb N/day [AG26]}}$$

4.3.3 Total nutrient load to system:

The total daily nutrient load to the system may now be determined as the milker ration load, minus the nutrients removed in milk leaving the dairy, plus the contribution from non-milkers and bedding for the example date.

For phosphorous:

$$(268 \text{ lb P/d ration in [U167]}) - (94.3 \text{ lb P/d milk out [V167]}) + (4.0 \text{ lb P/d bedding [AG27]}) + \\ + (5.3 \text{ lb P/d manure [AF11]}) = \mathbf{182.8 \text{ lb P/day [W167]}}$$

For nitrogen:

$$(1,926 \text{ lb N/d ration in [X167]}) - (471 \text{ lb N/d milk out [Y167]}) + (65.6 \text{ lb N/d bedding [AG26]}) + \\ + (40.28 \text{ lb N/d manure [AF12]}) = \mathbf{1,561 \text{ lb N/day [Z167]}}$$

4.4 Bion NMS load summary:

The **average total load** to the Bion NMS over the period from **12/10/03 to 5/17/04** during the **nutrient study** was:

180 lb P/day [W287] and 1,529 lb N/day [Z287]

The **average total load** to the Bion NMS over the **entire study period** from **11/21/03 to 7/16/04** was:

182 lb P/day [W278] and 1,540 lb N/day [Z278]

5. HARVESTED SOLIDS MATERIAL (HSM)

Raw data and analysis are contained in the Excel spreadsheet entitled “Master Spreadsheet.” Individual data and computational areas are contained in separate worksheets or tabs on the spreadsheet and are referenced in the explanations below.

Solids separated from the process waste stream are referred to as Harvested Solids Material (HSM). HSM sources include coarse solids from a preliminary coarse screening unit operation and fine solids from effluent polishing unit operations. Coarse solids are separated from the process waste stream by an inclined plane screen manufactured by Houle. This screen removes coarse solids from the combined recycled bioreactor process water and influent waste stream prior to discharge to the two-stage bioreactor. Effluent from the two-stage bioreactor is discharged through either a fine vibratory screen or centrifuge for fine solids separation prior to discharge to the Lagoon 1 storage volume outside of the two-stage bioreactor. The lagoon 1 storage volume provides quiescent conditions for separation of additional fine solids prior to discharge to for storage lagoon (Lagoon 2). Refer to the process flow diagram in Figure 1.1.

During the nutrient study period from December 10, 2003 through May 17, 2004 coarse and fine solids were separated from the process flow, respectively, by the inclined screen and fine screen (Sweco screen 1). Laboratory and field data from this period are presented and assessed to determine the mass of solids; phosphorus and nitrogen separated from the waste stream by the coarse and fine solids separation unit operations. Performance of the centrifuge for removing fine solids from the effluent flow is presented under a separate section of this report.

Laboratory and field data were collected on coarse and fine HSM from September 2003 through June 2004. Coarse and fine HSM laboratory data used herein includes Total Phosphorus (P) (mg/kg), Total Kjeldahl Nitrogen (TKN) (mg/kg), and percent Total Solids (% TS expressed in decimal form). Field data used in the analysis includes measurements of the mass (lb) of coarse and fine HSM separated from the process waste stream and trucked from the site.

5.1 HSM Field Data.

The mass of coarse and fine HSM separated from the process waste stream were measured in the field over the course of the study as follows:

- Coarse and fine HSM separated from the process waste stream at the DeVries Dairy are trucked from the site to licensed composting operations in the area. Trucks hauling HSM

from the site were weighed on the scale at the farm to determine the mass of HSM removed. Throughout the study period there was a great deal of variability in the schedule and regularity with which HSM was removed from the site to the composting operations. This variability ranged from removing HSM every few days to not removing any for 60+ days. The variability was due to the fact that the composting operations were “full” in the early winter and could not take in any more HSM for extended time periods.

- The mass discharge of fine HSM from fine screen 1 was tracked daily and reported as a lb/minute discharge rate. The mass discharge rate could then be used with equipment run time to determine the mass of fine solids produced over a given time period.
- Periodic HSM production tests were conducted wherein all the coarse and fine HSM would be collected over a given time period (ranging from 1 to 3 days) and weighed as produced. These test could only be conducted when the concrete pad where the HSM is stored was clean enough to permit segregation of freshly produced HSM and maneuvering of heavy equipment necessary for completing the work.

Field data on the mass of coarse and fine HSM separated from the process waste stream is summarized in the HSM Field Data worksheet. The coarse solids HSM daily production rates (lb/day) shown on row [11] of the HSM Field Data worksheet serve as input values on the Coarse Solids Data Analysis worksheet for estimating the amount of wet and dry solids separated from the process waste stream on a daily basis. Similarly, the fine solids HSM daily production rates (lb/day) shown on row [15] of the HSM Field Data worksheet serve as input values on the Fine Solids Data Analysis worksheet for estimating the amount of wet and dry solids separated from the process waste stream on a daily basis.

An explanation of how the HSM field data is used in this analysis and sample calculations follow for coarse and fine solids:

5.2 Coarse Solids Example:

- On the HSM Field Data worksheet the Coarse Solids HSM (wet weight) production rate for the period from May 3 through May 7, 2004 was measured at 73,970 lb/day [111]. The 73,970 lb/day Coarse Solids HSM production rate is then used as an input value to cell [M254] on the Coarse Solids Data Analysis worksheet. The 73,970 entered in cell [M254] represents the mass of coarse solids (lb), on a wet weight basis, separated from the process waste stream on May 5, 2004. The 73,970 lb/day was used as the input value for May 5th as it is the midpoint of the May 3 through May 7 time interval over which the coarse solids HSM production averaged 73,970 lb/day.
- Coarse Solids HSM production rates for days lying between input data dates, such as between May 5th [M254] and May 1st [M250] are calculated on a proportionate basis relative to adjoining input values as follows:

- Coarse Solids HSM Production Rate Change/Day (lb/day) = (May 5th rate of [M254] 73,970 lb – May 1st rate of [M250] 69,667 lb) / 4 days (May 5 – May 1 = 4 days) = 1,075.75 lb/day.
- Coarse Solids HMS Production Rate Calculations for May 1st through May 5th:

Date	Solids Production (lb/day) [Cell #]	Solids Production Rate Incremental Change (lb)	Comments
5/1/04	69,667 [M250]	+ 1,076 lb to 5/2 value	Field Data Input Value
5/2/04	70,743 [M251]	+ 1,075 lb to 5/3 value	
5/3/04	71,818 [M252]	+ 1,076 lb to 5/4 value	
5/4/04	72,894 [M253]	+ 1,076 lb to 5/5 value	
5/5/04	73,970 [M254]		Field Data Input Value

5.3 Fine Solids Example:

- On the HSM Field Data worksheet the Fine Solids HSM (wet weight) production rate for the period from May 3 through May 7, 2004 was measured at 14,415 lb/day [I15]. The 14,415 lb/day Fine Solids HSM production rate is then used as an input value to cell [M254] on the Fine Solids Data Analysis worksheet. The 14,415 entered in cell [M254] represents the mass of fine solids (lb) separated from the process waste stream on May 5, 2004. The 14,415 lb/day was used as the input value for May 5th as it is the midpoint of the May 3 through May 7 time frame over which the fine solids HSM production averaged 14,415 lb/day.
- Fine Solids HSM production rates for days lying between input data dates, such as between May 5th [M254] and May 1st [M250] are calculated on a proportionate basis relative to adjoining input values as follows:
 - Fine Solids HSM Production Rate Change/Day (lb/day) = (May 5th rate of [M254] 14,415 lb – May 1st rate of [M250] 15,713 lb) / 4 days (May 5 – May 1 = 4 days) = **324.5 lb/day.**

- Fine Solids HMS Production Rate Calculations for May 1st through May 5th:

Date	Solids Production (lb/day) [Cell #]	Solids Production Rate Incremental Change (lb)	Comments
5/1/04	15,713 [M250]	- 324 lb to 5/2 value	Field Data Input Value
5/2/04	15,389 [M251]	- 325 lb to 5/3 value	
5/3/04	15,064 [M252]	- 324 lb to 5/4 value	
5/4/04	14,740 [M253]	- 325 lb to 5/5 value	
5/5/04	14,415 [M254]		Field Data Input Value

5.4 HSM Laboratory Data.

Coarse and fine HSM laboratory data used in this analysis includes Total Phosphorus (P) (mg/kg), Total Kjeldahl Nitrogen (TKN) (mg/kg), and percent Total Solids (% TS expressed in decimal form). Laboratory data for P, TKN and % TS are reported on both the Coarse Solids Data Analysis and Fine Solids Data Analysis worksheets, respectively, in columns [D], [G] and [J]. Between September 2, 2003 and June 22, 2004 there were 40 sampling events including 23 during the December 10, 2003 through May 17, 2004 nutrient study period. An explanation of how the HSM laboratory data is used in this analysis and sample calculations follows for coarse and fine solids. These explanations and sample calculations use data contained in row [254] of the Coarse Solids Data Analysis worksheet as was presented for the HSM Field Data example provided above.

5.4.1 Coarse Solids Example:

5.4.1a Phosphorus:

The P content of the Coarse Solids HSM on May 5, 2004 was 2,430 mg/kg as shown in cell [D254] of the Coarse Solids Data Analysis worksheet.

21-day Running Average P Content (mg/kg) (Column [E]): The P laboratory data input in column [D] is converted to the 21-day Running Averages shown in column [E] as follows: May 5, 2004, 21-day Running Average for P (mg/kg) [E254] = Average of Laboratory Input Values in column [D] between cells [D230] and [D254] (mg/kg) = 2,282 mg/kg [E254]. The 21-day running averages are used to determine the daily P content of HSM shown in the Coarse Solids Data Analysis worksheet. The 21-day running averages are then used with statistical data for the nutrient study period to determine the Normalized 21-day Average P contents shown in column [F] of the Coarse Solids Data Analysis worksheet.

Normalized 21-day Average P Content (mg/kg) (Column [F]): The Normalized 21-day P content of the coarse solids on May 5th was 2,237 mg/kg as shown cell [F254]. Thus, the May 5th input laboratory input value of 2,430 mg/kg [D254] has corresponding 21-day Running Average and Normalized Averages of 2,282 mg/kg [E254] and 2,237 mg/kg [F254],

respectively. The 21-day Normalized Average P Content of the HSM of 2,237 mg/kg [F254] = $(2,185 \text{ mg/kg [D305]} / 2,229 \text{ mg/kg [E305]}) \times 2,282 \text{ mg/kg [E254]}$. The 21-day Normalized P Content of the HSM of 2,237 mg/kg [F254] = $(\text{P Laboratory Input Value Data Average from December 10, 2003 through May 17, 2004 [D305]} / 21\text{-day Running P Average from December 10, 2003 through May 17, 2004 [E305]}) \times (\text{May 5th 21-day Running Average P Value [E254]})$.

5.4.1b Nitrogen as Measured by TKN:

The TKN content of the Coarse Solids HSM on May 5, 2004 was 15,385 mg/kg as shown in Cell [G254] of the Coarse Solids Data Analysis worksheet.

21-day Running Average TKN Content (mg/kg) (Column [H]): The TKN laboratory data input in column [G] is converted to the 21-day Running Averages shown in column [H] as follows: May 5, 2004, 21-day Running Average for TKN (mg/kg) [H254] = Average of Laboratory Input Values in column [G] between cells [G230] and [G254] (mg/kg) = 15,366 mg/kg [H254]. The 21-day running averages are used to determine the daily TKN content of HSM shown in the Coarse Solids Data Analysis worksheet. The 21-day running averages are then used with statistical data for the nutrient study period to determine the Normalized 21-day Average TKN contents shown in column [I] of the Coarse Solids Data Analysis worksheet.

Normalized 21-day Average TKN Content (mg/kg) (Column [I]): The Normalized 21-day Average TKN content of the coarse solids on May 5th was 15,307 mg/kg as shown in cell [I254]. Thus, the May 5th input laboratory input value of 15,385 mg/kg [G254] has corresponding 21-day Running Average and Normalized Averages of 15,366 mg/kg [H254] and 15,307 mg/kg [I254], respectively. The Normalized 21-day Average TKN Content of the HSM of 15,307 mg/kg [I254] = $(15,305 \text{ mg/kg [G305]} / 15,364 \text{ mg/kg [H305]}) \times 15,366 \text{ mg/kg [H254]}$. The Normalized 21-day Average TKN Content of the HSM of 15,307 mg/kg [I254] = $(\text{TKN Laboratory Input Value Data Average from December 10, 2003 through May 17, 2004 [G305]} / 21\text{-day Running Average TKN from December 10, 2003 through May 17, 2004 [H305]}) \times (\text{May 5th 21-day Running Average TKN Value [H254]})$.

5.4.1c Percent TS (% TS):

The % TS content of the Coarse Solids HSM on May 5, 2004 was 22.1% or 0.221 as shown in cell [J254] of the Coarse Solids Data Analysis worksheet. Laboratory and calculated TS data is presented in decimal form.

21-day Running Average for % TS (Column [K]): The % TS laboratory data input in column [J] is converted to the 21-day Running Averages shown in column [K] as follows: May 5, 2004 21-day Running Average % TS [K254] = Average of Laboratory Input Values in column [J] between cells [J230] and [J254] = 0.205 [K254]. The 21-day running averages are used to determine the daily % TS of the HSM shown in the Coarse Solids Data Analysis worksheet. The 21-day running averages are then used with statistical data for the nutrient study period to determine the Normalized 21-day Average % TS shown in column [L] of the Coarse Solids Data Analysis worksheet.

Normalized 21-day Average for % TS (Column [L]): The Normalized 21-day Average % TS of the coarse solids on May 5th was 0.209 as shown in cell [L254]. Thus, the May 5th input laboratory input value of 0.221 [J254] has corresponding 21-day Running Average and Normalized Averages of 0.205 [K254] and 0.209 [L254], respectively. The 21-day Normalized Average % TS of the HSM of 0.209 [L254] = $(0.188 [J305] / 0.185 [K305])(0.205 [K254])$. The 21-day Normalized Average % TS of the HSM of 0.209 [L254] = $(\% \text{ TS Laboratory Input Value Data Average from December 10, 2003 through May 17, 2004 [J305]} / 21\text{-day Running Average \% TS from December 10, 2003 through May 17, 2004 [K305]})(\text{May 5th 21-day Running Average \% TS Value [K254]})$.

5.4.2 Fine Solids Example:

Separate examples for fine solids laboratory data are not provided for P, TKN and % TS as the approach is identical as that explained for coarse solids above.

5.5 HSM Phosphorus and Nitrogen Content.

The coarse and fine solids separated from the process waste stream contain phosphorus and nitrogen. Thus, when HSM is removed from the farm to a remote composting facility, phosphorus and nitrogen are also being exported from the dairy. Estimating the amount of phosphorus and nitrogen contained in the coarse and fine HSM requires data on the nutrient content (P and TKN) of the HSM and the mass of fine and coarse solids removed as HSM. Column [M] in the Coarse Solids Data and Fine Solids Data Analysis worksheets provides estimates of the mass of coarse and fine HSM removed from process waste stream on a daily basis. On May 5th, 2004 approximately 88,385 lb of HSM were removed from the process waste stream including 73,970 lb [M254] (from Coarse Solids Data Analysis worksheet) of coarse solids and 14,415 lb [M254] (from Fine Solids Data Analysis worksheet) of fine solids.

Explanations and sample calculations follow for determining the P and TKN content of the coarse and fine solids components of HSM removed from the process waste stream at the dairy on May5, 2004. These explanations and sample calculations use data contained in row [254] of the Coarse Solids Data Analysis and Fine Data Analysis worksheets as presented for the HSM Field and Laboratory Data examples provided above.

5.5.1 Coarse Solids Example:

5.5.1a Convert Coarse Solids from Wet to Dry Weight Basis: In the Coarse Solids Data Analysis worksheet, input data for the amount of coarse solids HSM separated from the process waste stream on May 5, 2003 equaled 73,970 lb [M254]. The 73,970 lb of coarse solids HSM is on a wet weight basis and needs to be converted to a dry weight basis to determine the P and TKN contents of the solids. Coarse solids HSM wet weights presented in column [M] of the Coarse Solids Data Analysis worksheet are presented as dry weights in column [N]. Conversion of wet solids weights to dry solids weights was completed as follows:

For the May 5, 2004 Coarse Solids Data: Coarse Solids HSM Wet Weight (73,970 lb) [M254] x Coarse Solids Normalized 21-day Average % TS (0.209) [L254] = Coarse Solids HSM Dry Weight (15,446 lb) [N254].

5.5.1b Determine Coarse Solids P Content on May 5, 2004: The mass of P contained in the 15,466 lb of dry weight solids [N254] is calculated as follows: Coarse Solids HSM Dry Weight (15,466 lb) [N254] x Normalized 21-day Average P Content (2,237 mg/kg) [F254] x Conversion Factor (1 kg/1,000,000 mg) = P Content of Coarse Solids (35 lb) [O254].

5.5.1c Determine Coarse Solids TKN Content on May 5, 2004: The mass of TKN contained in the 15,466 lb of dry weight solids [N254] is calculated as follows: Coarse Solids HSM Dry Weight (15,466 lb) [N254] x Normalized 21-day Average TKN Content (15,307 mg/kg) [I254] x Conversion Factor (1 kg/1,000,000 mg) = TKN Content of Coarse Solids (236 lb) [P254].

5.5.2 Fine Solids Example:

5.5.2a Convert Coarse Solids from Wet to Dry Weight Basis: In the Fine Solids Data Analysis worksheet the input data for the amount of coarse solids HSM separated from the process waste stream on May 5, 2003 equaled 14,415 lb [M254]. The 14,415 lb of fine solids HSM is on a wet weight basis and needs to be converted to a dry weight basis to determine the P and TKN contents of the solids. Fine solids HSM wet weights presented in column M of the Fine Solids Data Analysis worksheet are presented as dry weights in column N. Conversion of wet solids weights to dry solids weights is as follows:

For the May 5, 2004 Fine Solids Data: Fine Solids HSM Wet Weight (14,415 lb) [M254] x Fine Solids Normalized 21-day Average % TS (0.097) [L254] = Fine Solids HSM Dry Weight (1,392 lb) [N254].

5.5.2b Determine Fine Solids P Content on May 5, 2004: The mass of P contained in the 1,392 lb of dry weight solids [N254] is calculated as follows: Fine Solids HSM Dry Weight (1,392 lb) [N254] x Normalized 21-day Average P Content (4,421 mg/kg) [F254] x Conversion Factor (1 kg/1,000,000 mg) = P Content of Fine Solids (6 lb) [O254].

5.5.2c Determine Fine Solids TKN Content on May 5, 2004: The mass of TKN contained in the 1,392 lb of dry weight solids [N254] is calculated as follows: Fine Solids HSM Dry Weight (1,392 lb) [N254] x Normalized 21-day Average TKN Content (29,031 mg/kg) [I254] x Conversion Factor (1 kg/1,000,000 mg) = TKN Content of Fine Solids (40 lb) [P254].

5.6 HSM Solids, P and TKN Capture Overview.

Following are summaries of the mass of solids, P and TKN contained in the coarse and fine solids HSM separated from the process waste stream during the December 10, 2003 through May 17, 2004 nutrient study period. Coarse and fine solids cell references below refer to their respective Coarse and Fine Solids Data Analysis worksheets.

5.6.1 Coarse Solids HSM:

Average HSM Separated Solids = 58,573 lb/day (wet weight basis) [M305] = 11,069 lb/day (dry weight basis) [N305].

Average % TS = 18.8% [J305].

Average HSM Solids P Content = 24 lb/day [O305].

Average HSM Solids TKN Content = 169 lb/day [P305].

5.6.2 Fine Solids HSM:

Average HSM Separated Solids = 12,998 lb/day (wet weight basis) [M305] =
= **1,268 lb/day** (dry weight basis) [N305].

Average % TS = 9.8% [J305].

Average HSM Solids P Content = 5 lb/day [O305].

Average HSM Solids TKN Content = 34 lb/day [P305].

6. ATMOSPHERIC EMISSIONS

6.1 General.

The document entitled “DeVries Dairy, Bion NMS Waste Management System, Sealed Process System Description for Air Emissions Monitoring,” referred to as the Air Protocol, provides details on the sampling program, laboratory analyses and methodology for identifying, quantifying and assessing air emissions from the Bion NMS anaerobic and anoxic bioreactor unit processes. In accordance with the above protocol, air emissions from the anaerobic and anoxic bioreactor treatment zones have been monitored using, respectively, air emissions monitoring tanks T1 and T2. In addition to monitoring process off gases from tanks T1 and T2, air emissions gas parameter readings and samples have been collected at several other locations throughout the Bion NMS process including barn flush alleys, contact chamber and flow splitter box. A Flux-Chamber was also used to measure and sample off gases from the anaerobic and anoxic bioreactor unit processes for comparative purposes. Results from these data gathering efforts are presented herein in support of work completed under the air emissions protocol referenced above.

The air emissions data analysis is presented on seven worksheets. Worksheets are provided for each of the six gaseous generation parameters as detailed in the air emissions protocol and are named CH₄, CO₂, NH₃, H₂S, NO_x, NMOC. The reference worksheet entitled “Air Emissions Basis” provides the operating conditions and dairy herd loading factors for the assessment period. This data is used for each air emission parameter to arrive at the calculated mass generation rates. Sampling of the vents from anaerobic tank T1 and anoxic tank T2 was performed as daily composites and hourly grab samples using evacuated sampling canisters, or as direct vent analysis using in-situ monitoring techniques as detailed in the air emissions protocol. The headspace gas in tanks T1 and T2 turns over approximately every one to two hours. Thus, the gas generation samples are addressed as daily sample

results, representative of the condition for that day. System loading factors and dairy herd served are utilized in the data analyses on a normalized 21-day average basis as detailed in previous sections.

6.2 Air Emissions Assessment Basis.

6.2.1 Dairy Herd.

In the air emissions analysis, collected air emissions data is used with bioreactor and dairy herd data to determine air emissions rates on a 1,000 lb live animal weight per year basis (KLAW-yr). To complete this analysis it is therefore necessary to utilize data on the dairy herd size and composition throughout the assessment period. Column [E] of the Air Emission Basis worksheet provides dairy herd size normalized 21-day estimates of herd size. The normalized 21-day herd size data values are imported from column [L] of the BNMS Herd & Load worksheet and consider all available data. Air Emissions Basis worksheet input values for Non-Milkers, Total Cows and Herd Weight are provided, respectively, in columns [F, G, H]. These input values are from columns [R, S, T] of the BNMS Herd & Load worksheet as well.

6.2.2 Tank T1 and T2 Ventilation and Liquid Feed Rates.

Ventilation rates are directly controlled for anaerobic tank T1 by the cross flow ventilation fan and by the aeration rate for anoxic tank T2. As controlled rates, the ventilation rates are considered to be step functions and, as such, data transitions are not required and daily rates are used in the data assessment process. The same principal holds true for the tank feed/liquid flow rates shown in columns [J] and [N] for tanks T1 and T2, respectively.

6.2.3 Process Temperature.

Air temperatures were recorded daily in deg F and are provided in column [O] and are presented in deg C in column [P] and deg K in column [Q].

6.2.4 Gas Parameter Mass Densities.

The volumetric determination of each gas parameter as ppm or % (volume to volume) must be converted to an equivalent mass. Thus, the mass density for the gas as sampled must be used to determine the mass generation rate from the vent at the time the sample was taken. The mass density @ Standard Temperature and Pressure (STP) for the four compound specific parameters are directly determined from the gas laws.

6.2.4a Mass Density for Methane (CH₄) cell [E3] may be determined as follows:

$$(16 \text{ g CH}_4/\text{mole CH}_4)(\text{mole CH}_4/22.414 \text{ L CH}_4)(\text{lb}/454 \text{ g})(28.317 \text{ L}/\text{ft}^3) = \\ = \mathbf{0.044524 \text{ lb CH}_4/\text{ft}^3 \text{ CH}_4 \text{ [E3]}}$$

Both NO_x and NMOC are potentially mixtures of many molecular weight substances. The quantitative measure on a mass basis is directly related to the calibration gas or standard

used. For NO_x the calibration or standard is NO₂ (USEPA 19, Method 7) and is also the standard for the Dragger tube and CMS Chip devices as well. Thus, the mass basis for NO_x [E7] may be determined as follows using the NO₂ standard:

6.2.4b Mass Density for Nitrogen Oxides (NO_x) cell [E7] may be determined as follows:

$$(46 \text{ g NO}_x \text{ as NO}_2/\text{mole NO}_2)(\text{mole NO}_2 / 22.414 \text{ L NO}_2)(\text{lb}/454 \text{ g})(28.317 \text{ L}/\text{ft}^3) = \\ = \mathbf{0.12801 \text{ lb NO}_x / \text{ft}^3 \text{ NO}_x \text{ [E7]}}$$

6.2.4c Non-Methane Organic Carbon (NMOC) cell [E8] may be determined as follows: The laboratory calibration standard for NMOC is pentane or C₅H₁₂. Thus, the mass basis for NMOC [E8] may be determined as follows using the standard C₅H₁₂:

$$(72 \text{ g NMOC as C}_5\text{H}_{12}/\text{mole C}_5\text{H}_{12})(\text{mole C}_5\text{H}_{12}/22.414 \text{ L C}_5\text{H}_{12})(\text{lb}/454 \text{ g})(28.317 \text{ L}/\text{ft}^3) = \\ = \mathbf{0.20036 \text{ lb NMOC}/\text{ft}^3 \text{ NMOC [E8]}}$$

Mass densities for Carbon Dioxide [E4], Ammonia [E5] and Hydrogen Sulfide [E6] were determined in the same manner as Methane except that their respective molecular weights were used in the computations.

6.2.5 Tank T1 and T2 Air Emissions Multipliers.

Air emissions from anaerobic tank T1 and anoxic tank T2 are sampled and monitored in accordance with the document entitled “DeVries Dairy, Bion NMS Waste Management System, Sealed Process System Description for Air Emissions Monitoring”. As explained in that document, air emissions monitoring tanks T1 and T2 are sized and operated such that they function from an air emissions perspective similar to the full-scale anaerobic and anoxic bioreactor treatment zones. Given that tanks T1 and T2 are a fraction of the size of the full-scale unit processes, multipliers are required for projecting tank T1 and T2 air emissions for the full-scale anaerobic and anoxic bioreactor unit processes. Multiplication factors for tanks T1 and T2 are determined as follows:

6.2.5a Anaerobic Tank T1 Multiplier. The liquid volume in tank T1 is such that the surface area to volume ratio is identical to the anaerobic zone in the bioreactor. The rate of mass generation for each parameter for the full-scale anaerobic treatment zone is thus proportional to either the surface areas or volume ratios in tank T1:

$$\text{Volume Anaerobic zone} = 100,000 \text{ gal} \qquad \text{Volume T1} = 7,269 \text{ gallon}$$

$$\text{Total System Volumetric Ratio} = (100,000 + 7,269)/7,269 = 14.76$$

$$\text{Surface area Anaerobic zone} = 1,550 \text{ ft}^2 \qquad \text{Surface are T1} = 113 \text{ ft}^2$$

$$\text{Total System Surface area ratio} = (1,550 + 113)/113 = 14.72$$

T1 multiplier = 14.74 (cell [J6] in the Air Emission Basis worksheet).

6.2.5b Anoxic Tank T2 Multiplier.

The rate of gas generation for the anoxic zone is determined by the average depth and rate at which aeration bubbles/air passes through this depth. Tank T2 is set at an operating depth of 13.0 feet, which is approximately equal to the overall depth of the full-scale anoxic zone. With those depths set equal, tank T2 will generate air emissions approximately the same as the full-scale anoxic zone on a volumetric basis as long as the aeration rates per unit volumes are set equal. The aeration rate for tank T2 is set to obtain the same volumetric rate as the full-scale anoxic treatment zone. Thus, the most representative multiplier for tank T2 is the ratio of the two volumes;

$$(1,000,000 \text{ gallon} + 11,000 \text{ gallons}) / 11,000 \text{ gallons} = 91.91$$

T2 multiplier = 91.91 (cell [J7] in the Air Emission Basis worksheet).

The aeration flow rate in T2 is variable as a function of the aeration rates delivered to the full-scale anoxic volume. The flow injected by the aeration system was typically measured 2 to 5 times per week. The aeration rate into T2 was adjusted to deliver the same volumetric flow rate. Mechanical problems prevented flow matching for short periods. However, T2 volumetric aeration rates were within $\pm 10\%$ of target values for about 80% of the entire period. On only 4 of the 35 sampling days were the rates 30% less than the matching rate or greater, which could lead to under stripping in T2. There is no apparent relationship between aeration flow in T2 and the emission rates determined. Thus, it would seem that the resulting rates measured would provide reasonable measures, perhaps conservatively high, for emission rates reported.

6.3 Methane (CH₄) Air Emissions.

6.3.1 Methane data and air emissions calculations are contained in the CH₄ worksheet. Recorded methane data for tanks T1, the anaerobic tank, and T2, the anoxic tank is presented in the CH₄ worksheet in the following locations:

Field & Sample/Laboratory Data	Anaerobic Tank T1	Anoxic Tank T2
Tank Vent Air Flow Rate	Columns [E] Rows [147–185]	Columns [E] Rows [193-231]
Tank Liquid Influent Flow Rate	Columns [F] Rows [147–185]	Columns [F] Rows [193-231]
Methane Sample/Lab Data	Columns [G,H,I] Rows [147–185]	Columns [G,H,I] Rows [193-231]
Data Edits	Columns [J,K] Rows [147–185]	Columns [J,K] Rows [193-231]

Starting in the area of cell [D140] the field or in-situ, and laboratory analysis results for methane measurements and vent and recirculation flows are recorded for Anaerobic Tank T1 and Anoxic Tank T2. In column [E] beginning with row [147]+ the vent flows resulting from ventilation for T1 and aeration for T2 are recorded. In column [F] beginning with row [147]+ the

influent tank feed flow rates from the respective unit processes in the full-scale system are presented. Both in-situ and laboratory methane concentrations (reported as % methane by volume) are entered in columns/row [G147]+, [H147]+, and [I147]+. The concentration values which are used in the emissions calculations in the rest of the CH₄ worksheet are obtained from these three columns and presented in “Data Edits Used” column [J] beginning with row [147]+. Since agreement between in-situ and laboratory values are good, a simple data editing approach was applied. If a laboratory value was available it was used, with composite samples shown in column [I] taking precedence over grab samples shown in column [H]. Otherwise the in-situ or field grab sample values from column [G] were used. Thus, for Methane computations no further data manipulation was required.

In a few instances vent flow readings were not recorded when concentration samples were taken. In these instances the earlier recorded vent flow reading which was closest in time to the sampling event was used in the calculations. The actual and edited vent flow readings are listed in column [K] beginning with row [147]+.

6.3.2 Supplemental Methane Air Emissions Data.

On April 7, 2004 and April 22, 2004 four additional whole air samples were collected at locations within the dairy to determine air quality influenced by the circulating process water which serves as recycled flush water in the Bion NMS process. Field grab samples were taken on April 1, 2004, at the Houle and second barn flush lane locations. Supplemental data collection locations were as follows:

- Active flushing and draining of alleys occurs for about 15 minutes per flush cycle and four flushes cycles occur daily. Ten-minute canister grab samples were taken at two locations along an actively flushing alley for the two separate sampling days. Collected data is presented in the CH₄ worksheet in columns [D–I] in rows [257–276].
- A one-hour canister grab sample was taken below the rim of the coarse screen sump or contact / mixing tank at an elevation one foot above the maximum flush water elevation. Collected data is presented in the CH₄ worksheet in columns [D–I] in rows [235–243].
- Flow from the coarse screen / contact mixing sump travels over an elevated inclined coarse static screen. The vertical down-flow effluent pipe from this screen produces a continuous vacuum draw through the screen. These gasses are released in the flow splitter box adjacent to the fine screens. An instantaneous (one minute) grab canister was sampled from the splitter box headspace during active coarse screen flow. Collected data is presented in the CH₄ worksheet in columns [D–I] in rows [246–254].

6.3.3 Tank T1 – Anaerobic Zone Methane Emissions.

Methane emissions from tank T1 are used to determine emissions from the full-scale anaerobic bioreactor treatment zone and presented on a KLAW-yr basis in the area of the CH₄ worksheet that includes columns [D–O] and rows [14–42]. Following are more detailed

explanations of the data and approach used in these calculations, including sample calculations used in the worksheet.

Herd weights utilized are the normalized 21-day herd weight previously discussed and are presented in cells [E14– E42].

Both in-situ and laboratory methane concentrations are reported as % methane. The values appear in cells [F14–F42]. The data is the “Edited Used Values” found in cells [J152-J185].

Vent flow rates are presented in cells [G14-G42] are as determined using a hot-wire anemometer on the vent.

The vent temperatures presented in cells [H14–H42] are the average ambient air temperature for the day from the column [Q] of the Air Emissions Basis worksheet as converted into °K.

The amount of methane in tank T1 vent air flow is shown in cells [I14–I42] and is labeled as “Methane Flow’ (ft³CH₄/min). The methane flow rate is calculated using methane concentration times vent flow rate. Using the 5/12/04 data set contained in row [20] as an example:

$$(0.19\% \text{ CH}_4/\text{vent [F20]})(1/100\%)(17.67 \text{ ft}^3/\text{min}[G20]) = \mathbf{0.03357 \text{ ft}^3 \text{ CH}_4/\text{min [I20]}$$

To obtain the mass density at the vent temperature the density at STP from the Air Emissions Basis worksheet [E3] Methane = 0.044524 lb CH₄/ft³_{STP} must be corrected for temperature. These calculated values are presented in cells [H14 – H42]. The mass density on 5/12/04 in cell [J20] is determined as follows:

$$(0.044524 \text{ lb CH}_4/\text{ft}^3_{\text{STP}})(273.15 \text{ }^\circ\text{K}_{\text{STP}}/298.15 \text{ }^\circ\text{K [H20]}) = \mathbf{0.04079 \text{ lb CH}_4/\text{ft}^3 \text{ [J20]}$$

Calculations of the daily amount of methane generated from tank T1 are presented in cells [K14–K42]. The amount of methane generated on 5/12/04 in cell [K20] is determined as follows:

$$(0.03357 \text{ ft}^3 \text{ CH}_4/\text{min}[I20])(0.04079 \text{ lb CH}_4/\text{ft}^3[\text{J20}])(1,440 \text{ min/d}) = \mathbf{1.97 \text{ lb CH}_4/\text{d [K20]}$$

The amount of methane emitted by the full-scale bioreactor anaerobic zone on 5/12/04 equals the multiplier from the Air Emissions Basis worksheet cell [J6] (14.74) times tank T1 emission rate or:

$$(1.97 \text{ lb CH}_4/\text{d}[K20])(14.74 \text{ total system anaerobic zone/anaerobic tank}) = \mathbf{29.07 \text{ lb CH}_4/\text{d [L20]}$$

Emission rates are stated as mass of the gas parameter per animal weight per year and most often as pounds of the parameter per thousand pounds of live animal weight per year or lb/KLAW-yr. This figure is obtained for 5/12/04 by dividing the emission rate by the herd weight served on that day:

$$(29.07 \text{ lb CH}_4/\text{d}[L20])(365 \text{ d/yr})/(1,970 \text{ KLAW}[E20]) = \mathbf{5.38 \text{ lb CH}_4/\text{KLAW-yr [M20]}$$

Average values for the period may be obtained by applying standard numerical integration of the generation rate for each increment of the period, then dividing the total by the total period to obtain the properly weighted average for the period. For 5/12/04 these values are provided in cells [N20 & O20].

6.3.4 Tank T2 – Anoxic Zone Methane Emissions.

Methane emissions from tank T2 are used to calculate emissions from the full-scale anoxic bioreactor treatment zone and are presented on a KLAW-yr basis. The data and calculations are provided in the area of the CH₄ worksheet that includes columns [D–O] and rows [55–89]. The approach taken in estimating the anoxic tank T2 Methane air emission rate is identical to the method employed for anaerobic tank T1 with two exceptions, as follows:

The vent flow rates presented in column [G] (rows [55–89]) were initially measured using a hot-wire anemometer on the vent. Aeration of tank T2 is the only significant source of vent flow in tank T2. To provide positive control of the aeration rate, a rotometer with a flow indicator was installed on the aeration line downstream of the aeration compressor and prior to discharge into tank T2. Once this flow control device was installed readings from it were used as recorded daily vent flow rates.

The vent temperatures in column [H] rows [55-89] is the bioreactor temperature for the day with the value taken from the Air Emissions Basis worksheet, column [L] as converted into °K.

6.3.5 Total Methane Emissions.

Total Methane Emissions from the DDBS Facility are presented in the CH₄ worksheet area including columns [D–M] and rows [99–133]. Data presented here includes the data from anaerobic tank T1 and anoxic tank T2 worksheet calculation sections of the worksheet. Tank T1 data is presented in columns [E,F] and tank 2 data in columns [G,H]. The combined T1 and T2 methane emissions data are then added to obtain a total emission rate for the Bion NMS system. A final weighted average for the full system’s production of methane, reported as pounds of methane per KLAW per year, is presented in column [M] in rows [99-133].

6.3.5 Emission Rates for methane

CH₄ emission rate **27.49 lb CH₄/KLAW-yr entire test period [M135]**

21.74 lb CH₄/KLAW-yr last 30 days of test period [M139]

6.4 Carbon Dioxide (CO₂) Air Emissions.

6.4.1 Carbon Dioxide data and related air emissions calculations are contained in the CO₂ worksheet. The procedure for calculating Carbon Dioxide emissions is essentially identical to that presented for Methane above. There were a few differences in data points collected and therefore a few differences in cell identifications within the respective sheets. For example there is no data entry for tank T2 methane on 3/31/04 while there is a data entry for tank T2

carbon dioxide on 3/31/04. Consequently the 4/1/04 entries for the respective tests have different cell numbers in their respective worksheets.

The density of carbon dioxide at STP is obtained from the Air Emissions Basis worksheet, cell [E4] (not cell [E3] as was the case for methane). This value is used to obtain the carbon dioxide mass density at the vent temperature as calculated for Methane. Carbon Dioxide density as adjusted for temperature is presented in column [J] rows [14-42] for anaerobic tank T1 and rows [55-89] for tank T2.

Carbon Dioxide air emissions data are presented in the CO2 worksheet in the following locations:

Field & Sample/Laboratory Data	Anaerobic Tank T1	Anoxic Tank T2
Tank Vent Air Flow Rate	Column [E] Rows [147–184]	Column [E] Rows [192-230]
Tank Liquid Influent Flow Rate	Column [F] Rows [147–184]	Column [F] Rows [192-230]
CO ₂ Sample/Lab Data	Columns [G,H,I] Rows [147–184]	Columns [G,H,I] Rows [192-230]
Data Edits	Columns [J] Rows [147–184]	Columns [J] Rows [192-230]
Closest Gas Flow Reading	Columns [K] Rows [147–184]	Columns [K] Rows [192-230]

6.4.2 Supplemental Carbon Dioxide Air Emissions Data is located as follows in the CO2 worksheet:

Flush Alleys: Collected data is presented in the CO2 worksheet in columns [D–I] in rows [257–276].

Coarse Screen: Collected data is presented in the CH4 worksheet in columns [D–I] in rows [235–243].

Splitter Box: Collected data is presented in the CH4 worksheet in columns [D–I] in rows [246–254].

6.4.3 Carbon Dioxide air emissions rate calculation for the anaerobic zone and anoxic zone are presented in the CO2 worksheet in the following locations:

Parameter	Anaerobic Zone Tank T1	Anoxic Zone Tank T2
Herd Weight (KLAW)	Column [E] Rows [14–42]	Column [E] Rows [55-89]
Carbon Dioxide (%)	Column [F] Rows [14–42]	Column [F] Rows [55-89]
Vent Flow Rate (ft ³ /min)	Column [G] Rows [14–42]	Column [G] Rows [55-89]
Vent Temp, (°K)	Column [H] Rows [14–42]	Column [H] Rows [55-89]
CO ₂ Flow (ft ³ CO ₂ /min)	Column [I] Rows [14–42]	Column [I] Rows [55-89]
CO ₂ Density (lb CO ₂ /ft ³)	Column [J] Rows [14–42]	Column [J] Rows [55-89]
CO ₂ Generation	Columns [K,L,M] Rows [14–42]	Columns [K,L,M] Rows [55-89]
Data Weighting Factors	Columns [N,O] Rows [14–42]	Columns [N,O] Rows [55-89]

- Carbon Dioxide air emissions calculations for the anaerobic zone, anoxic zone and total system are presented in the CO2 worksheet in the following locations:

Parameter	Anaerobic Zone T1	Anoxic Zone T2	Total System
CO ₂ (lb/day)	Column [E] Rows [99–133]	Column [G] Rows [99–133]	Column [I] Rows [99–133]
CO ₂ (lb CO ₂ /KLAW-yr)	Column [F] Rows [99–133]	Column [H] Rows [99–133]	Column [J] Rows [99–133]
Data Weighting Factors	-	-	Columns [L,M] Rows [99–133]

6.4.4 Emission Rate for carbon dioxide

Emission rate **621 lb CO₂/KLAW-yr [M135]**

6.5 Ammonia (NH₃) Air Emissions.

6.5.1 Ammonia data and air emissions calculations are contained in the NH3 worksheet. Ammonia differs from Methane and Carbon Dioxide in that the sample results are reported as parts per million of volume (ppm) instead of percent by volume. This changes the calculation for the amount of ammonia exiting tank T1 and T2 vents. Ammonia vent discharge flow rates are presented in column [I] rows [14–42] for anaerobic tank T1 and in column [I] rows [55-89] for tank T2. Using the 5/12/04 data for tank T1 as an example:

$$(8 \text{ ppm NH}_3/\text{vent}[J20])(1/1,000,000)(17.67 \text{ ft}^3/\text{min}[G20]) = \mathbf{0.00014 \text{ ft}^3 \text{ NH}_3/\text{min [I20]}$$

The density of ammonia at STP is obtained from cell [E5] of the Air Emissions Basis worksheet. The density of ammonia at STP is used to obtain the ammonia density at various

air temperatures. Ammonia density as adjusted for temperature is presented in column [J] rows [14-42] for anaerobic tank T1 and rows [55-89] for tank T2.

In a number of cases for tank T2 the laboratory composite analysis reported levels of ammonia below their detection limits of 5 ppm. In some of these cases field grab measurements had also been taken. Since the field grab values have been very close to the lab composite values for this parameter, and the field grab detection limit of 1 ppm is lower than the lab detection limit, the field grab values were used when available in the “Data Edits Used” column [J] rows [147 - 184] for anaerobic tank T1 and rows [192-229] for tank T2. If no other values were available then the value recorded in the Data Edits Used column was one half of the lab detection limit (2.5 ppm in this case, see [J201] for example]). In all cases when multiple values were measured or recorded for the same sampling event the higher value was used to compute the emission rate.

Ammonia air emissions data are presented in the NH3 worksheet in the following locations:

Field & Sample/Laboratory Data	Anaerobic Tank T1	Anoxic Tank T2
Tank Vent Air Flow Rate	Column [E] Rows [147–184]	Column [E] Rows [192-229]
Tank Liquid Influent Flow Rate	Column [F] Rows [147–184]	Column [F] Rows [192-229]
Ammonia Sample/Lab Data	Columns [G,H,I] Rows [147–184]	Columns [G,H,I] Rows [192-229]
Data Edits	Columns [J] Rows [147–184]	Columns [J] Rows [192-229]
Closest Gas Flow Reading	Columns [K] Rows [147–184]	Columns [K] Rows [192-229]

6.5.2 Supplemental Ammonia Air Emissions Data is located as follows in the NH3 worksheet:

Flush Alleys: Collected data is presented in the NH3 worksheet in columns [D–I] in rows [257–276].

Coarse Screen: Collected data is presented in the NH3 worksheet in columns [D–I] in rows [235–243].

Splitter Box: Collected data is presented in the NH3 worksheet in columns [D–I] in rows [246–254].

6.5.3 Ammonia air emissions rate calculation for the anaerobic zone and anoxic zone are presented in the NH₃ worksheet in the following locations:

Parameter	Anaerobic Zone Tank T1	Anoxic Zone Tank T2
Herd Weight (KLAW)	Column [E] Rows [14–42]	Column [E] Rows [55-89]
Ammonia (ppm)	Column [F] Rows [14–42]	Column [F] Rows [55-89]
Vent Flow Rate (ft ³ /min)	Column [G] Rows [14–42]	Column [G] Rows [55-89]
Vent Temp, (°K)	Column [H] Rows [14–42]	Column [H] Rows [55-89]
NH ₃ Flow (ft ³ NH ₃ /min)	Column [I] Rows [14–42]	Column [I] Rows [55-89]
NH ₃ Density (lb NH ₃ /ft ³)	Column [J] Rows [14–42]	Column [J] Rows [55-89]
NH ₃ Generation	Columns [K,L,M] Rows [14–42]	Columns [K,L,M] Rows [55-89]
Data Weighting Factors	Columns [N,O] Rows [14–42]	Columns [N,O] Rows [55-89]

Ammonia air emissions calculations for the anaerobic zone, anoxic zone and total system are presented in the NH₃ worksheet in the following locations:

Parameter	Anaerobic Zone T1	Anoxic Zone T2	Total System
NH ₃ (lb/day)	Column [E] Rows [99–133]	Column [G] Rows [99– 33]	Column [I] Rows [99– 133]
NH ₃ (lb NH ₃ /KLAW-yr)	Column [F] Rows [99 – 133]	Column [H] Rows [99 – 133]	Column [J] Rows [99–133]
Data Weighting Factors	-	-	Columns [L,M] Rows [99–133]

6.5.5 Emission Rate for ammonia

Emission rate **0.15 lb NH₃/KLAW-yr [M135]**

6.6 Hydrogen Sulfide (H₂S) Air Emissions.

6.6.1 Hydrogen Sulfide data and air emissions calculations are contained in the H₂S worksheet. The Hydrogen Sulfide data used in the computations was measured as parts per million and so the computational procedures used were the same as those used for Ammonia.

The density of Hydrogen Sulfide at STP is obtained from cell [E6] of the Air Emissions Basis worksheet. The density of hydrogen sulfide at STP is used to obtain the hydrogen sulfide density at various air temperatures. Hydrogen Sulfide density as adjusted for temperature is presented in column [J] rows [14-28] for anaerobic tank T1 and rows [41-59] for tank T2.

No lab data was used in the Data Edits Used column [J] rows [102–142] for tank T1 and rows [150–188] for tank T2. The detection limit for the field grab samples varied with the type of instrument used. Non-detect values are recorded in column [G] for tanks T1 and T2 as less than the detection limit (i.e. <20). The values which were entered in the Data Edits Used column for non detect readings are one half of the detection limit (i.e. 10 if the detection limit was 20).

Hydrogen Sulfide air emissions data are presented in the H2S worksheet in the following locations:

Field & Sample/Laboratory Data	Anaerobic Tank T1	Anoxic Tank T2
Tank Vent Air Flow Rate	Column [E] Rows [102–142]	Column [E] Rows [150-188]
Tank Liquid Influent Flow Rate	Column [F] Rows [102–142]	Column [F] Rows [150-188]
Hydrogen Sulfide Sample/Lab Data	Columns [G,H,I] Rows [102–142]	Columns [G,H,I] Rows [150-188]
Data Edits	Columns [J] Rows [102–142]	Columns [J] Rows [150-188]
Closest Gas Flow Reading	Columns [K] Rows [102–142]	Columns [K] Rows [150-188]

6.6.2 Supplemental Hydrogen Sulfide Air Emissions Data is located as follows in the H2S worksheet:

Flush Alleys: Collected data is presented in the H2S worksheet in columns [D–I] in rows [214–237].

Coarse Screen: Collected data is presented in the H2S worksheet in columns [D–I] in rows [192-200].

Splitter Box: Collected data is presented in the H2S worksheet in columns [D–I] in rows [203-211].

6.6.3 Hydrogen Sulfide air emissions rate calculation for the anaerobic zone and anoxic zone are presented in the H2S worksheet in the following locations:

Parameter	Anaerobic Zone Tank T1	Anoxic Zone Tank T2
Herd Weight (KLAW)	Column [E] Rows [14–28]	Column [E] Rows [41-59]
Hydrogen Sulfide (ppm)	Column [F] Rows [14–28]	Column [F] Rows [41-59]
Vent Flow Rate (ft ³ /min)	Column [G] Rows [14–28]	Column [G] Rows [41-59]
Vent Temp, (°K)	Column [H] Rows [14–28]	Column [H] Rows [41-59]
H ₂ S Flow (ft ³ H ₂ S/min)	Column [I] Rows [14–28]	Column [I] Rows [41-59]
H ₂ S Density (lb H ₂ S/ft ³)	Column [J] Rows [14–28]	Column [J] Rows [41-59]
H ₂ S Generation	Columns [K,L,M] Rows [14–28]	Columns [K,L,M] Rows [41-59]
Data Weighting Factors	Columns [N,O] Rows [14–28]	Columns [N,O] Rows [41-59]

Hydrogen Sulfide air emissions calculations for the anaerobic zone, anoxic zone and total system are presented in the H2S worksheet in the following locations:

Parameter	Anaerobic Zone T1	Anoxic Zone T2	Total System
H ₂ S (lb/day)	Column [E] Rows [69-88]	Column [G] Rows [69-88]	Column [I] Rows [69-88]
H ₂ S (lb H ₂ S/KLAW-yr)	Column [F] Rows [69-88]	Column [H] Rows [69-88]	Column [J] Rows [69-88]
Data Weighting Factors	-	-	Columns [L,M] Rows [69-88]

6.6.4 Emission Rates for hydrogen sulfide

Emission rate **0.40 lb H₂S/KLAW-yr average for entire test period**

0.23 lb H₂S/KLAW-yr average for last four weeks

6.7 Nitrogen Oxides (NO_x) Air Emissions.

6.7.1 Nitrogen Oxide data and air emissions calculations are contained in the NO_x worksheet. In the case of nitrogen oxides, all measurements including field and laboratory analyses have been below detection limits for anaerobic tank T1 and anoxic tank T2. To obtain numerical estimates for total emissions, values of one half of the laboratory detection limit of 1 ppm have been used. This would give a value of 0.5 ppm in the Data Edits Used column [J] rows [143–180] for anaerobic tank T1 and rows [189–226] for anoxic tank T2. If no lab reading was available and a field grab analysis had been made (detection limit of 0.5 ppm), then a

value of 0.25 ppm was used in the Data Edits Used column. All data (detection limits in this case) was in terms of ppm and so the calculation procedures follow that used for Ammonia.

The density of Nitrogen Oxides NO_x at STP is obtained from cell [E7] of the Air Emissions Basis worksheet. The density of Nitrogen Oxides at STP is used to obtain the Nitrogen Oxide density at various air temperatures. Nitrogen Oxide density as adjusted for temperature is presented in column [J] rows [14-41] for anaerobic tank T1 and rows [54-86] for tank T2.

Nitrogen Oxide air emissions data are presented in the NO_x worksheet in the following locations:

Field & Sample/Laboratory Data	Anaerobic Tank T1	Anoxic Tank T2
Tank Vent Air Flow Rate	Column [E] Rows [143 - 180]	Column [E] Rows [189-226]
Tank Liquid Influent Flow Rate	Column [F] Rows [143-180]	Column [F] Rows [189-226]
Nitrogen Oxides Sample/Lab Data	Columns [G,H,I] Rows [143-180]	Columns [G,H,I] Rows [189-226]
Data Edits	Columns [J] Rows [143-180]	Columns [J] Rows [189-226]
Closest Gas Flow Reading	Columns [K] Rows [143-180]	Columns [K] Rows [189-226]

6.7.2 Supplemental Nitrogen Oxides Air Emissions Data is located as follows in the NO_x worksheet:

Flush Alleys: Collected data is presented in the NO_x worksheet in columns [D–I] in rows [257–276].

Coarse Screen: Collected data is presented in the NO_x worksheet in columns [D–I] in rows [235-243].

Splitter Box: Collected data is presented in the NO_x worksheet in columns [D–I] in rows [246-254].

6.7.3 Nitrogen Oxide air emissions rate calculation for the anaerobic zone and anoxic zone are presented in the NOx worksheet in the following locations:

Parameter	Anaerobic Zone Tank T1	Anoxic Zone Tank T2
Herd Weight (KLAW)	Column [E] Rows [14-41]	Column [E] Rows [54-86]
Nitrogen Oxide (ppm)	Column [F] Rows [14-41]	Column [F] Rows [54-86]
Vent Flow Rate (ft ³ /min)	Column [G] Rows [14-41]	Column [G] Rows [54-86]
Vent Temp, (°K)	Column [H] Rows [14-41]	Column [H] Rows [54-86]
NOx Flow (ft ³ NOx/min)	Column [I] Rows [14-41]	Column [I] Rows [54-86]
NOx Density (lb NOx/ft ³)	Column [J] Rows [14-41]	Column [J] Rows [54-86]
NOx Generation	Columns [K,L,M] Rows [14-41]	Columns [K,L,M] Rows [54-86]
Data Weighting Factors	Columns [N,O] Rows [14-41]	Columns [N,O] Rows [54-86]

Nitrogen Oxide air emissions calculations for the anaerobic zone, anoxic zone and total system are presented in the NOx worksheet in the following locations:

Parameter	Anaerobic Zone T1	Anoxic Zone T2	Total System
NOx (lb/day)	Column [E] Rows [96-129]	Column [G] Rows [96-129]	Column [I] Rows [96-129]
NOx (lb NOx/KLAW-yr)	Column [F] Rows [96-129]	Column [H] Rows [96-129]	Column [J] Rows [96-129]
Data Weighting Factors	-	-	Columns [L,M] Rows [96-129]

6.8 Non-Methane Organic Carbon (NMOC) Air Emissions.

6.8.1 NMOC data and air emissions calculations are contained in the NOMC worksheet. As with Nitrogen Oxides, all NMOC measurements including field and laboratory analyses were below detection limits for anaerobic tank T1 and anoxic tank T2. NMOC measurements were in terms of ppm.

The density of NMOC at STP is obtained from cell [E8] of the Air Emissions Basis worksheet. The density of NMOC at STP is used to obtain the NMOC density at various air temperatures. NMOC density as adjusted for temperature is presented in column [J] rows [14-28] for anaerobic tank T1 and rows [41-59] for tank T2.

NMOC air emissions data are presented in the NMOC worksheet in the following locations:

Field & Sample/Laboratory Data	Anaerobic Tank T1	Anoxic Tank T2
Tank Vent Air Flow Rate	Column [E] Rows [127-164]	Column [E] Rows [172-209]
Tank Liquid Influent Flow Rate	Column [F] Rows [127-164]	Column [F] Rows [172-209]
NMOC Sample/Lab Data	Columns [G,H,I] Rows [127-164]	Columns [G,H,I] Rows [172-209]
Data Edits	Columns [J] Rows [127-164]	Columns [J] Rows [172-209]
Closest Gas Flow Rate	Columns [K] Rows [127-164]	Columns [K] Rows [172-209]

6.8.2 Supplemental NMOC Air Emissions Data is located as follows in the NMOC worksheet:

Flush Alleys: Collected data is presented in the NMOC worksheet in columns [D–I] in rows [234-253].

Coarse Screen: Collected data is presented in the NMOC worksheet in columns [D–I] in rows [212- 20].

Splitter Box: Collected data is presented in the NMOC worksheet in columns [D–I] in rows [223-231].

6.8.3 NMOC air emissions rate calculation for the anaerobic zone and anoxic zone are presented in the NMOC worksheet in the following locations:

Parameter	Anaerobic Zone Tank T1	Anoxic Zone Tank T2
Herd Weight (KLaw)	Column [E] Rows [14–36]	Column [E] Rows [49-75]
NMOC (ppm)	Column [F] Rows [14–36]	Column [F] Rows [49-75]
Vent Flow Rate (ft ³ /min)	Column [G] Rows [14–36]	Column [G] Rows [49-75]
Vent Temp, (°K)	Column [H] Rows [14–36]	Column [H] Rows [49-75]
NMOC Flow (ft ³ NMOC/min)	Column [I] Rows [14–36]	Column [I] Rows [49 - 75]
NMOC Density (lb NMOC/ft ³)	Column [J] Rows [14–36]	Column [J] Rows [49-75]
NMOC Generation	Columns [K,L,M] Rows [14–36]	Columns [K,L,M] Rows [49-75]
Data Weighting Factors	Columns [N,O] Rows [14–36]	Columns [N,O] Rows [49-75]

NMOC air emissions calculations for the anaerobic zone, anoxic zone and total system are presented in the NMOC worksheet in the following locations:

Parameter	Anaerobic Zone T1	Anoxic Zone T2	Total System
NMOC (lb/day)	Column [E] Rows [85-113]	Column [G] Rows [85-113]	Column [I] Rows [85-113]
NMOC (lb NMOC/KLAW-yr)	Column [F] Rows [85-113]	Column [H] Rows [85-113]	Column [J] Rows [85-113]
Data Weighting Factors	-	-	Columns [L,M] Rows [85-113]

6.9 Emission Rates and Reduction ranges for NOX and NMOC

NO_x emission rate **0.012 lb NO_x/KLAW-yr [M131]**

NMOC emission rate **0.020 lb NMOC/KLAW-yr [M115]**

Note that all measurements for NO_x and NMOC were non-detect. The actual values could be far lower than the one-half detection limit values used for arriving at an emissions rate. Thus, while these emission rates are low, they may well significantly overstate actual emissions.

6.10 Air Emissions Estimate Summary.

Estimated annual, average air emission rates on a 1,000 live animal weight basis for the Bion NMS waste management system as based on the Devries Dairy system are as follows:

- **Methane: 27.49 lb CH₄/KLAW-yr (21.74 lb CH₄/KLAW-yr last 30 days of test period)**
- **Carbon Dioxide: 621 lb CO₂/KLAW-yr**
- **Ammonia: 0.15 lb NH₃/KLAW-yr**
- **Hydrogen Sulfide: 0.40 lb H₂S/KLAW-yr (0.23 lb H₂S/KLAW-yr last 30 days of test period)**
- **Nitrogen Oxides: 0.012 lb NO_x/KLAW-yr**
- **Non-Methane Organic Carbon: 0.020 lb NMOC/KLAW-yr**

6.11 Area whole air samples

6.11.1 Approach

On April 7, 2004 and April 22, 2004 canister samples were collected to determine air quality influenced by the circulating process water or recycled flush water within the dairy but outside the Bion NMS bioreactor per the air emissions protocol.

- 1) A one-hour canister grab sample was taken below the rim of the coarse screen sump or contact / mixing tank at an elevation one foot above the maximum flush water elevation.
- 2) An instantaneous (one minute) grab canister was sampled from the splitter box headspace during active coarse screen flow. Flow from the coarse screen sump travels over an elevated inclined coarse screen. The vertical down-flow effluent pipe from this screen produces a continuous vacuum draw through the screen. These gasses are released in the flow splitter box adjacent to the fine screens. The headspace in this splitter box, where the sample was taken, is enclosed but not airtight to allow the gasses drawn through the screen to escape.
- 3 & 4) Ten-minute canister grab samples were taken at two locations along an actively flushing alley (1/3 and 2/3 flow points) for the two separate sampling days.

Field grab samples were taken on April 1, 2004, at the Houle and second flush lane locations as well.

All of these data are presented immediately following the Tank T2 Recorded Data Section for each of the six target parameters respectively.

6.11.2 Area Concentrations Measured

Area air concentration measurements of the six target parameters were taken from four locations outside the active volume of the Bion NMS bioreactor. Samples were taken at: 1) the contact mix sump serving the Houle static inclined screen; 2) the gravity overflow splitter box between the inclined plain static coarse screen and the bioreactor anaerobic zone influent (see Figure 1 in Nutrient Protocol and Figure 1.1 in this document); and 3 & 4) two locations along the flush lanes serving the dairy.

The concentrations recorded at the contact mix sump, splitter box, and flush lanes were compared with comparable readings made the same day at the air emission monitoring tanks (T1 – anaerobic & T2 – anoxic). These area measurements were generally much lower than measurements made at the air emissions tanks. To illustrate this, the highest area concentrations as recorded in-situ or in the laboratory analysis of the sampling canisters taken, will be compared with air emissions monitoring tank concentrations determined on the same day. Non-detects will be noted but not compared.

1. At the contact mix sump serving the Houle static inclined screen all measurements for NO_x, NMOC, and H₂S were non-detect. The highest measurement for CH₄ of 0.045% by volume on 4/22/04 “CH4” [H243] compared with 0.045% at T1 [J153] and 0.38% at T2 [J199]. Carbon dioxide (CO₂) had a high value of 0.054% by volume on 4/22/04 “CO2” [H243] and this compared with 0.13% at T1 [J153] and 4.2% at T2 [J198]. Ammonia (NH₃) had only a single

field measurement that was not non-detect and this was a 2.08 ppm reading on 4/1/04 "NH₃" [F241]. This compared with 18 ppm at T2 [J193] (no measurement was made for T1 on 4/1/04).

In summary, all contact mix sump measurements for NO_x, NMOC, and H₂S were non-detect. Measurements for CH₄, CO₂, and NH₃, when they did occur, were generally significantly less than measurements at the air emission monitoring tanks.

2. For the splitter box, measurements for NO_x, NMOC, and H₂S were again non-detect. The highest measurement for CH₄ of 0.028 % by volume on 4/22/04 "CH₄" [G254] compared with 0.045% at T1 [J153] and 0.38% at T2 [J199]. Carbon dioxide (CO₂) had a high value of 0.82% by volume on 4/22/04 "CO₂" [G254] and this compared with 0.13% at T1 [J153] and 4.2% at T2 [J198]. The highest measurement for NH₃ was 20 ppm on 4/22/04 "NH₃" [G254] and this compared with 25 ppm at T1 [J153] and 18 ppm at T2 [J198]. Generally the splitter box was covered and there did not appear to be any detectable flow of air out of the box.

Thus, for the splitter box, concentrations for NO_x, NMOC, and H₂S were again non-detect. Concentrations for CH₄ were significantly lower than those at the air emission monitoring tanks but the measurements for CO₂ and NH₃ were comparable to those at the tanks. Generally the splitter box was covered and there did not appear to be any detectable flow of air out of the box.

3 & 4. For the flush lane measurements non-detect concentrations were obtained for NH₃, NO_x, and NMOC. Hydrogen sulfide (H₂S) was not detected except for one set of field instrument readings, which were 0.5 ppm or less on 5/27/04 "H₂S" [F236-237]. Comparable concentrations at T1 were 0.5 ppm [J120], and 90 ppm at T2 [J168]. The highest measurement for CH₄ of 0.0095% by volume on 4/7/04 "CH₄" [H264] compared with 0.59% at T2 [J195]. No reading was taken at T1 on 4/7/04. CO₂ had a high value of 0.15% by volume on 4/7/04 "CO₂" [H264] and this compared with 6.6% at T2 [J198]. Again, no reading was taken at T1 on 4/7/04.

For the Flush Lane measurements non-detect readings were obtained for NH₃, NO_x, and NMOC. H₂S was not detected except for one set of field instrument readings, which were 0.5 ppm or less. This was equal to the reading at the T1 tank but much lower than the reading at the T2 tank. Concentrations for CH₄ and CO₂ were significantly less than measurements at the Tanks.

6.11.3 Exposure Times and Surface Area Factors

Two additional factors are important for this analysis.

1. Concentrations were measured at each of the four locations during periods of maximum potential emissions. Active mixing and pumping from the contact mix sump and screening through the coarse Houle screen occurs only for a portion of each day. Active flushing wets each flush alley only for 45 minutes to an hour each day.

2. The surface area exposed in the contact mix sump and the splitter box combined is an insignificant fraction of the surface area of the mixed liquor bioreactor volume.

6.11.4 Area Air Emissions Summary

Low concentrations of H₂S, CH₄, CO₂, and / or NH₃ were recorded in the four areas sampled outside of the active Bion NMS reactor volume. All area samples were non-detect for NMOC and NO_x. Concentration determinations were performed at 1 & 2) two locations along the flush lanes serving the dairy, 3) the contact mix sump serving the Houle static inclined screen, and 4) the gravity overflow splitter box between the inclined plain static coarse screen and the bioreactor anaerobic zone influent (see Figure 1 in Nutrient Protocol and Figure 1.1 in this document). These measurements indicate that some emissions do occur outside of the bioreactor. Also, area measurements, especially those returned from the laboratory as non-detects, can not be taken to mean that emissions for those parameters from areas outside the bioreactors do not exist. However, the concentrations detected were generally much lower than the combined measurements made at the air emission monitoring tanks (T1 – anaerobic & T2 – anoxic) on the same operating day. Thus, even though the potential exists for the emission rates to be underestimated for these sources their contribution appears small in comparison to that coming from the bioreactors.

Although no attempt was made (nor specified in the air protocol) to quantify the area mass emission rates it appears to be reasonably unlikely that significant additional average daily mass emissions occur for any of the six target parameters from these area sources. This appears to be particularly true for NMOC and NO_x based on the universal non-detects measured for these two parameters.

6.12 Flux Chamber Data and Analysis

Surface emission rate measurements using floating flux chambers has had wide application across many waste management systems for assessing atmospheric mass loadings. The protocols for performing Flux-Chamber analyses are accepted and a substantial number of reports in the waste management literature provide a basis for comparison. Flux-Chamber assessments of the hydrogen sulfide emission rates from the Bion NMS process were performed in order to compare measurements obtained using the air emission tank approach used in this project to this other widely applied approach.

6.12.1 Measurements and Analysis

On 7/1/04 and 7/14/04 a Flux-Chamber was used on the system surface in conjunction with an Interscan H₂S Analyzer with a 0.1 ppm detection limit to check the air emission monitoring tank based analytical procedure with this alternative measurement approach. Sampling zones, the number of sampling points required and sample locations were determined following accepted flux chamber protocols and with direct guidance from Mark Gould and Lynn Moss of Camp, Dresser & McKee, who have extensive experience with flux chamber in-situ sampling and analysis (*USEPA (1986). "Measurement of Gaseous Emission Rates from Land Surfaces using an Emission Isolation Flux-Chamber Users Guide,"* Leinbusch, M.R., Radian Corporation, Austin, Texas,

EPA/600/8-86/008). The entire bioreactor system's liquid surface was sectioned into 18 different zones, each judged to be relatively homogeneous as to surface emission characteristics, and a flux chamber sampling point was identified at a generally central point within each zone. The number of flux chamber sampling points and their specific locations are shown in the "Flux Setup" worksheet, and the areas of their respective zones are calculated.

In the "Flux 7-1-04" and "Flux 7-14-04" sheets the zones are identified in [A] and measured H₂S concentrations recorded in [C]. To convert ppm to mg/m³ a conversion factor of 1.52 is used. This is obtained as follows:

$$(34 \text{ gm H}_2\text{S/mole H}_2\text{S})(\text{mole H}_2\text{S}/22.414 \text{ L H}_2\text{S})(1000 \text{ L/m}^3) = \mathbf{1.517 \text{ gm/m}^3}$$

$$\mathbf{\text{So 1 ppm H}_2\text{S} = 1.517 \text{ mg H}_2\text{S/m}^3}$$

For a flux chamber covering an area of 1.4375 sq ft (a square of about 1 foot 2-3/8 inch), equivalent to 0.1335 m², and a nitrogen gas flow rate of 5 L/min, the volumetric flux rate is:

$$(5 \text{ L/min})(\text{m}^3/1000 \text{ L})(\text{min}/60 \text{ sec})(0.1335 \text{ m}^2) = \mathbf{0.0006240 \text{ m}^3/\text{sec-m}^2}.$$

Thus, converting a measured ppm H₂S reading from the exhaust from the flux chamber into a flux rate is as follows, example for zone 5, "Flux 7-1-04" [D8].

$$(3.3 \text{ ppm H}_2\text{S})([1.52 \text{ mg/m}^3]/\text{ppm})(0.0006240 \text{ m}^3/\text{sec-m}^2) = \\ = \mathbf{0.00313 \text{ mg H}_2\text{S}/\text{sec-m}^2} \text{ [D8]}$$

This was converted into lb/acre–day in [E8]:

$$(0.00313 \text{ mg H}_2\text{S}/\text{sec-m}^2)(\text{lb}/453,600 \text{ mg})/[(\text{day}/86,400 \text{ sec})(4,047 \text{ m}^2/\text{acre})] = \\ = \mathbf{0.585 \text{ lb/acre-day}} \text{ [E8]}$$

Multiplying by the area of the zone [F8] (obtained from "Flux Setup" [AF12]) calculates the surface zone emissions in lb/day [G8]:

$$(0.585 \text{ lb H}_2\text{S}/\text{acre-day})(74.3 \text{ m}^2/4,047 \text{ m}^2/\text{acre}) = \mathbf{0.04431 \text{ lb H}_2\text{S}/\text{day}} \text{ [G8]}$$

If the zone contains the boil from a surface injection aerator then an additional emission due to air stripping from the aerator is calculated in lb/day for that zone. Since a 20 Hp aerator has its boil in zone 5 the 240 ft³/min aeration air flow for that aerator is allocated to zone 5 and its value entered in [H8]. This is then used in conjunction with the H₂S concentration in [C8] to calculate the lb H₂S/day coming from that aerator, see [I8]:

$$(240 \text{ ft}^3/\text{min})(0.028 \text{ m}^3/\text{ft}^3)(60 \text{ min}/\text{hr})(24 \text{ hr}/\text{day})(3.3 \text{ ppm H}_2\text{S})([1.52 \text{ mg/m}^3]/\text{ppm}) \\ (2.2 \text{ lb}/\text{kg})(\text{kg}/1,000,000 \text{ mg}) = \mathbf{0.10679 \text{ lb H}_2\text{S}/\text{day}} \text{ [I8]}$$

Finally, for the bioreactor there is a general air stripping effect from the 46 ft³/min from the subsurface Mazzei injection system. This applies to zones 4 – 18 and is calculated by

allocating the ft³/min equally to each of the zones. Thus, each zone receives 3.2857 ft³/min (1/14 of the 46 ft³/min total) [J8] as its share of the Mazzei contribution. The lb/day contribution from this aeration flow uses exactly the same calculation as was used for the injection aerator's contribution and the result is shown in [K8].

These three components are then summed in [L] and totalized at [L23]. When divided by the total herd live animal weight for that day, [E39] obtained from the appropriate cell in [T260] in "BNMS Herd", this gives a final calculation of lb H₂S per KLAW per year in [E41]. For easy reference this is then compared to the corresponding number obtained from the Tank Analysis for that date, shown in [E43] and referenced back to the appropriate day for "H₂S" [J86] for 7-1-04.

6.12.2 Summary Results

Parallel mass emission rate results from the Flux-Chamber analysis and the air emission tank approach applied in this project, indicate that mass emission rates for H₂S measured using Flux-Chamber analysis were about one-third lower than those obtained from the air emission tank analysis. Thus, the air emission tank approach applied in this project appears to provide a conservatively high valuation of H₂S mass air emission rates compared to the Flux-Chamber approach.

7. SPIKED SAMPLES

Two sets of spiked samples were prepared according to the nutrient sampling protocol and sent out for analysis. These were sampled on 4/22/04 and 6/22/04. The results are presented in the "Spikes" sheet.

On 4/22/04 the 8B2 and 9B2 samples were used as unspiked controls. 20 ml of the spiking solution was added to the 8B3 and 9B3 samples, and 30 ml was added to the 8B and 9B samples.

On 6/22/04 the 8A2, 8B2 and 9B2 samples were used as unspiked controls. 20 ml of the spiking solution was added to the 8A3, 8B3 and 9B3 samples, and 30 ml was added to the 8A, 8B and 9B samples. All of these samples were then analyzed along with the regular samples for that date.

Performance was measured as a Relative Difference between the actual measured value and the projected value of baseline plus spike.

Sample Calculation: 8B3 spike for TKN on 4/22/04; "Spike" sheet [F20-26]

Three liters of baseline sample were collected and homogenized. A sample of this became the unspiked baseline value, and was labeled the 8B2 sample. It had a value of 2135 mg/l [F20] To make up the 8B3 sample 20 ml of spiking solution was added to 980 ml of the baseline sample. This added 1000 mg of TKN [F22] and displaced 2 percent of the baseline volume,

thereby removing 2 percent of the 2135 mg/l. (42.7 mg removed from the final sample [F21]. The 8B3 sample had a projected value of;

$$2135 \text{ mg/l baseline} + 1000 \text{ mg spike} - 42.7 \text{ mg displaced by the 20 ml of spiking solution} = \\ = \mathbf{3092 \text{ mg/L}} \text{ [F23]}$$

The laboratory value for 8B3 was 2999 mg/l [F24].

The difference (actual – projected) was $2999 - 3092 = \mathbf{-93 \text{ mg/L}}$ [F25], and

The Relative Difference (difference/actual) was $-93/2999 = \mathbf{-0.030}$ [F26].

This means that the actual was 3 percent less than the projected value for the spiking.

All of the spiked samples had a Relative Difference of less than thirty percent which is a reasonable criteria for manure and manure derived liquids. Most of the Relative Differences were less than ten percent which is excellent recovery.

8. SPLIT SAMPLES

One set of split samples were tested on 1/7/04. Similar precautions and procedures as used for the spiked samples were followed with the splits to insure homogeneity and sample integrity. Duplicate samples were treated identically and sent to USBiosystems and Midwest laboratories for analysis. Sample results are contained in the “Split” sheet.

In this case the Relative Difference is the difference between the two results divided by the average of the two values.

The results were not as good as those for the split samples with only 25 out of 43 duplicated analyses showing less than 30 percent Relative Difference. As expected the larger variations were found on the solids samples.

APPENDIX

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March 30, 2004

Bion NMS Waste Management System

**Sealed Process System Description for
Air Emissions Monitoring**

APPENDIX A

MEMORANDUM

DATE: August 1, 2004
TO: Verification / Review Team Members
FROM: James Morris, George Bloom
RE: DeVries Dairy – Centrifuge Trial Data Assessment.



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**A-1. CENTRIFUGE TRIALS - CENTRIFUGE TSS, P AND N WORKSHEET**

Solids separation in the Bion system is accomplished using a coarse, inclined plane screen (Houle) and a medium vibrating screen with an opening of 355 µm (Sweco 1) followed by either a fine vibrating screen with an opening of 106 µm (Sweco 2) or during the centrifuge trials a Sharples centrifuge. Effluent from the Bion system, from either the fine screen or centrifuge, is discharged to the Lagoon 1 storage volume outside of the bioreactor for polishing before discharge to the storage lagoon (Lagoon 2). Removals achieved by the centrifuge are determined by knowing the various centrifuge feed rates tested and appropriate parameter analysis of influent, effluent and solids produced. Results will be applied to the long term operating data to determine removal efficiencies for the Bion system incorporating centrifuge technology.

Centrifuge removal efficiencies are a function of machine set-up parameters such as solids dam height, bowl rotation speed and scroll differential speed. Dam height and rotation speed combinations for a given wastestream which yield the best performance may be determined. These set-up parameters may then be tested for solids capture; thus removals of TSS, P and N; and discharged solids content or percent solids may be determined.

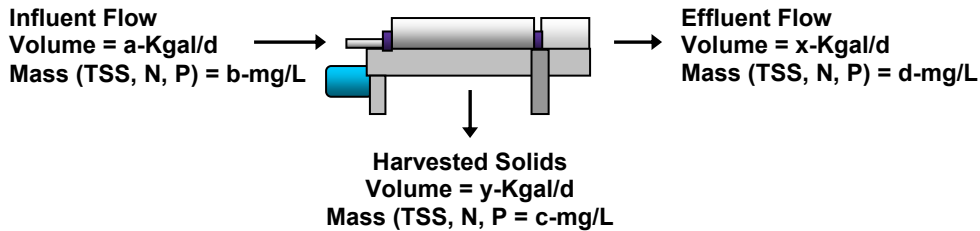
Several discharge rates and scroll differentials will be tested for short periods of typically a few hours to determine an efficient operating setting. Then the centrifuge will be operated continuously for several days with data collected on efficiencies achieved. The data and analysis presented on the "Centrifuge TSS, P and N" worksheet address the results obtained.

**A-2. APPROACH**

Flow into the centrifuge is set by the variable speed positive displacement feed pump. Of the analyses performed on conservative parameters (not generated or consumed), solids data is the most accurate. Knowing the TSS concentration for influent, effluent and solids removed, together with the influent flow rate, allows the effluent and solids generation flow rates to be accurately determined. These flow rates may then be used to determine parameter mass influent loading, mass effluent discharge and mass solids harvested or removed for each

parameter: TSS, Tot-P and TKN. Figure 1 depicts the mass balance approach used herein to determine centrifuge performance.

Figure 1 – Centrifuge Mass Flow Diagram



Governing Mass Balance Equation:  

$$ab = xd + yc$$

Sample computations follow for the 20 gpm or 28.8 Kgal/d centrifuge trial run performed on 6/22/04 with the centrifuge set at a 17% bowl to scroll differential and an effluent dam height of 101 mm. Spreadsheet values are provided ignoring rounding errors.

### A-3. HARVESTED SOLIDS TSS [AD18]:

Solids harvested are in a high solids slurry or semi-cake form. The most accurate analysis for solids content is TS. However, TS contains both the TSS and TDS components of the slurry. For harvested solids  $TSS = TS - TDS$ . The TDS for each sampling date is determined in the “TDS” worksheet.

#### A-3.1TDS

Analyses were performed on samples from locations 9B, 8A, 8B & 11 for TS and TSS as shown on the “TDS” worksheet. As may be seen [F18] the TDS value obtained for 9B for that date is clearly substantially larger than the other samples and since it is greater than two standard deviations larger than the mean it was ignored as an outlier. Assuming the impact on dissolved solids is minimal across solids removal unit operations use of an average value for the TDS in the three accepted sample values for that date should be a valid indication of the TDS levels in the process stream including the harvested solids. Since  $TDS = TS - TSS$  a value was determined for each sample and an average of 7,109.0 mg TDS/L was used [AC18+].

#### A-3.2 TS

When TS values are reported by the laboratory as mg TS/L direct raw laboratory values are entered in column AB.

If TS laboratory results are reported as percent solids, % then the specific gravity of the sample must be known and the following computation is required:

Laboratory reported:

16.85% solids or 0.1685 mass TS/mass wet slurry

Specific gravity = 1.076 Kg slurry/L slurry

Thus:

$$(0.1685 \text{ mass TS/mass wet slurry})(1.076 \text{ Kg slurry/L slurry})(10^6 \text{ mg slurry/Kg slurry}) = \\ = 181,306 \text{ mg TS/L [AB18]}$$

### A-3.3 TSS

TSS values are from laboratory analysis except for harvested solids which are TS – TDS.

Harvested solids TSS [AD18]:

$$181,306 \text{ mg TS/L} - 7,109.0 \text{ mg TDS/L} = 174,197.0 \text{ mg TSS/L [AD18]}$$

### A-4. EFFLUENT AND HARVESTED SOLIDS FLOWS [N18 & AA18]:

If known centrifuge influent forward flow is equal to **a Kgal/d** and effluent flow and harvested solids flow are **x** and **y Kgal/d** respectively, then:

$$a = x + y \text{ Kgal/d}$$

or

$$\text{Influent kgal/d} = \text{Effluent kgal/d} + \text{Harvested Solids kgal/d}$$

The mass of TSS delivered to the centrifuge by definition must also be equal to that exiting. Thus, if the known influent, harvested solids and effluent concentrations are **b**, **c** and **d** mg TSS/L respectively, by mass balance the mass per time in and out is equal to:

$$ab = dx + cy, \text{ mass/time (carrying consistent units of mg TSS/L and Kgal/d)}$$

Solve the two equations simultaneously for **x** effluent flow:

$$x = (ab - ac)/(d-c) = \text{[N18]}$$

$$x = [(754,560 \text{ Kgal/d,mgTSS/L}) - (5,016873.6 \text{ Kgal/d,mg TSS/L})] / [(6,033 \text{ mgTSS/L}) - (174,197.0 \text{ mgTSS/L})]$$

$$x = (-4,262,313.6 \text{ Kgal/d,mgTSS/L}) / (-168,164.0 \text{ mgTSS/L})$$

$$x = 25.30 \text{ Kgal/d [N18]}$$

Since:  $y = a - x \text{ Kgal/d} = \text{[AA18]}$

$$y = 28.8 - 25.30 = 3.50 \text{ Kgal/d}$$

**A-5. INFLUENT CENTRIFUGE LOADING, EFFLUENT DISCHARGE AND HARVESTED MASS RATES FOR EACH PARAMETER:**

Using the flow rates and the laboratory data for each parameter their mass rates may be determined:

Mass TSS [Influent – K18, Effluent – R18 and Harvested Solids – AG18]:

$$\text{Influent TSS Mass [K18]} = (28.8 \text{ Kgal/d})(26,200 \text{ mg TSS/L})[(3.7854 \text{ L/gal})(1,000/\text{K})(\text{lb}/453,590 \text{ mg})]$$

$$= (28.8 \text{ Kgal/d})(26,200 \text{ mg TSS/L})[0.0083454 \text{ conversion factor } \lambda \text{ in (L9)}]$$

$$= 6,297.1 \text{ lb TSS/d [K18]}$$

$$\text{Out} = \text{Effluent TSS} [(25.3 \text{ Kgal/d})(6,033 \text{ mg TSS/L})[0.0083454 \lambda] = 1,276.1 \text{ lb TSS/d [R18]}] + \text{Harvested Solids} [(3.50 \text{ Kgal/d})(174,197.0 \text{ mg TSS/L}) [0.0083454 \lambda] = 5,021.0 \text{ lb TSS/d [AG18]}]$$

$$\text{Out} = 6,297 \text{ lb TSS/d}$$

**Closure error of mass balance for each parameter [AP18, AQ18 and AR18]:**

$$\text{Closure error} = [1.00 - (\text{mass in}/\text{mass out})](100\%) = \% \text{ closure error}$$

Because TSS is used as the pivotal parameter, its percent closure error will always be 0.0% by definition.

***However, error is expected for P and N.***

Using P as an example [AQ18]:

Mass Tot-P [Influent-L18, Effluent-S18 and Harvested Solids-AH18]:

$$\text{Influent P mass} = (28.8 \text{ Kgal/d})(123.8 \text{ mg Tot-P/L})[(3.7854 \text{ L/gal})(1,000/\text{K})(\text{lb}/453,590 \text{ mg})]$$

$$= (28.8 \text{ Kgal/d})(515.0 \text{ mg Tot-P/L})[0.0083454 \text{ conversion factor } \lambda \text{ in [L9]}]$$

$$= 123.8 \text{ lb Tot-P/d [L18]}$$

**Out = Effluent P** [(25.3 Kgal/d)(174 mg Tot-P/L)[0.0083454 λ] = 36.8 lb Tot-P/d [S18]] +  
**+ Harvested Solids P** [(3.50 Kgal/d)(2,084.0 mg Tot-P/L) [0.0083454 λ] = 60.1 lb Tot-P/d  
[AH18]]

Out = 96.9 lb Tot-P/d

Closure error = [1.00 – (123.8/96.9)](100%) = -27.8% closure error for Tot-P [AQ18]

#### **A-6. MASS RATE BASIS FOR SOLIDS LEAVING IN THE EFFLUENT AND HARVESTED SOLIDS:**

The exiting mass rate for each parameter (TSS, N and P) may be determined either by using the derived flow rate times the concentration at the point considered or by the difference between the influent mass rate and the mass rate for the exit point not being considered. Since there is but one value for the influent flow and concentration this value becomes the mass set point. Consider the analysis for the lb Tot-P/d exit rates.

As calculated above using the effluent flow rate and concentration, the 14.8 lb Tot-P/d value appearing in [S18] is based on the measured effluent concentration and flow rate. However, since no one data value of Tot-P is inherently more error free than another, if the effluent mass rate is calculated on an alternate mass balance basis as the difference between the harvested solids mass rate and the influent mass rate, 123.3 [L18] – 60.1 [AH18] = 63.7 lb Tot-P/d [V18] is said to be based on a harvested solids basis. If no measurement basis is deemed stronger than the other the most likely data value would be the average of these two mass rate bases, or 50.3 lb Tot-P/d [Y18].

This same approach was applied to N data.

Note TSS values are identical as they are the pivotal values used.

#### **A-7. REMOVAL ACROSS THE CENTRIFUGE [AS18 THROUGH BA18]:**

In a similar fashion there are two bases for determining the mass removal rate accomplished by the centrifuge: 1) by the difference between the mass influent and effluent or “Effluent” basis; or 2) by the difference between the influent and the solids captured or “Cap Solids” basis. Again since there is no inherent strength of one basis over another the most probable value is the average of the two bases as reported in [AU18] for TSS, [AX18] for P and [BA18] for N.

Again note that TSS values are identical as are the pivotal values applied.

##### **A-7.1 Average Removal Across the Centrifuge:**

As for removal rates, the removal efficiency measured as % removed across the centrifuge may be calculated on two bases, similar to the above. Notice that TSS removals are equal using either basis and therefore the TSS percent error ±% is zero.

### **A-7.2 Removal Efficiency Across the Centrifuge Value Used:**

Though data values are not inherently different as discussed above, the laboratory analyses are considered far more accurate for the influent and effluent relatively dilute liquid matrix samples than for the same determinations on the high solids matrix stream resulting from the centrifuge's solids removal. Therefore, except for when the mass balance closure was less than 5% as was the case for four (4) nitrogen values (green highlighted cells used), the influent and effluent based values were used as the most probable value. The values selected in this way are in columns [BN & BO].

### **A-8. RESULTS**

Centrifuge operational settings that yielded the most consistent and best results for capture of solids, phosphorus and nitrogen included a dam height of 102 mm and differential of 22.5 %. Based on the performance data collected during the trials the centrifuge manufacturer, Alfa Laval, has indicated that the tested unit will reliably achieve 80% solids capture. The performance data further demonstrates that total phosphorus and total nitrogen capture rates of 70% and 45%, respectively, are achieved when the centrifuge is operated under the above settings.

# **APPENDIX B**



**MEMORANDUM**

**DATE:** March 26, 2004  
**TO:** Verification / Review Team Members  
**FROM:** James Morris  
**RE:** **Verification / Review of DeVries Operating Results.**



**Background:**

Bion Environmental Technologies, Inc. has developed and field-tested the proprietary biological waste management process deployed as the Bion Nutrient Management System or Bion NMS™ (u.s. Patent 6,689,274). When installed at animal production operations, the system substantially reduces the mass of nitrogen and phosphorous in final treated water discharged, and also substantially reduces atmospheric discharge of ammonia, oxides on nitrogen (NO<sub>x</sub>), hydrogen sulfide, sulfur dioxide, methane, non-methane volatile organic compounds and other compounds including the complex mixtures that produce odors. The subject system is a dairy in Central Texas.

The DeVries Dairy located in Erath County, Texas, presently averages milking approximately 1,250 cows. Located in the Bosque River watershed, the key issue faced by the DeVries Dairy is nutrient management with the focus principally on phosphorus. Odor and air emissions are also important issues although of less importance to DeVries at present than nutrient phosphorous. TCEQ agreed to allow a retrofit installation of the existing lagoon treatment system as long as the total volume of the system was not significantly changed and operations were not to be interrupted. These constraints were challenging but the Bion Nutrient Management System installed has addressed these hurdles.

Biological conversion of nutrients to particulate form is the heart of the Bion NMS process. The biologically mediated process converts the nutrients from solubles to particulates and nitrogen gas, and therefore makes the particulate form available for removal. (One of the objectives of the air emission testing phase of this project is to verify that the majority of atmospheric nitrogen emissions are as inert nitrogen gas not problematic ammonia nitrogen.) Once the nutrients present in the liquid stream have been converted to particulates they may be removed to meet the needed nutrient management goals. Different solids removal levels will be required from facility to facility as driven by the many variables of the particular dairy, the water shed it is located in, specific soil conditions, local climate, regulatory constraints, etc. The appropriate efficiencies and thus technologies applied will be determined by the specific situation's need for nutrient control, as well as the size of the facility served.

**Current Need:**

Bion needs to have the efficacy of the Bion NMS for producing phosphorous and nitrogen in removable particulate form in the effluent discharged from the biological process and the quantity of atmospheric releases to be expected from a properly operated system determined within the regulatory, operational, physical and budgetary constraints in force at the DeVries Dairy retro-fit installation validated by an independent individual or entity such that the results reported are accepted as valid by regulatory, governmental, industry, engineering / scientific and investment communities within the constraints imposed. This could entail qualifying or validating limited initial results or providing recommendations to be followed by further testing and analysis. The goal is to complete the verification within approximately 60 days.

It is expected that the entity retained to validate process efficacy will provide refinements to the sampling, monitoring and data analysis protocols developed.

Recommendation of the technology to the industry, a specific or general endorsement, a definitive fully detailed and rigorous elucidation of the science or engineering fundamentals at work, or complete research report or article ready for peer review **is not required**. The verification sought is more along the lines of a rigorous auditing function or a peer review as would be performed for a refereed journal article with a defined limited scope.

**Goal:**

Within the limited time and budget available, quantify the nutrient conversion and air emissions of a retro-fitted Bion NMS and prepare a report so that regulatory/governmental, agriculture industry, engineering / scientific, and investment communities can understand it's potential application.

**Deliverables:**

Review, input and refinements to the protocols, sampling and analyses are expected.

The final product is anticipated to be a simple, concise four to six page letter report. The report should provide an overview of the steps performed, referring to the protocols, data and analyses performed and / or reviewed by the verifier. Then the general conclusions drawn shall be detailed and the appropriate limitations and constraints on those conclusions provided. A final statement of how the qualifiers or caveats to conclusions may be removed with subsequent work may also be desirable. This deliverable is not to be the final definition for applying technology solutions to the CAFO emissions issue. The efforts laid out here are one phase of a developing multiphase approach for addressing treatment options for CAFO's. For instance, there are other research programs being initiated on a National level to address CERCLA and criteria pollutant emissions (VOC's, etc.), which are focused primarily on uncontrolled effluent emissions from the dairy waste management systems. Efforts here are to document the emissions from the

Bion System and then at a later date compare those emissions to a baseline established for the other management approaches. Other research entities are establishing the baseline for multiple management systems deemed responsible for large-scale uncontrolled emissions.

**Verification Overview:**

**I. Nutrient Conversion**

**A. Goal Nutrients**

Mass and form (particulate / dissolved) of phosphorous and nitrogen discharged with sources and fate defined.

**B. Validation Objectives**

Protocol

Field Sampling

Lab data

Analysis

**C. Report**

**II. Atmospheric Emissions**

**A. Goal Air**

Quantify mass of atmospheric emissions generated by an operating Bion NMS

**B. Validation Objectives**

Protocol

Field Sampling

Lab data

Analysis

**C. Report**

**Verification team members and responsibilities:**

**TEAM LEADER**

**Lynne Moss, P.E. – Review Coordinator**

**Environmental Engineer, Camp Dresser & McKee, Austin, Texas**

***RESPONSIBILITIES***

Gather input from team members that impacts goals and objectives then address with Bion

Coordinate with Bion operations and technical personnel

Provide on-site verification of system operation and testing

Lead report efforts

Provide specific review input in areas of expertise

***EXPERTISE***

Odor control issues in animal manure management and wastewater treatment (especially dairy and poultry)

Planning and evaluation studies for river and watershed based animal waste management impacts on water quality (including projects in the Brazos River / Navasota Watershed / Erath County)

Industrial pretreatment programs

**TEAM MEMBERS**

***RESPONSIBILITIES***

All team members are to review and provide guidance to activities and protocols impacting the goals and objectives of the verification program.

Members are to focus particularly on their areas of expertise.

**Richard Nicolai, Ph.D., P.E.**

**Assistant Professor/Extension Specialist, South Dakota State University**

***EXPERTISE***

Atmospheric emissions and odor control issues in animal manure management

Animal agriculture related air quality

Nutrient management

**Richard R. Stowell, Ph.D.**

**Asst Professor / Extension, University of Nebraska Lincoln**

***EXPERTISE***

Air pollution monitoring and control from dairy operations

Dairy waste management

**Mark Gould, P.E.**

**Senior Environmental Engineer**

***EXPERTISE***

Atmospheric emissions sampling, monitoring, quantification and modeling.

Generation of odors and VOCs from waste management operations

Waste management process design and operation

Bion Technologies, Inc.

**William W. Clarkson, Ph.D., P.E.**  
**Associate Professor, Oklahoma State University**

***EXPERTISE***

Biological waste management systems  
Process engineering for nutrient control  
Industrial / agricultural waste treatment

**Kevin Young, P.E.**  
**Senior Vice President, J. R. Wauford & Company, Jackson, Tennessee**

***EXPERTISE***

Process engineering for nutrient control  
Biological waste management systems for municipal and industrial wastewater

**Clyde H. Burnett, P.E.**  
**Associate, Camp, Dresser & McKee**

***EXPERTISE***

Process engineering for wastewater management and nutrient control  
Biological waste management systems

**TEAM ADVISORS**

**Raymond C. Loehr, Ph.D.**  
**Hussein M. Alharty Chair Emeritus in Civil Engineering**  
**University of Texas at Austin**

***EXPERTISE***

Agricultural waste management  
Environmental and Water Resources Engineering

**Ron Heavner**  
**National Air Quality Specialist, USDA/NRCS/CED**

***EXPERTISE***

Air emissions

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## Resumes of Review Team Members:

### Lynne H. Moss, P.E., DEE

*Principal*

#### Education

B.S. Civil Engineering,  
University of Texas, 1982

Ms. Moss has been involved in a wide variety of environmental projects during her 20 years with CDM. Over the past decade, her work has focused on biosolids management, manure management and odor control issues.

#### Biosolids and Manure Management

#### Registration

Professional Engineer: Texas  
(1991)

**Principal Investigator, Water Environment Research Foundation (WERF) Assessment.** Ms. Moss completed a multi-year study comparing the risks and benefits of soil amendments and fertilizers used in agriculture. The study, which focuses on biosolids, manures, and chemical fertilizers, summarizes state-of-the-art research on these products for the agricultural community and other interested parties.

#### Certifications

Texas Nutrient Management  
Specialist (#TX20035)

American Academy of  
Environmental Engineers  
Diplomate

**Investigator, Various WERF Projects.** Ms. Moss performed an assessment of innovative biosolids management processes. For the study, she investigated numerous thickening, dewatering, stabilization, and other emerging technologies. Results of the assessment were summarized in a user-friendly guidance document for municipalities and others wishing to investigate innovative biosolids processes. Ms. Moss was also an investigator for a WERF project assessing biosolids stability issues.

**Project Engineer/Manager, Various Solids Management Plans.** Ms. Moss has developed numerous long-term solids management plans for clients throughout Texas and the Northeast. Ms. Moss led a project to develop a solids management strategy for sludges generated at three wastewater treatment plants operated by the San Antonio River Authority, and she is now managing the design of facilities recommended in that assessment. The project evaluated innovative and conventional Class A processes, dewatering options to meet increasing sludge production and plant operational requirements, and investigated regionalization of sludge operations to improve solids management efficiency. For the City of Denton, Texas, she assessed multiple composting strategies to accommodate projected growth at the Pecan Creek WWTP and the inclusion of primary sludge as a composting feedstock. Based on her assessment, she recommended a continuance of the plant's windrow process, modified to improve operational efficiency. For the Greater Lawrence Sanitary District, Ms. Moss prepared a Facilities Plan that recommended improvements to thickening and dewatering processes, as well as the construction of anaerobic digesters and a biogas-fueled heat-drying facility. She has performed similar efforts for the towns of Mansfield, Amherst, Wayland, and Westboro, Massachusetts and for the Narragansett Bay Commission (Rhode Island).

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**Project Engineer, Erath County Animal Waste Management Study.** For the Brazos River Authority, Ms. Moss assessed the feasibility of regionalized dairy manure processing in Erath County. Ms. Moss evaluated both conventional and innovative processes, and she developed an implementation plan that considered probable facility construction costs, market development needs and economic constraints. The recommended plan for the county was based upon the construction of a regional composting facility to process about 50 dry tons of manure daily, with provisions for the construction of additional facilities to demonstrate innovative processes.

**Project Manager, Biosolid Utilization Evaluation Program.** Ms. Moss managed a comprehensive program to develop land application guidelines for the Connecticut Department of Environmental Protection. For the project, CDM developed nitrogen and metal-based application rates for biosolid composts, heat-dried biosolids, and alkaline-stabilized biosolids. The recommendations were based upon laboratory studies conducted at the University of Connecticut.

**Project Manager, Brazos River/Navasota Watershed Management Project Integrated Resource Planning (IRP).** Ms. Moss is managing CDM's efforts in a proactive program to maintain, and in some areas improve, water quality in the Navasota watershed, an area that is experiencing explosive growth in poultry production. For the project, CDM is facilitating stakeholder meetings, as well as preparing and presenting summaries of previous project-related efforts. Ms. Moss' efforts specifically support organics (biosolids and poultry litter) management aspects of the project.

**Project Engineer/Manager, Various Biosolids Marketing Studies.** For the City of College Station, Texas, Ms. Moss assessed marketing options for various Class A stabilization processes that the city was considering (Autothermal Thermophilic Aerobic Digestion (ATAD), composting, advanced alkaline stabilization, and the proprietary BioSet process). Based upon telephone surveys, onsite interview with potential users, an assessment of competing products in the area, and expected product characteristics, Ms. Moss identified market constraints and opportunities for each product. For the ATAD process, which the city is currently operating, she recommended facilities and equipment that would be required to generate a soil-like product that could be commercially marketed in the area. For the Eastern Hampshire Regional Refuse District (Massachusetts), Ms. Moss assessed potential markets for both a biosolid compost and a select organic compost. She also assessed markets and developed a marketing strategy for a heat-dried biosolid that was to be produced by the South Essex Sewerage District in eastern Massachusetts.

## **Odor Control**

**Project Manager/Engineer, Zacate Creek Wastewater Treatment Plant (WWTP) Odor and Corrosion Control Improvements.** Ms. Moss managed a project to identify an odor management strategy for this plant in Laredo, Texas, assisted design engineers during the design of her recommendations and led a subsequent study to assess collection system treatment options. A comprehensive sampling program looking at odor, hydrogen sulfide and reduced sulfurs, identified the aerated grit and primary clarifier systems as key odor contributors. Comprehensive changes to the existing containment and ventilation strategy are under design for these sources, and as well as a 12,000 cfm bioscrubber to treat odorous

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exhausts (extreme site constraints limited the choice of odor control systems to bioscrubbers or chemical scrubbers, with the former being more cost-effective for this application). These designs are part of a three phase strategy developed by Ms. Moss that includes rehabilitation of severely corroded facilities, the odor containment and treatment upgrades, and collection system improvements.

**Project Engineer, Walnut Creek WWTP Expansion Preliminary Design.** For this project in Austin, Texas, Ms. Moss led all odor control efforts, which began with an identification of odor sources requiring control at the 60-mgd Walnut Creek WWTP. Her assessment identified excessive hydrogen sulfide-related corrosion at the plant, and recommended improvements to address these issues as well. The recommended plan for the facility included improved ventilation in the existing headworks and primary treatment buildings, refurbishing the existing carbon units for odor control, and a split-flow treatment scheme that incorporated both carbon and activated sludge treatment for odorous exhausts. Subsequent to this study, the City of Austin elected to construct a new headworks building and Ms. Moss led efforts to identify an appropriate technology for that new source. She revised the existing management strategy to integrate treatment for the new headworks exhaust (roughly 45,000 cfm) and selected an innovative carbon to control odors from the new facility. The carbon has been placed in refurbished carbon canisters onsite and is expected to be operational in spring 2004.

**Project Engineer, Carters Creek WWTP Odor Control Preliminary Design.** Ms. Moss led preliminary design efforts for odor control improvements at the Carters Creek WWTP in College Station, Texas. Odor sources at the plant included ATAD exhausts, sludge thickening operations and centrifuge exhausts. For the ATAD, she recommended replacement of the existing biofilter with a larger unit that offered a lower loading rate, an improved media, and better accessibility for media replacement. For the lower volume and strength centrifuge and sludge thickening exhausts, she recommended aeration basin treatment. In subsequent work, Ms. Moss also recommended bioscrubbing for the plant headworks odors (scrubbing in biotowers is an effective, but lower cost option than the robust system required for the difficult-to-treat ATAD odors). All odor control systems are operational and have significantly reduced odors and, critically, odor complaints from a neighborhood next to the plant.

**Project Engineer, San Marcos Biofilter Preliminary Engineering.** Ms. Moss identified design criteria for a biofilter to treat exhausts from digested sludge and waste activated sludge holding tanks, sized the biofilter, and designed a media appropriate to treat expected exhausts. When the biofilter was complete, she also trained plant staff on biofilter operations.

**Project Engineer/Manager, Various Odor Control Projects.** Ms. Moss's experience with odor issues also includes: odor assessments for the cities of Hartford, Connecticut and Woonsocket, Rhode Island; performance of Best Available Control Technology (BACT) assessments for a private co-composting facility in Pepperell, Massachusetts and for the Greater Lawrence Sanitary Districts wastewater treatment facility in North Andover, Massachusetts; the development of an Odor Management Plan for the Pepperell co-composting facility; and the refurbishment of a biofilter treating high strength exhausts in Springfield, Massachusetts.

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## **Professional Activities**

Member, Water Environment Federation Residuals and Biosolids Committee

Member, Water Environment Association of Texas

Member, American Academy of Environmental Engineers

Member, American Society of Agricultural Engineers

## **Publications**

Prosperity and Quality Water: A Model Partnership at Work, April 2003, *Public Works* (with P. Glass and L. Fernandez).

Comparing the Risks and Benefits of Soil Amendments Used in Agriculture, Report to the Water Environment Research Foundation, 2002 (with E. Epstein and T. Logan).

Comparing the Characteristics, Risks and Benefits of Soil Amendments Used in Agriculture. Proceedings of the 16<sup>th</sup> Annual Water Environment Federation Residuals and Biosolids Management Conference: Privatization, Innovation, and Optimization: How to Do More for Less, Austin, TX, 2002. 2002 (with E. Epstein and T. Logan).

Developing an Animal Waste Management Plan for Erath County, Texas, 1999 (with M. Meadows and S. Norvell). Proceedings from the Water Environment Federation Animal Residuals Management Conference: Developing, Testing, and Implementing Technological Advances.

Biosolids Management: Assessment of Innovative Processes. Report to Water Environment Research Foundation, 1998 (with A.B. Pincince, J.F. Donovan and M.S. Switzenbaum).

A Matrix Approach for Assessing Biosolids Stability. ASCE Proceedings of the 1998 National Environmental Engineering Conference, 1998 (with M.S. Switzenbaum, E. Epstein, A.B. Pincince, and J.F. Donovan).

Defining Biosolids Stability, *Journal of Environmental Engineering*, 123, 1178, 1997 (with M.S. Switzenbaum, E. Epstein, A.B. Pincince, and J.F. Donovan).

Review of Innovative Biosolids Processes. For presentation at the workshop Biosolids Management: Innovative Treatment Technologies and Processes at the Water Environment Federation's 70th Annual Conference, Chicago, IL, 1997 (with A.B. Pincince, J.F. Donovan, and M.S. Switzenbaum).

Application of U.S. Biosolids Experience to the Spanish Market. Proceedings of the Specialty Conference on Beneficial Reuse of Water and Biosolids, Marbella, Spain, 1997 (with A.B. Pincince, J.F. Donovan, and F.I. Plaza).

Summary Paper: Establishing Biosolids Stability Criteria. WEFTEC '96. Dallas, TX, 1996 (with M.S. Switzenbaum, E. Epstein, A.B. Pincince, and J.F. Donovan).

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Establishing Biosolids Stability Criteria. Report to Water Environment Research Foundation, 1996 (with M.S. Switzenbaum, E. Epstein, A.B. Pincince, and J.F. Donovan).

"Beneficial Use Programs for Biosolids Management," Water Environment Federation Special Publication, 1994 (contributing author).

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## **Clyde H. Burnett, P.E., DEE**

*Senior Environmental Engineer*

### **Education**

M.S.-Environmental Engineering,  
Washington State University, 1976

B.S.-Electrical Engineering,  
Southern Methodist University,

### **Registration**

Professional Engineer: Texas,  
Arkansas, Oklahoma, and Louisiana

Mr. Burnett has a broad experience base in environmental engineering resulting from more than 26 years in the consulting engineering practice. He has worked extensively in wastewater collection and treatment, and specializes in process design and facilities planning for wastewater utilities. He is experienced in all types of wastewater and biosolids treatment having managed or participated in planning and/or design of improvements for over 40 different facilities, ranging in size from 0.03 to 160 mgd. He is an authority on high temperature sludge digestion systems and enhanced high-rate clarification systems.

### *Wastewater*

**Pine Bluff, Arkansas.** Mr. Burnett analyzed loadings and developed upgrade alternatives for 490-acre aerated and facultative lagoon system. He evaluated alternatives to increase treatment capacity and achieve ammonia removal.

**Fort Smith, Arkansas.** Mr. Burnett developed a comprehensive wastewater management plan to comply with regulatory orders, achieve water quality goals and meet future wastewater treatment needs. Included was an analysis of sanitary sewer overflows within the collection system and evaluation of ballasted flocculation enhanced high-rate clarification for management of peak flows.

**Little Rock, Arkansas.** Mr. Burnett developed preliminary cost estimates for a proposed WWTP as part of a larger study involving a detailed analysis of wastewater conveyance alternatives and collection system costs for western Little Rock.

**San Antonio, Texas.** Mr. Burnett completed a comprehensive master plan for a wastewater system to determine the optimum plan to provide future wastewater treatment, serve reuse customers, address collection system needs, and serve areas of future growth by constructing satellite treatment facilities or conveying flows to existing plants. Hydraulic needs were coupled with results of a physical inspection of the major interceptors to prioritize overall collection system hydraulic and structural improvements, which are currently being implemented.

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**Laredo, Texas.** Mr. Burnett developed a comprehensive wastewater master plan for this rapidly growing city of 130,000. Included was creation of a dynamic collection system flow model to identify hydraulic limitations of the system and prioritize collection system improvements, develop future population and flow projections, and evaluate various alternatives for providing future wastewater treatment.

**Nuevo Laredo, Mexico.** Mr. Burnett prepared a comprehensive wastewater master plan for this border city of 300,000. Completed population and flow projections, detailed sampling and characterization of raw wastewater from 30 separate outfalls, city-wide survey and physical sampling of industrial wastes, and analysis of wastewater collection and treatment alternatives. He subsequently designed new 31-mgd wastewater treatment plant south of the city.

**Texas State Parks.** Mr. Burnett managed a large team of engineers and subconsultants to evaluate wastewater treatment plants and collection system conditions statewide, consisting of 116 state parks and recreation areas. The team developed individual facility plans for each park. The project also included developing a computerized facility management system using Microsoft Access.

### **Honors/Awards**

Diplomate: American Academy of Environmental Engineers

President (2000-2001): Water Environment Association of Texas

### *Biosolids Management*

Mr. Burnett has extensive experience in all aspects of biosolids management. His biosolids projects include:

**Northwest Arkansas Conservation Authority.** Mr. Burnett is managing a regional biosolids project with capacity to handle biosolids from Fayetteville, Springdale, Rogers, Bentonville, and Siloam Springs. He is investigating various stabilization and beneficial use options for municipal sludge including possible incorporation of poultry litter produced in the region.

**Hot Springs, Arkansas.** Mr. Burnett completed planning and design of a new state-of-the-art covered aerated static pile composting facility using horse track straw, wood chips, and 3.5 DT/day of sludge from the city's WWTPs. He performed a regional marketing and valuation study for finished compost. The project is currently under construction.

**Little Rock, Arkansas.** Mr. Burnett conducted an energy recovery and digester gas optimization study for Adams Field and Fourche Creek WWTP anaerobic digestion facilities. He evaluated the economics of sludge drying versus on-site electrical generation using engine generators and gas turbines.

**Denton, Texas.** Mr. Burnett designed sludge handling improvements as part of a plant enlargement from 15 to 21 mgd, including investigating conversion of conventional anaerobic digesters to temperature-phased (thermophilic/mesophilic) digesters to produce Class A sludge.

**College Station, Texas.** Mr. Burnett prepared a sludge master plan including evaluation of feasible sludge processing options; implemented new autothermal thermophilic aerobic digestion (ATAD) process for sludge stabilization to Class A standards. He assisted with

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designing a new waste activated sludge (WAS) rotary drum thickening facility for Carters Creek plant, and new flexible thickening/dewatering centrifuge installation for the Lick Creek plant.

**Austin, Texas.** Mr. Burnett directed improvements to Hornsby Bend 60 DT/day centralized sludge management facility, including new thickening facility with six gravity belt thickeners; digester improvements; odor control facilities; reclamation of sludge lagoons; new administration, laboratory, and maintenance facilities; and beneficial use of sludge through land application and windrow composting.

**Fort Smith, Arkansas.** Mr. Burnett prepared a sludge master plan to evaluate alternatives available for producing Class A sludge suitable for land application. Based on results of study, a new Class A lime pasteurization process using supplemental heat was implemented and is now installed.

**San Marcos, Texas.** Mr. Burnett developed a sludge master plan; he was project manager for design of a new sludge treatment train including centrifuge thickening and dewatering facility, new thermophilic aerobic digestion system (ATAD) for producing Class A sludge, and new land application disposal program.

**East Texas Council of Governments.** Mr. Burnett performed a regional biosolids management study. Identified and evaluated alternatives for most cost effective and environmental friendly means of managing biosolids from a 10-county area including the cities of Tyler, Kilgore, Longview, and Marshall.

**Sludge Management Plan. Alexandria, Louisiana.** Mr. Burnett evaluated sludge alternatives and recommended new centralized windrow composting facility incorporating green waste from the local landfill.

**Laredo, Texas.** Mr. Burnett prepared a sludge master plan; he recommended a new sludge dewatering facility and continued reliance on landfill disposal. Subsequently he designed a new belt press dewatering facility.

**Bryan, Texas.** Mr. Burnett prepared a sludge master plan. He assisted with design of a new windrow composting facility. The operation has proven to be very successful with demand exceeding supply.

**Manure Management Study, Erath County, Texas.** Mr. Burnett performed a study of alternative manure management techniques for this milk producing region containing over 100,000 dairy cows producing daily biosolids quantities equivalent to the City of Houston. He evaluated the cost, feasibility, and practicality of a centralized regional composting facility coupled with a novel marketing and distribution program.

**Nuevo Laredo, Mexico.** Mr. Burnett designed a sludge holding tank and 10 acres of sand drying beds for a 31-mgd facility.

*Process Design*

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Mr. Burnett has also planned and assisted with design of liquid process improvements for numerous WWTPs including:

- Arlington, Texas
- Austin, Texas
- Baton Rouge, Louisiana
- Bryan, Texas
- Cedar Park, Texas
- College Station, Texas
- Dallas, Texas
- Fort Worth, Texas
- Gulfport, Mississippi
- Houston, Texas
- Nuevo Laredo, Texas
- Odessa, Texas
- San Marcos, Texas
- Spokane, Washington
- St. Bernard Parish, Louisiana
- Stillwater, Oklahoma
- Victoria, Texas

## **Professional Activities**

American Academy of Environmental Engineers

Water Environment Federation

Arkansas Water Environment Association

Water Environment Association of Texas

## **Publications**

"Tamaulipas Consta Con Nueva de Tratamiento de Aguas Residuals," Construccion y Obras Publicas Latinoamerica 1(4):22-25, 1994.

"Small Cities + Warm Climates = Windrow Composting," WEF Operations Forum 10(7):22-26, 1993.

"Emergency Treatment Facility Relieves Capacity Crunch," Public Works 118(7):67-69, 1987 (with R. Bhattarai).

"Total Domestic Wastewater Treatment Costs," Water Pollution Control Federation 53:522-529, 1981 (with M. Cullum).

"Conquering Time and Space: Spokane's New Advanced Wastewater Treatment Plant," Water and Wastes Engineering 15(11):49-52, 1978 (with R. E. Smith and D. V. Neal).

"Relative Measurement Response for a Group of Sulfur Compounds," J. Chromatographic Science 16:68-73, 1978 (with D.F. Adams and S.O. Farwell).

## **Seminar Presentations**

"New Directions in Biosolids Management", 2003, Arkansas Water Works and Water Environment Association Annual Conference, Hot Springs, Arkansas.

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"State-of-the-Art Headworks Rises in Austin", 2003, Water Environment Association of Texas Annual Conference, Corpus Christi, Texas.

"Innovative Peak Flow Management for Fort Smith", 2001, Arkansas Water Works and Water Environment Association Annual Conference, Hot Springs, Arkansas.

"Resourceful Trickling Filter Upgrade Provides New Life for Victoria's Willow Street WWTP", 1999, Water Environment Association of Texas Annual Conference, Ft Worth, TX.

"A Comparison of UV Disinfection Technology", 1998, Texas Water '98, Galveston, Texas.

"Dewaterability of ATAD Sludges", 1997, 70th Annual Conference of the Water Environment Federation, Chicago, Illinois.

"An Overview of Autothermal Thermophilic Aerobic Digestion Facilities in Europe and Canada", 1995, Water Environment Federation New and Emerging Wastewater Technologies Conference, Toronto, Canada.

"Design of Thermophilic Digestion Facilities for College Station, Texas", 1994, Water Environment Association of Texas Annual Meeting, Corpus Christi, Texas.

"Technology and Process Options for Autothermal Thermophilic Aerobic Digestion", 1994, 67th Annual Conference of the Water Environment Federation, Chicago, Illinois.

"Design of Wastewater Treatment Facilities for Nuevo Laredo, Mexico", 1993, 66th Annual Conference of the Water Environment Federation, Anaheim, California.

"A Comparison of Windrow Composting Operations in Texas", 1992, Texas Water Pollution Control Association Annual Meeting, Dallas, Texas.

"Small Cities + Warm Climates = Windrow Composting", 1992, 65th Annual Conference of the Water Environment Federation, New Orleans, Louisiana.

"The Nuevo Laredo Sanitation Project", 1991, Texas Water Pollution Control Association Annual Meeting, Galveston, Texas.

"Plastics Removal from Sludge", 1990, 63rd Annual Conference of the Water Pollution Control Federation, Washington, D.C..

"Removal of PCB and Asbestos Contamination from the Seaholm Power Plant", 1990, Texas Water Pollution Control Association Annual Meeting, Arlington, Texas.

"Austin's 13.5 MGD Temporary Wastewater Treatment Plant", 1988, Texas Water Pollution Control Association Annual Meeting, Corpus Christi, Texas.

"Impacts of Phosphorus Removal on the Spokane Wastewater Treatment Plant", 1979, Pacific Northwest Pollution Control Association Annual Meeting, Victoria, B.C., Canada.

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**William W. Clarkson, Ph.D., P.E.**  
**Associate Professor of Environmental Engineering**

**EDUCATION:**

- B.S.E. in Civil Engineering, Duke University, 1971
- M.S. in Environmental Systems Engineering, Clemson University, 1972
- Ph.D. in Agricultural Engineering, Cornell University, June 1986  
‘Major: Waste Management Minors: Microbiology, Environmental Engineering
- National Award: 1986 Engineering-Science / Association of Environmental Engineering Professors Doctoral Thesis Award in field of Environ. Eng. and Sci.

**PROFESSIONAL ACTIVITIES:**

- Registered Professional Engineer, Oklahoma (No. 18129)
- Association of Environmental Engineering and Science Professors
- International Association on Water Quality / Specialist Groups:  
Use of Macrophytes in Water Pollution Control, Anaerobic Digestion
- Manuscript Reviewer: J. Environ. Engineering, Water Environment Res., Water Research, Environ. Sci. & Technol., Biomass and Bioenergy, Environmental Software, Chemosphere, Environ. Engrg. Science, Environ. Technology, Bioremediation Journal
- Proposal Reviewer: EPA Environmental Engineering Panel, EPA STAR Fellowships,  
USGS Section 104 Western Regional Competitive Grants Program
- Wentz Project Reviewer (OSU Undergraduate Research Grants) (1999-2000)
- Wastewater Treatment Plant Operator, North Carolina (Grade II Certificate No. 1176)
- Who’s Who in the World (various editions) / Men of Achievement

**PRINCIPAL RESEARCH AND CONSULTING INTERESTS:**

Innovative biological treatment systems, bioremediation, anaerobic microbial processes, biofilm processes, nutrient management, biodegradation, industrial waste treatment, agricultural waste management, land application, biomass conversion.

**PROJECT MANAGEMENT AND PROFESSIONAL EXPERIENCE:**

- Assistant Professor, Clarkson Univ. (1984-1987), Asst. / Assoc. Professor, OSU (1987-present).
- Principal Investigator or Co-Principal Investigator on research projects totaling approximately \$1.05M (1985 to present). Sponsors include Army Corps of Engineers, IBM Corporation, National Science Foundation, Environmental Protection Agency, USGS (Oklahoma Water Resources Research Institute), Oklahoma Alliance for Public Policy, Oklahoma Center for Advancement of Science and Technology, Duncan Instruments, OSU Center for Water Research, Transok Inc., Agricultural Minerals Corporation, Amoco Research.

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- Instructor for numerous courses related to biological waste treatment, bioremediation, unit operations and processes, fluid mechanics, and environmental engineering. Major Advisor for 2 Ph.D. and over 35 M.S. graduates. Author or co-author of more than 30 journal articles and conference proceedings publications. Consulting assignments with Sequoyah Fuels; Battelle Corp. (at Tinker Air Force Base); City of Fort Gibson, OK; Atkins Americas (now Benham).

- Project engineering and design experience with consulting engineering firms (Wiggins-Rimer & Assoc., Peter B. Crist Assoc., and W. H. Gardner Assoc.) in Durham, NC (1972-1974). Peace Corps assignment with Western Samoa Public Works (1974-1976). Research Associate, Graduate Research Assistant, and Instructor in Agricultural Engineering Dept., Cornell University (1977-1984).

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**MARK GOULD, P. E.**  
**Senior Environmental Engineer**  
**Camp Dresser & McKee**

*Summary*

Mr. Gould has extensive experience in the field of odor and VOC emission controls for wastewater treatment facilities, biosolids and solid waste composting facilities, and industrial processes spanning the full range of services, including planning, permitting, design, monitoring, and operations.

*Experience*

The Inland Empire Utilities Agency operates five wastewater reclamation plants and a facility to digest manure and generate electricity. Mr. Gould developed a program to sample emissions sources at all the facilities and develop models to predict off-site odor impacts. He developed a quarterly off-site monitoring program to calibrate and validate the model results for each facility and expanded the models to cover future expansion and odor control scenarios. Completion will be in November 2003.

The City of New York Department of Environmental Protection (DEP) is developing new zoning performance standards for odor and noise emissions to apply to industries in proximity to residential areas. Mr. Gould surveyed the industries nine study areas around the city, identified case studies for modeling of odor emissions, trained DEP inspectors and conducted odor monitoring to provide inputs for odor dispersion modes for each industry type.

For the Camden County Municipal Utilities Authority. Mr. Gould managed stack testing for the scrubbers at the Camden WWTP. The testing was to demonstrate permit compliance for emissions of VOCs, hydrogen sulfide, and odor.

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As part of the upgrade of the Attleboro, MA WWTP, Mr. Gould managed the design of three biofilter odor control systems to treat exhaust from the headworks, primary effluent pumping and sludge thickeners. Projects will be bid late in 2003.

As part of the upgrade of the Brocton, MA WWTP, Mr. Gould managed the design of a 24,000 CFM scrubber system to treat exhaust from sludge storage and sludge dewatering operations.

The St. Louis Metropolitan Sewer District is undertaking odor control improvements at three wastewater treatment plants. For the Missouri River Plant, Mr. Gould designed an air collection system serving the headworks, pre-aeration tanks, and primary settling tanks and developed procurement documents for a 9,000 cfm proprietary biofiltration system. For the Grand Glaize and Fenton plants, he completed an odor sampling program to prioritize future odor control improvements.

The South Walton Utility Company operates an advanced wastewater treatment plant in Miramar Beach Florida that has been a source of odor complaints. Mr. Gould conducted a sampling program and recommended a proprietary bio-trickling filter to treat exhaust from the headworks. He prepared request for vendor proposals for a pre-selection, assisted the client in negotiating purchase of a system and directed the design of the odor collection system and supporting utilities. The system became operational in mid 2003 and is successfully treating high concentrations of hydrogen sulfide, organics, and odors.

The 30 mgd Upper Blackstone Water Pollution Abatement Facility in Worcester, MA is undertaking odor control improvements for construction in 2003. Mr. Gould conducted sampling and prepared a facility plan recommending a 18,000 cfm proprietary package biofilter to treat the headworks and covered primary clarifiers, activated carbon for sludge tanks, and integration of sludge processing odors into existing regenerative thermal oxidizers. The systems will be bid late in 2003.

For the Solid Waste Authority of Palm Beach County, Florida, Mr. Gould developed an odor sampling and modeling plan to evaluate design alternatives to update the 150,000 cfm odor control system at the 22 dry ton/day in-vessel biosolids composting facility. The sampling and modeling was expanded to include the adjoining landfill and waste to energy facility to assess area-wide odor impacts from all SWAPBC operations. He designed a new 180,000 cfm biofilter system that became operational late in 2002.

The Water and Sewer Authority of Washington DC (DC WASA) is undertaking a major capital improvement project at the 350 mgd Blue Plains Plant including new headworks and sludge handling facilities. WASA engaged CDM to sample and model all odor sources and develop a comprehensive odor management plan for all proposed improvements. Mr. Gould reviewed all projects, designed the sampling program and conducted workshops for WASA staff and consultants to integrate all projects from an odor control standpoint.

The City of Austin, TX is upgrading the Walnut Creek Wastewater Plant. Mr. Gould designed a system of buried odor collection ductwork up to 72 inches in diameter and refurbishment of an existing 100,000 CFM activated carbon system.

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For the Metropolitan Area Environmental Services (MCES) of the Minneapolis St. Paul area, Mr. Gould conducted a staff workshop on odor and corrosion control in the regional interceptor system. He designed an odor control system for the Colby Lake Pump Station.

Federal Creosote is a superfund site in Manville, NJ, where houses had to be evacuated and demolished because they were built on old lagoons containing soil contaminated with wood preservatives. The soil is being excavated from the lagoons while the surrounding houses remain occupied. Mr. Gould developed the odor monitoring protocol and odor control options for the project specifications, which are being implemented, with modifications, by the Corps of Engineers and the remediation contractor.

The City of Wichita, Kansas upgraded the No.2 Wastewater Treatment Plant, which treats primary effluent from Plant No. 1, wastewater, and septage. Mr. Gould designed a plant wide odor control system consisting of underground collector ducts and balancing fans feeding a central 18,000 cfm biofilter, plus a satellite active carbon treatment system.

Mr. Gould assisted the City of Boulder, Colorado and a private waste hauling company in developing a conceptual design and business plan for a privatized 5 dry ton/day composting facility to treat biosolids from Boulder and nearby communities.

Mr. Gould conducted an odor study for the Haverhill MA Wastewater Treatment to identify odor sources resulting in increased community complaints. Through source sampling he discovered that most of the odor was caused by a single mal-functioning wet scrubber, and was able to eliminate complaints at little cost to the Town.

For the City of St. Petersburg, Florida, Mr. Gould designed a 3000 cfm odor control system including scrubber to remove high concentrations of hydrogen sulfide, followed by a biofilter. System became operational in October 2003.

For the Northeast Monmouth County Regional Sewerage Authority in New Jersey, Mr. Gould designed two biofilter system at the Monmouth Beach WWTP; one to treat odors from the aeration tanks and headworks; and one to treat odors from sludge dewatering. He also designed activated carbon odor control systems for two pump stations in highly sensitive residential areas. Systems become operational in mid 2003.

Mr. Gould served as operations consultant for the Hartford, Connecticut Metropolitan District biosolids composting facility. He conducted laboratory simulations to optimize the process with respect to ammonia generation, worked with plant staff to develop monitoring and response procedures to reduce odor emissions, developed biofilter operating procedures to maximize ammonia removal, and prepared the technical portion of the air pollution control permit.

For the City of Columbus, Ohio, Mr. Gould was responsible for the preliminary design of a totally enclosed 50 dry ton/day biosolids composting facility to replace an existing outdoor operation. He designed and conducted a comprehensive odor study, which included setting up pilot piles under various aeration modes, sampling for odor emissions, and modeling to predict impacts for each design scenario.

He designed and conducted a VOC emissions compliance monitoring program for the Baltimore City Composting Facility, and utilized models to assess compliance with EPA Title 5, NIOSH,

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OSHA, and Maryland state air toxics regulations. The model covered area sources, scrubber stack, and innovative simulations of active material handling operations.

Mr. Gould served as process design consultant to Trans Alta Enterprises for the design of a totally enclosed and mechanized 1,500 ton/day facility to convert solid waste and biosolids into compost for mine revegetation, located in Edmonton, Alberta. He was specifically responsible for mass and energy balances, heat transfer, and in handling systems and optimizing design of scrubbers and biofilters. Construction began in 1998.

For the Bluestem Solid Waste Agency in Cedar Rapids, Iowa, he developed the experimental design and monitoring protocol for a pilot scale landfill bioreactor, in which the landfill cell environment is optimized for maximum gas production and biodegradation rate. The cells will be filled in spring 1999. Also for Bluestem, he developed process modifications for a composting facility treating papermill and pharmaceutical sludges to reduce ammonia emissions. The project included bench scale simulations, modeling, and an information system to track carbon and nitrogen through the process. Odor complaints were eliminated.

He served on the Massachusetts Department of Environmental Protection (MADEP), Task Force to develop new odor control regulations for Massachusetts treatment facilities, using point of discharge compliance monitoring and modeling to predict off site impacts.

For Oleet Processing Ltd. Of Regina Sask., he developed the preliminary design of an odor control system using scrubbers and biofilters to remove amines from the exhaust at a protein supplement manufacturing operation.

For Western Lakes Sanitary District in Duluth, Minnesota, he evaluated alternative methods to control acidity in a two-stage biofilter-removing hydrogen sulfide from wastewater pumping station exhaust.

He designed odor control systems for operating composting plants at the Hoosac Water quality District in Williamstown, Massachusetts, and the East Hampton, New York composting facility, and for composting facilities in Marlboro and Nantucket, Massachusetts.

### *E d u c a t i o n*

BS - Electrical Engineering, Cornell University, 1967

MS - Environmental Engineering, Northeastern University, 1980

Mr. Gould is trained in conducting field odor assessments using ASTM Standards Practice E-544-99.

### *R e g i s t r a t i o n*

Professional Engineer: Massachusetts, Maine, Pennsylvania, New York, Illinois

### *M e m b e r s h i p s*

New England Water Environment Association  
Chairman, NEWEA Residuals Committee  
Water Environment Federation

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### *Publications/ Presentations*

Gould, M., Wu, N., Meek, D., Hoff, J., Use of Odor Emissions Monitoring and Dispersion Modeling to Design a New Biosolids Composting Facility in Columbus, Ohio Water Environment Federation Residuals Specialty Conference Boston, MA February 2000

Gould, M. Management of Food Processing Residuals by Composting—Can it Work for You? 30th Annual Conference on Environmental Engineering in the Food Processing Industry Durango, Colorado March 2000

Gould, M., Moss, L.H., Boyette, A. Extreme Biofilters-- Treatment of High Concentrations of Ammonia and Reduced Sulfur Compounds New England Water Environment Federation Annual Conference Boston, Massachusetts January, 2000

Gould, M. Measurement of Odor at Composting Facilities. Demonstration at the BioCycle Northeast/Midwest Conference, Columbus, Ohio. August 1998.

Gould, M., D. Hogan, K.A. Feldman, and N.T. Wu. Controlling Composting Odors. Industrial Wastewater. May/June 1998.

Gould, M. Emissions of Greenhouse Gases from Solid Waste Disposal Operations: A Comparison of Technologies. Fourteenth International Conference on Solid Waste Technology and Management, 1998.

Gould, M. Composting Technology from MSW. Proceedings of the 97 International Symposium on Systems and Technologies for Recycling of Wastes, Seoul, Korea. October 21, 1997.

Gould, M., E. Epstein, and N.T. Wu. Composting of Wastewater Biosolids to Reduce Total Petroleum Hydrocarbons. Presented at the Fourth International In Situ and On Site Bioremediation Symposium, New Orleans, Louisiana. April 29, 1997.

Gould, M. Pre Processing Technologies to Prepare Solid Waste for Composting. Proceedings of the 17th Biennial Waste Processing Conference, American Society of Mechanical Engineers, Atlantic City, New Jersey. April 1996.

Gould, M., and C.M. Alix. Impact of Amendment Type on Odor Generation at the Hartford MDC In Vessel Composting Facility. Presented to the New England Water Environment Federation, Westford, Massachusetts. November 1995.

Gould, M. Planning and Development of an Integrated Composting and Recycling Facility: East Hampton, New York. Presented at the New York State Legislative Commission Summit on Solid Waste Management, New York, New York. February 22, 1995.

Gould, M. A Short Course on Composting. Presented to the Korea Advanced Institute of Science and Technology, Taejon, Republic of Korea. April 22, 1994.

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Gould, M., and N.T. Wu. Factors Affecting Gaseous Emissions from Solid Waste Composting, Tipping, and Landfilling. Presented at Air and Waste Management Association, Denver, Colorado. June 14 18, 1993.

Gould, M., T.O. Williams, and G. Croteau. Dewatering and Composting of Septage: A Comparison of Three Facilities. Presented at AWWA/WPCF Joint Residuals Management Conference, Research Triangle Park, North Carolina. August 13, 1991.

Geribo, S.H., and M. Gould. Analysis and Mitigation of Odor Emissions at a Totally Enclosed Sludge Composting Plant. New York State Legislative Conference, New York. February 1990.

Gould, M. Recoverable Energy from Compost Exhaust Gases. Presented at the National Conference on Composting of Municipal and Industrial Sludge, Washington, D.C. May 24 26, 1982.

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**Dick Nicolai** - Assistant Professor/Extension Specialist

### **Education**

- 2002, Ph.D., Biosystems Systems and Agricultural Engineering  
University of Minnesota, St. Paul
- 1970, M.S., Agricultural Engineering  
University of Minnesota, St. Paul
- 1965, B.S., Agricultural Engineering  
University of Minnesota, St. Paul

### **Research**

- Biofiltration of livestock gas and odor emissions.
- Odor measurement.
- Horsepower requirements for grain augers.

### **Extension Program Areas**

- Agricultural Safety
- Power Machinery
- Biomass Collection and Transportation
- Odor Measurement & Control Technologies
- Indoor/Outdoor Air Quality

### **Academic Teaching**

- **ABE 372** Microcomputers in Agricultural Engineering

## Professional Organizations

- American Society of Agricultural Engineers
- Minnkota-Agribuilders & Association
- National Institute for Farm Safety

## Professional Registration

- Agricultural Engineer, State of Minnesota, #12117, 1976

## Awards and Honors

- Environmental Stewardship for 2003 award from National Pork Board

Enviromental Steward 2003 from Minnesota Pork Producers Association

## Publications

- Nicolai, R.E., K.A. Janni. 2001. Biofilter Media Mixture Ratio of Wood Chips and Compost Treating Swine Odors. *Water Science & Technology* 44 (9) 261-267.
- Clanton, C. J., D. R. Schmidt, R. E. Nicolai, P. R. Goodrich, L. D. Jacobson, K. A. Janni, S. Weisberg, and J. A. Buckel. 1999. Dynamic olfactometry variability in determining odor dilutions-to-threshold. *Transactions of the ASAE* 42(4):1103-1112.
- Clanton, C.J., D.r. Schmidt, L.D. Jacobson, R.E. Nicolai, P.R. Goodrich, and K.A. Janni. 1999. Swine manure storage covers for odor control. *Applied Engineering in Aagriculture* 15(5) :567-572.
- Clanton, C. J., R. E. Nicolai, and V. J. Larson. 2000. Dynamic olfactometer airflow variation in determining odor dilutions-to-threshold. *Transactions of the ASAE*. In press.
- Clanton, C.J., D.r. Schmidt, R.E. Nicolai, L.D. Jacobson, P.R. Goodrich, and K.A. Janni, J.R. Bicudo. 2001. Geotextile Fabric-Straw Manure Storage Covers for Odor, Hydrogen Sulfide, and Ammonia Control. *Applied Engineering in Aagriculture* 17(6) :849-858.
- Spiehs, M.J., M.H. Whitney, G.C. Shurson, R.E. Nicolai, and J.A. Renteria-Flores. 2001. Odor and gas characteristics of swine manure and nutrient balance of grow-finish pigs fed diets with and without distiller's dried grains with solubles. *J. Anim. Sci.* In press.
- Zhu, J., L.D. Jacobson, D.R. Schmidt, R.E. Nicolai. 2000 Evaluation of INPUFF-2 Model for Predicting Downwind Odors from Animal Production Facilities. *Applied Engineering in Agriculture* 16(2):159-164.
- Nicolai, R. E., S.J. Hoff. 2003. Ventilation Requirements to Prevent Pit Air Up-Drafting in a Swine Finishing Barn. In *Proc. of the 2nd International Conference on Swine Housing*. Durham, NC. Oct 12-15.

- Nicolai, R. E., C. J. Clanton, K.A. Janni. 2002. Ammonia Removal and Nitrogen Accumulation in Biofilter Media. . In Proceedings of USC - TRG Conference on Biofiltration, 119-129. Newport Beach, California. October 31 – November 1
- Nicolai, R.E., K.A. Janni. 2001. Determining Pressure Drop through Copmpost-Woodchip Biofilter Media. ASAE Paper No 014080. St. Joseph, MI: ASAE
- Nicolai, R.E., K.A. Janni. 2001. Biofilter Media Mixture Ratio of Wood Chips and Compost Treating Swine Odors. In Proc. of the 1st International Conference on Odour and VOCs: Measurement, Regulation and Control Techniques. Pg 505-512. Sydney, Australia. Mar. 25-28.
- Nicolai, R. E., K.A. Janni. 2000. Designing Biofilters for Livestock Facilities. In Proc. of the 2nd International Conference, Air Pollution from Agricultural Operations. Pg 376-383. Des Moines, IA. . Sept. 9-11
- Nicolai, R.E., C.J. Clanton, and H. Guo. 2000. Modeling the relationship between detection threshold and intensity of swine odors. In Proc. of the 2nd International Conference, Air Pollution from Agricultural Operations. Pg 296-304. Des Moines, IA. Sept. 9-11.
- Nicolai, R.E. 1999. Biofiltration for Odor Reduction. In Proc. Manure Management '99, 268-278. Saskatoon, Saskatchewan, Canada, June 22-25.
- Nicolai, R.E., K.A. Janni. 1999. Effect of Biofilter Retention time on Emissions from Dairy, Swine, and Poultry Buildings. ASAE Paper No. 994149. St. Joseph, MI: ASAE
- Nicolai, R.E., G.C. Shurson, M.J. Spiehs, M.H. Whitney. 1999. Deep Pit Simulator Protocol for Individual Metabolism Crates During diet Studies. ASAE Paper No. 994135. St. Joseph, MI: ASAE
- Nicolai, R. E. 1998. Biofilter Design Information. BAEU-18, Biosystems and Agricultural Engineering Department, University of Minnesota. St. Paul, MN.
- Nicolai, R. E., K.A. Janni. 1998. Biofiltration - Adaptation to Livestock Facilities. In Proceedings of USC - TRG Conference on Biofiltration, 99-106. Los Angeles, California. October 22-23.
- Nicolai, R. E., K.A. Janni. 1998. Biofiltration - Technology for Odor Reduction from Swine Buildings. In Proceedings of the Animal Production Systems and the environment, 327-332. Des Moines, IA. July 19-22.
- Nicolai, R. E., K.A. Janni. 1998. Comparison of Biofilter Retention Time. Presented August 1998 at the ASAE Annual International Meeting, Paper No. 974040. ASAE, 2950 Niles Road, St. Joseph, MI: ASAE
- Clanton, C. J., D. R. Schmidt, L. D. Jacobson, R. E. Nicolai, P. R. Goodrich, and K. A. Janni. 1999. Swine manure storage covers for odor control. Applied Engineering in Agriculture 15(5):567-572.
- Clanton, C.J., r.E. Nicolai, and D.R. Schmidt. 1999. Chemical additions to swine manure to reduce hydrogen sulfide losses: a laboratory study. ASAE paper No. 994007. St. Joseph, MI.:ASAE.
- Guo, H., L.D. Jacobson, D.R. Schmidt, and R.E. Nicolai. 2000. Correlation of Odor Threshold and H<sub>2</sub>S and NH<sub>3</sub> Concentrations for Animal Feedlots. ASAE Paper No. 004043. St. Joseph, MI: ASAE.

- Janni, K.A., and R.E. Nicoali. 2000 Designing biofilters for livestock facilities. In Proc. of USC-TRG Conference on Biofiltration 11-20. Los Angeles, CA. Oct 19-20.
- Jacobson, L.D., H. Guo, D.R. Schmidt, R.E. Nicolai, J. Zhu, and K.A. Janni. 2000. Development of an Odor Rating System to Estimate Setback Distances from Animal Feedlots: Odor From Feedlots Setback Estimation tool (OFFSET). ASAE Paper No. 004044. St. Joseph, MI: ASAE
- Jacobson, L.D., H. Guo, D.R. Schmidt, R. E. Nicolai, K.A. Janni, and J. Zhu. 2000. Odor Ratings Systems: Odor from Feedlots Setback Estimation Tool (OFFSET). In Food Animal Production Systems Issues and Challenges, Proc. of 2000 NCR Extension Specialist Triennial Workshop (MWPS-TRI 1) 91-102. Lansing, MI, May 10-12.
- Jacobson, L.D., D.Paszek, D.R. Schmidt, R.E. Nicolai, B. Hetchler, and J.Zhu. 1999. Odor and Gas Emissions from Animal Manure Storage Units and Buildings. ASAE Paper No. 994004. St. Joseph, MI :ASAE
- Jacobson, L.D., D.R. Schmidt, R.E. Nicolai, and C.J. Clanton. 1999. Evaluating the Use of Straw and Other Floating Materials to Control Odor and Gases from Pig Manure Storage Units. ASAE Paper No. 994134. St. Joseph, MI: ASAE.
- Jacobson, L.D., C.J. Clanton, D.R. Schmidt, C. Radman, R.E. Nicolai, K.A. Janni. 1997. Comparison of Hydrogen Sulfide and Odor Emissions from Animal Manure Storages. In Proceedings of the International Symposium on Ammonia and Odour Control from Animal Production Facilities. October 6-10, Vinkeloord, The Netherlands.
- Shurson, J., M. Whitney, and R. E. Nicolai. 1998. Dietary manipulations to reduce hydrogen sulfide emissions in the nursery. In Proceedings of the 54th Minnesota Nutrition Conference. Bloomington, MN.
- Zhu, J., L.D. Jacobson, D.L. Schmidt, and R.E. Nicolai. 1999. Daily Variations in Odor and Gas Emissions from Animal Facilities. ASAE Paper No. 994146. St. Joseph, MI: ASAE.
- Zhu, J., L.D. Jacobson, D. Schmidt, and R. Nicolai. 1998. Modeling the Agricultural Odor Dispersion Using Atmospheric Dispersion Models. Presented July 1998 at the ASAE Annual International Meeting, Paper No. 984046. ASAE, 2950 Niles Road, St. Joseph, MI: ASAE



SE-301 (Environmental physiology); SE- 302 (Controlled environment for animal structures)

SE-403 (Dairy housing), Dairy Housing V Program Chair  
ASEE, American Society for Engineering Education  
NACTA, North American College Teachers in Agriculture  
MWPS, Midwest Plan Service, representative and member Executive Committee

**Professional Awards**

ASAE Educational Aids Blue Ribbons (3), 1995 and 2001

**Recent Publications**

- Stowell, R. R., C. A. Gooch, and W. G. Bickert. 2003. Design Parameters for Hot-Weather Ventilation of Dairy Housing: A Critical Review. In: *Proceedings of Fifth International Dairy Housing Conference*. ASAE, St. Joseph, MI.
- Gooch, C. A., and R. R. Stowell. 2003. Tunnel Ventilation for Freestall Facilities – Design, Environmental Conditions, Cow Behavior, and Economics. In: *Proceedings of Fifth International Dairy Housing Conference*. ASAE, St. Joseph, MI.
- Stowell, R.R., and C. Henry. 2003. The economic potential of methane recovery: Projected impacts of various public-policy scenarios. 2003 Nebraska Swine Report, p. 52-55. Cooperative Extension Service, University of Nebraska, Lincoln, NE.
- Stowell, R.R. 2002. Applicability of High-rise™ hog housing for finishing operations. 2002 Nebraska Swine Report. Cooperative Extension Service, University of Nebraska, Lincoln, NE.
- Stowell, R. R., H. Keener, P. R. Goodrich, and S. Foster. 2002. Gas and odor emissions from High-rise™ and deep-pit swine finishing facilities, ASAE paper #02-4122. ASAE, St. Joseph, MI.
- Keener, H. M., D. L. Elwell, T. A. Menke, and R. R. Stowell. 2001. Design and performance of a High-rise™ hog facility manure drying bed. *Applied Engineering in Agriculture* 17(5): 703-709.
- Stowell, R.R., H. Keener, D. Elwell, T. Menke, and S. Foster. 2001. High-rise™ hog facility. In: *Livestock Environment VI, Proceedings of the Sixth International Symposium*, p.273-282. ASAE, St. Joseph, MI.
- Stowell, R.R., C.A. Gooch, and S. Inglis. 2001. Performance of tunnel ventilation for freestall dairy facilities as compared to natural ventilation with supplemental cooling fans. In: *Livestock Environment VI, Proceedings of the Sixth International Symposium*, p.29-40. ASAE, St. Joseph, MI.
- Stowell, R.R., R. Bucklin, and R.W. Bottcher (Editors). 2001. *Livestock Environment VI, Proceedings of the Sixth International Symposium*. ASAE, St. Joseph, MI.
- Eastridge, M.L., and S. Steel (Ed.). [R. Stowell, Technical contributor]. 2001. Questions pertaining to large dairy enterprises in Ohio: Environment. Extension Fact Sheet AS-9-01. The Ohio State University Extension, Columbus, Ohio.
- Stowell, R. R., H. Keener, D. Elwell, T. Menke, and S. Foster. 2000. High-Rise™ Hog Facility. In: *Proceedings of the International Swine Housing Conference*. ASAE, St. Joseph, MI 49085.
- Stowell, R.R., H. Keener, D. Elwell, T. Menke, and S. Inglis. 2000. Indoor air quality and pig performance within a High-rise™ hog facility. In: *Swine Housing*,

Bion Technologies, Inc.

*Proceedings of the First International Conference*, p.741-748. ASAE, St. Joseph, MI.

Stowell, R. 2001. Pit additives. Manure Matters website, Vol. 7, No. 8  
(<http://www.ianr.unl.edu/manure/>)

Kacira, M., T. H. Short, and R. R. Stowell. 1998. A CFD evaluation of naturally ventilated, multi-span, sawtooth greenhouses. *Transactions of the ASAE* 41(3):833-836.

Stowell, R. R., and A. McKenney. 1998. Solids content analysis of dairy farm flushwater in storage and at critical points of the waste stream. Presented at: ASAE Annual International Meeting, Paper #984120. ASAE, St. Joseph, MI 49085.

Stowell, R. R., and W. G. Bickert. 1995. Storing & handling of sand-laden dairy manure, Extension bulletin, E-2561, Michigan State University, East Lansing, MI 48824.

\*\*\*\*\*

Experience and Qualifications

OF

**KEVIN S. YOUNG, P.E.**

PRESENT POSITION:

|                                                                    |   |                                                                         |
|--------------------------------------------------------------------|---|-------------------------------------------------------------------------|
| Senior Vice-President<br>and Manager, Jackson,<br>Tennessee Office | – | J. R. Wauford & Company<br>Consulting Engineers, Inc.<br>1983 - Present |
|--------------------------------------------------------------------|---|-------------------------------------------------------------------------|

PREVIOUS POSITIONS:

|                                  |   |                                                                     |
|----------------------------------|---|---------------------------------------------------------------------|
| Environmental Project<br>Manager | – | J. R. Wauford & Company,<br>Consulting Engineers, Inc.<br>1980-1983 |
|----------------------------------|---|---------------------------------------------------------------------|

|                    |   |                                    |
|--------------------|---|------------------------------------|
| Research Assistant | – | Syracuse University<br>1978 - 1980 |
|--------------------|---|------------------------------------|

|            |   |                                                   |
|------------|---|---------------------------------------------------|
| Engineer I | – | Tennessee Department of<br>Transportation<br>1978 |
|------------|---|---------------------------------------------------|

|                                              |   |                                                          |
|----------------------------------------------|---|----------------------------------------------------------|
| Engineering Cooperative<br>Education Student | – | Tennessee Department of<br>Transportation<br>1974 - 1975 |
|----------------------------------------------|---|----------------------------------------------------------|

EDUCATION:

|                                            |   |                                                   |
|--------------------------------------------|---|---------------------------------------------------|
| Master of Science,<br>Sanitary Engineering | – | Syracuse University<br>Syracuse, New York<br>1980 |
|--------------------------------------------|---|---------------------------------------------------|

Bion Technologies, Inc.

Bachelor of Science, – Tennessee Technological  
Civil Engineering University  
Cookeville, Tennessee  
1978

REGISTRATIONS:

Professional Engineer – Tennessee  
Professional Engineer – Alabama  
Professional Engineer – Mississippi  
Professional Engineer – Ohio  
Professional Engineer – Michigan  
Professional Engineer – Maine  
Professional Engineer – Kentucky  
Professional Engineer – Arkansas

**SPECIALTY CERTIFICATION:**

Diplomat – American Academy of Environmental Engineers with specialty in  
water supply/wastewater

MEMBERSHIPS:

American Water Works Association

Water Environment Federation

Tennessee Water and Wastewater Association (Outstanding Contribution as an Associate Member, 1992)

American Society of Civil Engineers (Environmental Engineering Research Council, 1991-1994)

Tennessee Society of Professional Engineers (West Section President, 1990; State Director, 1991-1994; West Section Outstanding Engineer of the Year, 1995)

Tennessee Water Quality Manager's Association (West Section Chairman, 1991)

National Society of Professional Engineers

PUBLICATIONS AND PRESENTATIONS:

- "Seasonal Nutrient Limitation in Cazenovia Lake, N.Y.", presented at 42nd Annual Meeting of American Society of Limnology and Oceanography, Inc.
- "New Observations with Fixed Film Anaerobic Reactors", presented at DOE-EPA Seminar.
- "Water Quality Analysis of Limestone Creek", presented at Syracuse University Civil Engineering Seminar Series.
- "Pretreatment of Tannery Beamhouse Wastewater Using an Anaerobic Filter: Preliminary Results", presented at 12th Mid-Atlantic Industrial Waste Conference.

- "Treatment of Combined Municipal/Packing House Wastewater Using an Innovative Continuously Fed - Intermittently Operated Activated Sludge Process: A Design rationale", presented at 41st Annual Purdue Industrial Waste Conference.
- "Performance of World's Largest Cyclical Activated Sludge Process Treating combined Municipal/Packing House Wastewater", presented at 42nd Annual Purdue Industrial Waste Conference.
- "Techniques for Treating Prewash Denim Laundry Wastewater", presented at 44th Annual Purdue Industrial Waste Conference.
- "Performance Analysis of a Continuously Fed, Intermittently Decanted Activated Sludge Plant Receiving a High Ammonia Packing House Waste", presented at the 44th Annual Purdue Industrial Waste Conference. (Co-Author)
- "Methods for Treating Prewashed Denim Laundry Wastewater, presented at the 44th Annual Kentucky-Tennessee Section Meeting, Water Pollution Control Association.
- "Treatment of Prewash Denim Laundry Wastewater-Case Histories", presented at the 46th Annual Purdue Industrial Waste Conference.
- "Implementation of Sequencing Batch Reactor Technologies in the United States", presented at the 1991 annual conference of the Water Pollution Control Federation. (Co-Author)

#### ILLUSTRATIVE RELATED PROJECT EXPERIENCE:

1. Cleveland Utilities Cyclical Activated Sludge Type Municipal Wastewater Treatment Plant Expansion

Principal Engineer/Project Manager/Designer during planning, design and construction administration. Project involved expansion of a 9.2 MGD cyclical activated sludge type wastewater treatment plant (ICEAS™ variant) to 29.8 MGD. The Cleveland Utilities Wastewater Treatment Plant will be the largest cyclical activated sludge type wastewater treatment plant in the world when completed. Interesting features include team approach to design and equipment selection involving Cleveland Utilities operators, maintenance personnel and managers in the design process along with J. R. Wauford & Company engineers; delivery of the constructed project using the construction management method; complete monitoring and control of the pumping and treatment systems using a PLC based SCADA system; and use of energy efficient membrane type diffuser fine bubble aeration system following a rigorous pilot scale operational and economic analysis.

2. Humboldt Utilities Trickling Filter/Activated Sludge Type Municipal Wastewater Treatment Plant Expansion

Principal Engineer during planning, design and construction administration. Project involved expansion of a 2.0 MGD trickling filter/activated sludge type wastewater treatment plant to 2.6 MGD. Interesting features include financing using a State Revolving Fund loan administered by the Tennessee Department of Environment and Conservation, Division of Construction Grants and Loans; automatic control and monitoring of the influent pumping system using a PLC based control system; construction within the 100 year flood plain of the Middle Fork of the Forked Deer River; and a 28 million gallon inflow/infiltration holding lagoon.

3. Henry I. Siegel Company, Inc. Aerated Lagoon Type Industrial Wastewater Treatment Plant

Principal Engineer during planning, design and construction administration. Project involved construction of a new three-cell 1.44 MGD aerated lagoon type wastewater treatment plant for treating prewashed denim laundry process wastewater at the Henry I. Siegel Company, Inc. facility in Hickman, Kentucky. Interesting features include a nine-month project delivery schedule from first meeting to first flow including all permitting; and delivery of the constructed project using the construction management method.

4. Union City, Tennessee Cyclical Activated Sludge Type Municipal Wastewater Treatment Plant

Principal Engineer/Project Manager/Designer during planning, design and construction administration. Project involved construction of a new 6.0 MGD cyclical activated sludge type (ICEAS™ variant) wastewater treatment plant. Interesting features include complete monitoring and control of treatment system using a PLC; project was largest cyclical activated sludge type wastewater treatment plant in the world when constructed; and project achieved National Finalist status in American Consulting Engineers Council Engineering Excellence Award competition.

5. Greenbrier, Tennessee Expansion of Trickling Filter Type Wastewater Treatment Plant Using Cyclical Activated Sludge Technology

Principal Engineer/Project Manager/Designer during planning, design and construction administration. Project involved converting a 0.33 MGD trickling filter type wastewater treatment plant to a 0.49 MGD cyclical activated sludge (SBR variant) type wastewater treatment plant. Interesting features include capability to meet 10 mg/l CBOD<sub>5</sub> and 2 mg/l ammonia nitrogen NPDES Permit effluent limitations.

6. South Fulton, Tennessee Expansion of Trickling Filter Type Wastewater Treatment Plant

Principal Engineer/Project Manager/Designer during planning, design and construction administration. Project involved expansion of a 0.35 MGD trickling filter type wastewater treatment plant to a 0.49 MGD. Interesting features include pumping the effluent approximately eight miles to the North Fork of the Obion River; and a 12 million gallon inflow/infiltration holding lagoon.

7. Smithville, Tennessee Expansion of Conventional Activated Sludge Type Wastewater Treatment Plant Using Cyclical Activated Sludge Technology

Conceptual Designer during planning and preliminary design. Project involved converting a 1.0 MGD conventional step-feed type activated sludge type wastewater treatment plant to a 2.16 MGD cyclical activated sludge (SBR variant) type wastewater treatment plant. Interesting features include capability to meet 10 mg/l CBOD<sub>5</sub> and 3 mg/l ammonia nitrogen NPDES Permit effluent limitations.

## Resume of Review Team Advisor:

### RAYMOND CHARLES LOEHR

#### OFFICE

19360 Magnolia Grove Square #405  
Lansdowne, VA 20176

email: r.loehr@mail.utexas.edu  
Tel: 703-858-1175

#### education

|       |                                                    |      |
|-------|----------------------------------------------------|------|
| Ph.D. | University of Wisconsin, Sanitary Engineering      | 1961 |
| M.S.  | Case Institute of Technology, Sanitary Engineering | 1956 |
| B.S.  | Case Institute of Technology, Civil Engineering    | 1953 |

#### positions

|              |                                                                                                                                          |
|--------------|------------------------------------------------------------------------------------------------------------------------------------------|
| 1985-Present | Hussein M. Alharthy Centennial Chair and Professor of Civil Engineering, The University of Texas at Austin; Emeritus---2003              |
| 1990-1999    | Head, Environmental Solutions Program, The University of Texas                                                                           |
| 1981-1985    | Liberty Hyde Bailey Professor of Engineering, Cornell University                                                                         |
| 1968-1985    | Professor, Cornell University -- joint appointment: Department of Agricultural Engineering and Department of Civil Engineering           |
| 1981-1982    | Senior Program Manager, Hazardous Wastes, Environmental Research and Technology, Inc., Concord, Massachusetts                            |
| 1971-1980    | Director, Environmental Studies Program, College of Agriculture and Life Sciences, Cornell University                                    |
| 1975-1978    | Associate Director, Office of Research and Agricultural Experiment Station, College of Agriculture and Life Sciences, Cornell University |
| 1974-1975    | Program Advisor, Effluent Guidelines Division, United States Environmental Protection Agency, Washington, DC                             |

#### PERSONAL DATA

Birthplace: Cleveland, Ohio  
Married

Bion Technologies, Inc.

1961-1968 Associate Professor, and Professor, University of Kansas

1954-1959 Instructor and Assistant Professor, Case Institute of Technology

## professional engineer

Texas, Ohio and Kansas

## honors and awards

Member, National Academy of Engineering -- 1983-Present

Best Paper Award, Environmental and Water Resources Institute, American Society of Civil Engineers, 2001

Simon W. Freese Environmental Engineering Award -- Amer. Soc. Civil Engrs - 1999

Environmental Engineering Centennial Lecture -- Clarkson University - 1998

Thomas R. Camp Medal - Water Environment Federation - 1997

Gordon M. Fair Award – American Academy of Environmental Engineers - 1996

Rachel Carson Award, Society of Environmental Toxicology and Chemistry -- 1995

T.H. Feng Distinguished Lecturer in Environmental Engineering, University of Massachusetts, Amherst, Mass. -- 1994

Thomas R. Camp Lecture Award, Boston Society of Civil Engineers, American Society of Civil Engineers -- 1992

Joe J. King Professional Achievement Award, The University of Texas at Austin -- 1992

Billy and Claude Hocott Distinguished Centennial Engineering Research Award, The University of Texas -- 1991

Vita- Raymond C. Loehr

2

Engineering Foundation Faculty Excellence Award, The University of Texas at Austin -- 1987

Senior Fulbright-Hays Scholar, New Zealand -- 1979

Rudolph Hering Medal, American Society of Civil Engineers -- 1969

Water Conservationist of the Year, Kansas Wildlife Federation -- 1967

National Science Foundation Faculty Fellowship -- 1960-1961

Public Health Service Research Fellowship -- 1959-1960

## PROFESSIONAL ACTIVITIES

### A. ENVIRONMENTAL PROTECTION AGENCY

#### a) SCIENCE ADVISORY BOARD COMMITTEES

- Executive Committee, Chairman, 1988 to 1993; Member -- 1978-1980; 1983-1994; 2000-2003
- Research Strategies Advisory Committee: Chairman, 2000-2003
- Environmental Engineering Committee, Chairman, 1983-1988; Member -- 1982-1988
- Hazard Ranking System Review Committee, Chairman – 1986-1987
- Groundwater Research Review Committee – 1983-1985
- Technology Assessment and Pollution Control Advisory Committee: Chairman – 1978-1980

#### b) SPECIAL RESPONSIBILITIES

- Chair, NACEPT Superfund Evaluation Subcommittee, 2002-2004
- Member, Board of Scientific Counselors, Office of Research and Development, 1996-2000
- Chair, Environmental Futures Committee, and author, editor, "Beyond the Horizon: Using Foresight to Protect the Environmental Future," EPA, January, 1995
- Chair, Expert Panel and author, editor, "Safeguarding the Future: Credible Science, Credible Decisions," EPA/600/9-91/050, March 1992.
- Author/co-editor, "Reducing Risk: Setting Priorities and Strategies for Environmental Protection," SAB-EC-90-021, September 1990

Bion Technologies, Inc.

**B. NATIONAL ACADEMY OF SCIENCE, NATIONAL ACADEMY OF ENGINEERING, NATIONAL RESEARCH COUNCIL COMMITTEES**

- Vice Chair, Committee to Review EPA's Research Grants Program --2002-2003
- Vice Chair, Committee on Remediation of PCB – Contaminated Sediments – 1999-2001
- Committee on Research and Peer Review in EPA -- 1994-2000
- Board on Environmental Science and Toxicology -- 1995-1998
- Chair, Committee on Research Opportunities and Priorities in EPA – 1995-1997
- Committee on Sustainable Water Supplies in the Middle East – 1996-1998
- Board on Science and Technology for International Development – 1988-1990
- Environmental Studies Board – 1983-1986
- Institutional Considerations in Reducing the Generation of Hazardous Industrial Waste, Chairman --1983-1984
- Disposal of Industrial Hazardous Wastes – 1981-1982

**C. AMERICAN ACADEMY OF ENVIRONMENTAL ENGINEERS**

- Vice-President – 2001-2002; President – 2002-2003; Past President—2003-2004

**D. DEPARTMENT OF DEFENSE**

- Scientific Advisory Board, Strategic Environmental Research and Development Program -- 1995-2000

**E. DEPARTMENT OF ENERGY**

- Environmental Science and Technology Advisory Committee, Los Alamos Natl. Laboratory -- 2002-2004
- Environmental Management Advisory Board, Office of Environmental Management – 2002-2003
- Risk Reduction and Environ. Stewardship Division Review Committee, Los Alamos Natl. Lab. – 2003-2005

Consultant to industries, engineering, and law firms on matters dealing with industrial and hazardous waste management, particularly in the petroleum, petrochemical, food processing, and pulp and paper industries; invited testimony to Congressional Committees and Sub-Committees.

**PUBLICATIONS**

**Over 300 technical publications and reports relating to municipal, industrial and hazardous waste management and 14 books authored or edited.**

**SUMMARY OF INTEREST AND EXPERTISE**

**Professor Loehr's teaching and research interests emphasize hazardous and industrial waste management, and land as a waste management alternative. Current research activities related to development and use of hazardous waste management technologies for contaminated liquids, slurries, soils, and sediments. Specific research involves the transformations, transport and fate of constituents when wastes are treated by hazardous and industrial waste management processes.**

## Resumes of Project Review Authors:

### James Wilbert Morris, Ph.D., P.E.

#### Education:

|                             |                                                                                                                                                                                                                                                               |             |
|-----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|
| <b>Bachelor of Science</b>  | <b>Civil Engineering</b> (Urban & Regional Planning)<br><b>1974</b><br>Tennessee Technological University<br>( <i>Extensive Coursework BSBA - Finance</i> )                                                                                                   |             |
| Coursework<br>M. E. Program | Environmental and Water Resources Engineering<br>Vanderbilt University (part time)                                                                                                                                                                            | 1975        |
| <b>Master of Science</b>    | <b>Civil Engineering</b> (Environmental)<br>Tennessee Technological University                                                                                                                                                                                | <b>1978</b> |
| <b>Doctor of Philosophy</b> | <b>Agricultural Engineering</b><br><b>1983</b><br><b>Environmental Quality Engineering</b><br>Cornell University (Agricultural Engineering)<br><u>Thesis title:</u> Conversion of Organic Particulates in an<br>Anaerobic Expanded Bed (W. J. Jewell advisor) |             |

#### Professional Profile

James Morris offers the environmental capabilities, knowledge and understanding gained through nearly 30 years of engineering experience. As a Chief Technology Officer and environmental engineering consultant he is responsible for study, technical evaluations, design, and operational guidance of processes to treat, handle, convey, and discharge liquid and solid wastestreams using aerobic and/or anaerobic biological and physical-chemical technologies. Dr. Morris has the in-depth training as an engineer / scientist who has helped to foster new technologies and improved operating techniques through applied research. James is able to address the many sides of environmental issues and understand varied viewpoints as someone who has dealt directly with and taught a wide array of environmental processes and impacts; as consultant, researcher and professor. He has the hands-on, down to earth, can-do approach of an engineering practitioner. James is a registered Professional Engineer in Vermont and Maine.

#### Honorary and Professional Affiliations

##### Honors

- Sigma XI - Member  
The Scientific Research Society of North America
- Tau Beta Pi - Member  
The Engineering Honor Society
- Chi Epsilon - Charter Member, Tennessee Technological University Chapter  
The Civil Engineering Honor Society



**PRIVATE CONSULTANT**

**JAMES W. MORRIS, PH.D., P.E.  
UNDERHILL, VERMONT**

**1976 –  
1989**

Maintained an active consulting practice throughout the period when graduate education, research, and engineering professor were the principle work focus. This enabled advanced study and teaching within the context of current practice and professional working contact with practitioners. Performed a broad scope of environmental engineering work with other consultants, for municipalities, and governmental agencies. This grew from a strong belief that those involved in teaching engineering, an applied science, should be actively applying it.

**Among the many roles played as a chief technology officer and consultant are:**

- |                                           |                                             |
|-------------------------------------------|---------------------------------------------|
| ♦Project formulation                      | ♦Technology transfer                        |
| ♦Project/client management                | ♦Training - peers, public, plant operators  |
| ♦Process engineering                      | ♦Waste minimization                         |
| ♦Facility troubleshooting/debottlenecking | ♦Experimental design                        |
| ♦Technical expert                         | ♦Statistical analysis                       |
| ♦Presentation/proposal manage/produce     | ♦Regulatory assistance, negotiations        |
| ♦Client development                       | ♦Expert witness, litigation assistance      |
| ♦Market evaluation/development            | ♦Career development, mentoring,<br>advising |
| ♦Recruitment                              | ♦Mediator                                   |

**ASSISTANT PROFESSOR**

**UNIVERSITY OF VERMONT**

**1983-  
1990**

Teaching responsibilities:

Required undergraduate courses in Water and Wastewater Engineering, and Surveying. Core graduate environmental engineering courses covering Biological, Chemical and Physical Unit Operations and processes. Graduate and undergraduate elective courses addressing land treatment of wastes and agricultural waste management.

Courses Taught:

- CE10 Surveying (4 sem. hr.)
- CE151 Water and Wastewater Engineering (3 sem. hr.)
- CE255 Water Renovation Processes - Physical/Chemical (3 sem. hr.)
- CE256 Water Renovation Processes - Biological (3 sem. hr.)
- CE295 Agricultural Waste Management (3 sem. hr.)
- CE242 Land Treatment of Wastes (3 sem. hr.)

Research Activities:

- Response of secondary sludge mass flux settling rates to seasonal and episodic changes in wastestream characteristics.
- Use of attached algal communities for tertiary wastewater nutrient removal.
- Impact of municipal wastewater sludge application to forest land.
- Development of high rate anaerobic wastewater treatment processes.
- Investigate the mechanisms controlling the uptake of solid organic substrates by mixed microbial communities in an anaerobic environment.

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**ASSISTANT PROFESSOR**                      **UNIVERSITY OF MANITOBA**                      **1982-1983**

Teaching responsibilities:

Instructor for graduate courses on the Theory of Wastewater Treatment, and Land Application of Wastes; and for undergraduate offerings in Environmental Engineering Design, Hydrology and Elements of Surveying Field Work. Shared responsibility for undergraduate instruction of Environmental Engineering, Water and Wastewater Laboratory, Graduation Projects, Technology and Society, and Technical Writing.

Courses Taught:

- CE 793 Theory of Wastewater Treatment (4 sem. hr.)
- CE 796 Land Application of Wastes (4 sem. hr.)
- CE 485 Environmental Engineering II (4 sem. hr.)
- CE 331 Hydrology (4 sem. hr.)
- CE 225 Elements of Surveying Field Work (2 sem. hr.)

Shared responsibility for:

- CE 349 Environmental Engineering I - (4 sem. hr.)
- CE 473 Water and Wastewater Laboratory (4 sem. hr.)
- CE 482 Graduation Project - (8 sem. hr.)
- CE 264 & 265 Technology and Society - (4 sem. hr. each)
- FE 100 Technical Writing - (3 sem. hr.)

**RESEARCH ASSISTANT**                      **CORNELL UNIVERSITY**                      **1980-1982 & 1977-1979**

Coordinator of the Waste Management Laboratory, Department of Agricultural Engineering

**INSTRUCTOR**                                      **CORNELL UNIVERSITY**                      **1979-1980**

Full time faculty appointment to teach and develop extensive course support materials and resources for two graduate / undergraduate offerings.

- Agr. Eng. 677 - Treatment and Disposal of Agricultural Wastes (3 sem. hr.)
- Agr. Engr. 679 - Use of Land for Waste Treatment and Disposal (3 sem. hr.)

**GRADUATE RESEARCH ASST.**                      **TENNESSEE TECHNOLOGICAL UNIVERSITY**                      **1976-1977**

Research assistant - J. A. Gordon, Department of Civil Engineering  
Tenn. Tech. Univ., Cookeville, Tenn.

**ENGINEER**                                      **SOUTHERN LAND & ASSOC., INC.,**                      **1974-1976**  
**NASHVILLE, TENNESSEE**

Engineering responsibilities:

Layout and design work on a wide variety of engineering projects. Concentrating on geometric, drainage and site utilities design for construction of 16 new hospitals across



Development (USAID). The three-week effort working with the USAID Water Resources team in Tel Aviv, Israel produced the detailed statement of work and supporting documentation for the Water Resources, Aquifer Protection, and Urban Planning (WRAP-UP) Program Design. This program aims to support the Palestinian Water Authority to effectively manage, utilize and protect all of the limited water resources in the West Bank. Specific work items included work plan tasking and cost estimates for all studies, engineering services and capital improvements envisioned by the WRAP-UP program. This multi-year program anticipates \$97,000,000 in capital improvements and \$12,000,000 in technical studies and engineering services.

- James Morris provides technical support to AnAerobics, Inc. a wastewater treatment technology firm offering full service management of industrial and municipal wastes. The principle technology offered by AnAerobics is the Mobilized Film Technology (MFT), which may be used to fully treat a wide range of wastewaters. He provides extensive process and engineering guidance. The foundation for the anaerobic MFT grew out of Dr. Morris' doctoral research on high-rate anaerobic wastewater treatment processes.
- Dr. Morris has provided expert witness support services addressing anaerobic biological processes, anaerobic treatment, and the impact of anaerobic biological activity for a number of confidential clients.
- Technical leader and analyst for a pretreatment option evaluation project for FMC Corporation, Newark, Delaware. High rate anaerobic technology was selected for the treatment of a stream by-product sugars and small portions of microcrystalline cellulose. James Morris directed the extensive six month proof of concept pilot study. The fluidized bed and UASB technologies were tested side by side. The pilot results proved high treatment efficiency and the superiority of the UASB system. These findings were used to establish design criteria, system process design, facility layout, and facility cost.
- Dr. Morris was the project manager for extensive design-related studies to optimize an industrial wastewater treatment facility at a major chemical company with a projected cost of \$100,000,000. This has required treatment feasibility evaluations of wastestreams containing multiple constituents, the flow and mass load characterization of wastes from seven large operating production facilities on this single site, and the evaluation of alternatives for waste minimization, source control, wastestream separation and flow segregation. Continuing successful efforts have brought the projected cost of this project down to well below \$40,000,000.
- Process options and development of concept design for a sequencing batch reactor system serving Peaks Island in Portland, Maine. An ACEC National Engineering Excellence award winner.
- Dr. Morris assisted Biotherm International, Portland, Maine with an anaerobic process design to convert fish wastes to a valuable soil and plant growth enhancer. This

product also produces remarkably efficient biocidal and biostatic effects against an array of plant bacterial, fungal, and invertebrate attack, when compared to synthetic chemicals, while being totally of organic origins. James was the project manager and lead technical expert on pilot studies, process modifications, plant startup and operation, and serves as this company's ongoing production advisor for this one-of-a-kind, innovative anaerobic process located in Blacks Harbor, New Brunswick.

- Troubleshooting of an anaerobic industrial pretreatment system required multiple process modification and a complete restart of this high rate technology application. Through careful analysis and fundamental understanding of the anaerobic process, Dr. Morris incorporated critical changes to bring a balky UASB from near failure to greater than design loadings and smooth operation in less than three months.
- Process evaluation and design considerations for upgrade, or expansion of numerous projects.
  - Upgrade for aerated lagoon P removal - Hinesburg, Vermont
  - Upgrade of RBC system serving a Vermont ski area
  - Expansion and upgrade of industrial aerated lagoon treatment in Swanton, Vermont
  - Retrofit/upgrade to improve chlorine contact system for Burlington, Vermont
  - Upgrade of a controlled discharge system serving Jackman, Maine for P removal
  - Determined system capacity & operation or design alternatives to increase capacity for Kennebunkport, ME
  - Overall design and state-of-the-art UV disinfection review for a new aerated lagoon system for Warren, ME.
  - Three year project evaluating the operational solids handling capacity of ten Vermont POTW.
  - Upgrade and expansion of wastewater treatment facility in Georgia, Vermont.
- A new 400 million gallon per day activated sludge treatment facility with gravity and mechanical thickeners, anaerobic digestion, and belt filter presses was nearing completion in early 1997. The Cairo Water Organization, governmental water and wastewater utility for Cairo, Egypt, required an independent operability evaluation of this truly mammoth facility to assure that the system built could perform successfully. Dr. Morris lead the process and operating controls effort. Results were incorporated into design modifications and operating guidance for contract operations.
- Project Manager and technical oversight for a project to determine the potential advantages of replacing an existing coarse bubble aeration system with fine bubble technology for a major chemical manufacturer. The approach was to perform on-site tests using the wastewater as produced in 20 foot aeration columns with off-gas analysis for oxygen transfer efficiency, and determining operations fouling and plugging potential for this 40 MGD facility.
- Dr. Morris has studied and performed research covering a broad range of environmental topics:
  - Clarifier solids separation and thickening, design, and operation.

- Biological nutrient uptake in aerobic, anoxic and anaerobic processes.
  - High rate anaerobic wastewater treatment processes.
  - Land treatment of wastes.
  - Nutrient interactions within lake and stream systems.
  - UV disinfection of wastewater
  - Septic tank/soil absorption systems for commercial and domestic wastewater treatment.
- 
- James Morris has worked for over six years as an environmental consultant to the Burlington, Vermont Department of Public Works. During this period, the design of a \$52 million upgrade of their three wastewater treatment facilities (10 MGD total design flow) including the separation of storm and sanitary flows, and treatment of combined sewer overflows (CSOs) was addressed. Dr. Morris was responsible for the review and selection of treatment technologies. Specifically he addressed advanced and/or innovative processes and was called upon for consultant selection, design review, and project oversight. James also provided regulatory negotiation aid and was the mediation leader with several environmental citizens groups. He also proved a key factor in obtaining funding for this effort by developing compelling background materials and presentations, and participated in meetings which led to near full funding.
  - Dr. Morris performed site investigations and designed a site-wide wastewater and runoff monitoring system leading to the design of collection, segregation, treatment and pollution prevention alternatives for a major metals manufacturer. The removal of oil and grease, PCB control, and upgrading the industrial wastewater treatment capacity were objectives of this study.
  - Project manager and client manager for several efforts at the Eastman Gelatine, Peabody, Massachusetts (subsidiary of Eastman Kodak) photographic gelatin production facility. Wastewater characterization, pretreatment options, waste minimization, and long term waste management program planning projects were successfully completed.
  - The Coca-Cola bottling facility in Nashua, NH pretreats its wastewater using an Upflow Anaerobic Sludge Blanket unit followed by conventional extended aeration. Dr. Morris has assisted the operations team with fine tuning, optimizing, and operation procedures for long term stable operation. He has provided troubleshooting and emergency response assistance as well.
  - As project manager James Morris directed an effort at Stinson Canning Company, Belfast, Maine to decrease their discharge of BOD and grease to the local wastewater treatment facility. Stinson was anticipating a capital budget of between \$1 and \$1.5 million. By making modest process and operations modifications and carefully characterizing waste releases, the discharge to the city was reduced to zero and a smooth discharge permit renewal resulted. This work required negotiations with the

state and city. The total budget for this success: capital, staff hours and consulting charges; was less than \$60,000 dollars.

- As lead technical consultant and project manager James provided CPF, Inc. the local bottler for Pepsi, in Ayer, Massachusetts, with discharge compliance assistance. Key services provided included: substantial waste minimization, identification and pilot testing of cost effective pretreatment options, and regulatory negotiation assistance.
- The controlled discharge lagoon system treating the municipal wastewater from Jackman, Maine was performing well but was struggling to meet tightened stream discharge phosphorus requirements. Dr. Morris designed a simple, effective, alum feed system for phosphorus removal. To remove P from the large lagoon volume, a metering pump was temporarily attached to a big gun spray irrigation unit to broadcast an alum dose across the entire surface of this system. This approach resulted in compliance in less than thirty days from modifications.
- The Raytheon production facility in Sudbury, Massachusetts converted an extended aeration facility to a sequencing batch reactor configuration. The wastewater discharge fluctuated widely in mass and hydraulic loading posing real challenges for meeting the strict groundwater recharge effluent nitrogen limits. Dr. Morris worked with plant operators, operations personnel, and vendor technical staff to formulate standard operating procedures and process operating modifications resulting in long term compliance and smooth operation.
- Tightening of industrial pretreatment requirements and expanded production at Cozy Harbor Seafood were creating concerns for this Portland, Maine processing facility. James Morris directed several efforts resulting in substantial waste minimization, identification and pilot testing of cost effective pretreatment options, and regulatory negotiation assistance
- The General Chemical, Windsor, Ontario facility was facing prohibitive pretreatment costs to remove dissolved salts, predominantly sodium and calcium chlorides, from their sodium bicarbonate production facility's discharge to the Detroit River. Extensive process investigations were performed based on a mass balance approach. James Morris was the project manager for this effort which included whole effluent toxicity testing in parallel with reagent salinity controls. This work was performed at the Ontario Ministry of the Environment Laboratory in Toronto working as a team with agency toxicologists. Results indicated that toxicity was due to salinity alone. Dr. Morris presented these findings to the Minister of Environment and successfully negotiated a favorable, no environmental degradation, discharge permit for this facility.
- Among Dr. Morris's fields of specialization and experience are extensive work with a wide array of sludge treatment approaches including:
  - High rate anaerobic treatment processes
  - Mechanisms of solid uptake in anaerobic reactors

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- Land-based treatment of municipal sludges
- Forest system use for sludge treatment
- Conducted graduate level courses at Cornell University and the University of Vermont on the use of land for waste treatment
- Gave the first trial course using the USEPA two volume textbook on Land Treatment developed at Cornell in order to improve the initial draft.

As a private consultant:

- Retained as specialist on wastewater system design, design of land treatment systems, agricultural waste management, and solids management by local consulting engineering firms.
  - Served the Vermont Whey Pollution Abatement Authority as special consultant for technology assessment and agricultural waste treatment practices from 1985 to 1990.
  - Retained as internal consultant for wastewater treatment engineering by the Department of Public Works, Burlington, VT
  - Program development and assisted with pilot facility analysis of slow rate anaerobic treatment of cheese processing wastewater.
  - Evaluated appropriateness of materials for use in septic tank leach fields for owners of several quarries in Vermont.
  - Consultant to Vermont Natural Resources Council. Advised on general approaches to evaluate and mitigate pollution problems posed to the waters of Vermont by agricultural, industrial, and municipal sources.
  - Evaluate potential for nitrogen removal using biological nitrification processes for an industrial wastewater treatment facility.
  - Frequently provided counsel to Vermont agency of Environmental Conservation personnel.
- James Morris has provided consultation services pertaining to the assessment of lake quality impacts including:
    - Modeling effort evaluation for recreational/drinking water impacts of POTW outfall location.
    - Advice and expert witness on industrial, municipal, and non-point impacts - Lake Champlain.
    - Development of mechanistic predictive water quality model for deep lakes and impoundments in the southern U.S.

## **PUBLICATIONS:**

Morris, J. W., "Dissolved Oxygen Depletion Mechanisms Operating in the Metalimnion of a Deep Impoundment", M.S. Thesis, Tenn. Tech. Univ., (1978).

Morris, J. W. and Gordon, J. A., "Mechanism of a Dissolved Oxygen Depletion Operating in the Metalimnion of a Deep Impoundment", Proceedings of the Internal Symposium on the Environmental Effects of Hydraulic Engineering Works, p. 29, Knoxville, Tenn., September (1978).

**PUBLICATIONS (continued):**

- Jewell, W. J. and Morris, J. W., "Agricultural Wastes," J. Water Pollution Control Federation, 51 (No. 6), pp. 1360-1384, (1979).
- Jewell, W. J., Switzenbaum, M.S., and Morris, J. W., "Municipal Wastewater Treatment with the Anaerobic Attached Film Expanded Bed Process", Journal Water Pollution Control Federation, 53 (No. 4), pp. 482-490, (1981).
- Morris, J. W. and Clarkson, W. W., "Agricultural Wastes." J. Water Pollution Control Federation, 52 (No. 6). pp 1342-1383, (1980).
- Jewell, W. J. and Morris, J. W., "Influence and Varying Temperature, Flow Rate and Substrate Concentration on the Anaerobic Attached Film Expanded Bed Process." Proceedings of the 36th Annual Purdue Industrial Waste Conference, pp. 655 (May 1981).
- Morris, J. W. and Jewell, W. J., "Utilization of the Anaerobic Attached Film Expanded Bed Reactor for the Removal of Organic Particulates" Proceedings of the 36th Annual Purdue Industrial Waste Conference, pp. 621, (May 1981).
- Morris, J. W. and Jewell, W. J., "Removal of Organic Particulates from Wastewaters with an Expanded Bed." Proceedings of the 57th Annual Conference of the Water Pollution Control Federation, (October 1984).
- Morris, J. W., "Conversion of Particulates in an Anaerobic Expanded Bed", Ph.D. Thesis, Cornell University (1983).
- Morris, J. W., Batchelder Adams, L. A., and Tozer, H. G. "Solids Settling Variability in Activated Sludge Secondary Clarifiers - Effect on Operation and Capacity", Proceedings of the 42nd Annual Purdue Industrial Waste Conference, pp 551-564 (May 1987).
- Hoffman, J. P.; Cook, J. W.; Morris, J. W.; and Stuart, L. S.; "Feasibility of Tertiary Wastewater Treatment by a Periphytic Algal Community During Winter", abstracted: Journal of Phycology Vol. 23 p. 237 (1987).
- Morris, J. W., Tozer, H. G. and Batchelder Adams, L. A., "The Influence of Operational Conditions on the Variability of Activated Sludge Settling Characteristics at Functional Treatment Plants". Proceedings of the 43rd Annual Purdue Industrial Waste Conference, pp 313-325 (May 1988).
- Morris, J. W., Stuart, L. S.; Hoffman, J. P.; and Cook, P. W.; "Tertiary Nitrogen Removal by a Periphytic Algal System (PAS)" Journal of Environmental Engineering - American Society of Civil Engineers, Accepted with revisions (September 1988).
- Clarkson, W. W.; Morris, J. W.; and Jewell, W. J.; "Anaerobic Digestion of Insoluble Cellulose in Expanded Bed Biofilm Reactors", Proceedings of 1988 Food Processing Waste Conference, Georgia Tech Research Institute, Atlanta, Georgia (Nov. 1988).

**PUBLICATIONS (continued):**

- Morris, J. W., Batchelder Adams, L. A., and Tozer, H. G. "Activated Sludge Secondary solids flux Variability", Journal Water Pollution Control Federation, 61:1, pp 73-82 (1989).
- Morris, J. W. and Robertson, T. V., "Modeling of a Large Multi-Product Industrial Site to Define Wastewater Production and Treatment Alternatives," Proceedings of the 47th Annual Purdue Industrial Waste Conference, in press, (May 1992).
- Morris, J. W. and Robertson, T. V., "Modeling of a Large Multi-Product Industrial Site to Define Wastewater Minimization and Treatment Alternatives," Proceedings Joint Conference on Pollution Prevention, Water Environment Federation, National Solid Waste Management Association, Air & Water Management Association, (November 1992).
- Morris, J. W., de Vegt, A. L., and Burke,, M. A., "Anaerobic Treatment Of An Electronics Manufacturing Glycol Solvent Wastewater," Proceedings of the 50th Purdue Industrial Waste Conference, (May 1995).
- Morris, J. W., and Cummings, R. J., "Winery Wastewater Treatment Using The Anaerobic Mobilized Film Technology (MFT)," Proceedings of the 53rd Purdue Industrial Waste Conference, (May 1998).
- Morris, James W. and Northrop, Jere, "Mass balance analysis of phosphorous / nitrogen removal and odor potential from pilot-scale operation of the Bion Technologies Dairy Waste Management System, *Proceedings International Symposium on Animal Production/Environmental Issues*, October 3-5, 2001, Research Triangle Park, North Carolina.
- Morris, James W. and Northrop, Jere, "Low Oxygen Organic Waste Bioconversion System," United States patent 6,689,274 (February 10, 2004).

Bion Technologies, Inc.

## Dr. Jere Northrop, Ph.D.

### **Bion Technologies, Inc.** Co Founder 1989

Current position: Senior Technology Director

1999 - 2002: Chief Technology Officer

1989 - 1999: President

### **As It Is, Inc.** Co Founder 1999

Current position: Director

1999 - 2000 President

### **Town of Amherst, Amherst, New York; Water Pollution Control Facility**

1980 - 1989 Assistant Superintendent - Process

1979 - 1980 Chemist

### **Post Graduate Positions**

1972 - 1975 Center for Theoretical Biology, State University of New York at Buffalo

1970 - 1972 Independent Research, New York, New York

1969 - 1970 Department of Microbiology, University of California at Davis

### **Education**

1964 - 1969 Syracuse University, PhD, Biophysics

1960 - 1964 Amherst College, AB, Biology

Jere Northrop is a co-founder of Bion Technologies Inc. and is the inventor of the bion technologies for which he holds seven patents. He has been a Director for the entire history of the company and has served as President for its first ten years of operation and more recently as Chief Technology Officer, and currently as Senior Technology Director. He also is a cofounder of AS IT IS, Inc and served initially as its President and is currently a Director.

He has extensive experience in the environmental sector having managed environmental testing and research laboratories, worked as an environmental chemist, and spent over nine years as a process superintendent at a large advanced wastewater treatment plant in Amherst, NY.

Dr. Northrop has a long standing interest in language and the foundations of science and philosophy. He has invented a series of languages, the most current of which is Ododu, and continues to do research on the nature of life and language at both the theoretical and applied levels.

Dr. Northrop has a PhD in biophysics from Syracuse University (1969) and an AB in biology from Amherst College (1964). He has done postdoctoral work at the University of California at Davis and at the Center for Theoretical Biology at the State University of New York at Buffalo.

**George Bloom, P.E.**

72 Woodlands Drive  
Falmouth, ME 04105  
207-781-9040

**Professional Registration:**

- Maine Professional Engineer, License # 6226

**Experience:**

**2000 – Present: Bion Technologies, Inc., New York, NY**

Director of Engineering for Bion Technologies, Inc. Bion Technologies, Inc. provides turn-key waste management systems to the Confined Animal Feeding Operations industry. As the Director of Engineering I am responsible for management of our technical staff, interfacing with regulatory agencies and clients. Active projects are in Indiana, Texas and California.

**1986 – 2000: Woodard & Curran, Inc., Portland, ME**

Served as a project engineer, project manager, and Vice President/Chief Engineer on a variety of wastewater collection and treatment facility projects. As Chief Engineer and Municipal Business Center VP I also served as the primary proposal writer for municipal wastewater projects in the Portland, ME office. As a W&C VP, I was involved in the managing the Municipal Business Center and Municipal Team in the Portland, ME office.

- Project Manager for the funding, permitting and design of the Acton, Massachusetts wastewater collection system and treatment facility. The wastewater collection system included approximately 60,000 feet of sewer, 7 pump stations and several thousand feet of force main. The wastewater treatment facility was designed in a modular fashion such that 0.5 MGD of capacity with build out to 1 mgd. The wastewater treatment facility process flow train includes influent pumping, fine screening with step screens, grit removal, sequencing batch reactors, post equalization basins, filtration, UV disinfection, and subsurface disposal via rapid infiltration basins. The SBRs are designed for BNR to accomplish nitrification, denitrification and P removal. Acetic acid is utilized to maximize BNR of P. Metal salt addition capabilities are also included to maximize P removal. Sludge is stored in aerated holding tanks and thickened via a GBT for off site disposal at a merchant facility. The initial facility will discharge to the groundwater via RIBs with increased future discharge volumes going to the Assabet River. NPDES permitting of the future discharge to the Assabet River necessitated development of a non-point source trading program under EPA's Watershed Trading Program.
- Project Manager on the Comprehensive Plant Evaluation (CPE), bar screen replacement and influent pumping system projects at the Lewiston-Auburn Water Pollution Control Authority's wastewater treatment facility. The CPE included design, operations, organization, cost, equipment and energy evaluations of the various treatment process and equipment. The CPE results were used in concert with the LAWPCA management team to develop a Management Action Plan (MAP). The MAP prioritized recommended improvements (large capital, small capital, and organizational) over an approximate five year period for implementation by the LAWPCA.
- Project Manager on the Devens, Massachusetts Regional Wastewater Facilities Planning Project. The Devens project included Comprehensive Plant Evaluations of the Ayer, MCI-Shirley, and Devens wastewater treatment facilities; extensive stakeholder meetings with several towns and environmental groups; wastewater flow and loads projections for the regional study area; septage volumes and loading projections for the regional study area; extensive meetings with the DEP and EPA regarding facility permitting (ENF, discharge, sewer extension, etc.); and preliminary design of a 3.0-mgd regional

wastewater treatment facility. The treatment facility design was modular, enabling the facility to be expanded to accommodate 6.0 mgd in the future. The process flow train included influent pumping, screening, grit removal, sequencing batch reactors (SBRs), filtration, UV disinfection, and groundwater discharge via rapid infiltration basins. The SBRs were designed for BNR for nitrification and denitrification. Metal salt addition and filtration will be utilized for P removal.

- Project Manager on the Comprehensive Plant Evaluation (CPE) and influent pump station upgrade for the Portland, Maine 19-MGD wastewater treatment facility. Pump station improvements at the India Street and Northeast Pump Stations included design, construction oversight and start-up of new control systems, VFDs and premium efficiency motors. The CPE of the Portland wastewater treatment facility included detailed evaluations of the unit processes, maintenance systems and practices, an organizational/staffing assessment, compliance review and assessment, operations and maintenance cost evaluations (with zero-based budgeting from privatized operations perspective), benchmarking with similar sized facilities, and development of a management action plan (MAP). The results of the CPE process were used in an interactive manner with the Portland Water District (PWD) to develop a MAP. The MAP prioritized recommended improvements (large capital, small capital, and organizational) over an approximate five year period for implementation by the PWD.
- Project Manager on the evaluation of odor control alternatives for the Augusta Sanitary District's interceptor sewer and pump station. Identification and development of an effective odor control strategy was challenging due to the extensive length of the interceptor sewer/force main system and large industrial components of wastewater flows being transported.
- Project Manager on the design/construction of the University of New England's wastewater treatment facility with Sargent Constructors, Inc. Unit processes designed at the reconstructed 100,000-GPD wastewater treatment facility included influent flow equalization, sequencing batch reactors (SBRs), effluent flow equalization, effluent filtration, chlorination and dechlorination. The various treatment systems are automated with PLC/touch screen controls. Project challenges included doubling of existing wastewater treatment facility organic load treatment capacity, maintenance of operations during construction operations, and adherence to a very tight project schedule.
- Project Manager for evaluation and design of upgrades to the Oakland, Maine wastewater treatment facility. Upgrades include new sludge storage and dewatering facilities, rehabilitation of the sludge pumping equipment, baffles in the clarifiers, and new chemical feed and pH control systems.
- Project Manager for the planning, financing, design and construction of new wastewater collection and treatment facilities for Warren, Maine. The facilities planning phase of the Warren project included the evaluation of wastewater treatment alternatives serving the District only, as well as regional alternatives to serve both the District and State of Maine Department of Correction's facilities in South Warren. The alternative jointly selected by the District and MDOC was a regional facility consisting of pump stations, aerated lagoons, adsorption-clarification, filtration and UV disinfection. Also served as Project Manager for CDBG-funded project to provide building sewer service connection, new sidewalks and curbing. This project involved significant research into the state-of-the-art for disinfection systems including conventional chlorination, ozone and ultraviolet (UV). The results of this work were presented at the annual national convention of the Water Environment Federation in October 1992.

- Preparation of a Facilities Planning Report for the St. Agatha Sanitary District, Maine. Options for elimination of the existing secondary waste discharge to Long Lake were evaluated based on environmental, technical and financial factors. A recommended plan was selected for design and construction.
- Performed planning, process mechanical and civil design of a 155,000-GPD stabilization lagoon treatment facility. Facilities designed included an influent flow splitter box, lagoon sizing and liner system, chlorination and dechlorination systems for Howland, Maine.
- Performed process mechanical and civil design of a 65,000-GPD pressure distribution subsurface wastewater disposal system in Brownville, Maine. Facilities designed include an influent splitter box, primary sedimentation tanks, infiltration bed, pump, design chambers and underdrain collection system.
- Performed process mechanical and civil design of a 20,000-GPD partial mix, aerated lagoon treatment facility. Facilities designed included an influent flow splitter box, lagoon sizing and liner system, aeration system, chlorination and dechlorination systems.
- Project Manager for CDBG and FmHA funded downtown improvement project in Waldoboro, Maine. Project included design of sanitary sewers, water main replacement, storm drainage system expansion, sidewalks, curbing, and road reconstruction. Project contract documents required structuring to account for CDBG funding over a two year period and FmHA funding.

**1980 - 1986: Metcalf & Eddy, Inc., Boston, MA & New York, NY**

Process engineer involved in the planning, design and construction management of a variety of projects including:

- Project Engineer on project done under contract with EPA which evaluated design and operations of screenings and grit systems. The work included a review of current state-of-the-art in this area, surveys of existing facilities, and visits to over 30 plants in the U.S.
- Responsible for the construction and start-up of a dissolving air flotation sludge thickening system in Pawtucket, Rhode Island.
- Preparation of Design and Information Reports for the EPA on Preliminary Treatment Operations, Scum Handling Systems and Digester Gas Cleaning and Use Systems.
- Engineer for combined sewer overflow studies in Cambridge and Boston, Massachusetts; and Providence, Rhode Island. Responsibilities on each project included data collection, field investigations, storm water management model set-up and calibration, and use of the SWMM to evaluate the effectiveness of CSO abatement/treatment alternatives. Output data from the SWMM was also used as input data in modeling of impact on receiving waters. CSO abatement/treatment alternatives were evaluated on technological and economic bases, and final reports were prepared containing recommended CSO abatement programs.
- Performed process mechanical design of a mesophyllic thermophillic anaerobic sludge digestion complex, centrifuge sludge dewatering, primary settling grit and scum handling, influent pumping and screening, and disinfection facilities at a 120-MGD, step aeration, activated sludge treatment facility in Brooklyn, New York. Served as office construction engineer coordinating the shop drawing review process, evaluated equipment substitution proposals and preparation of change orders for the construction of these facilities.

- Engineer responsible for the evaluation of Infiltration/Inflow and Sewer System Evaluation Survey data for the preparation of a SSES report in Milford, Connecticut. Cost estimates were prepared for elimination of I/I sources and sources were ranked based on volume and cost effectiveness.
- Engineer/Project Engineer responsible for the process mechanical and civil design of modifications to the influent screening facilities, primary settling facilities, pump and power house improvements, disinfection facilities, grit and scum processing facilities, gravity sludge thickeners, anaerobic digestion and dewatering complex at a 120-MGD activated sludge wastewater treatment facility. Other responsibilities included development of interim wastewater treatment facility operations plan during construction, coordination of design efforts between subcontractors and preparation of final contract documents for 22 contracts. Construction related responsibilities included coordination of shop drawing review, review of process mechanical shop drawings, evaluation of equipment substitutions, clarification of contract documents and preparation of change orders.
- Co-author on U.S. EPA Design and information reports entitled, “Design and Operational Considerations for Preliminary Treatment: Screenings and Grit Handling”, “Scum Handling Design and Operational Practices” and “A Technology Update on Anaerobic Digester Gas Cleaning and Use.” Research for document preparation included literature review, telephone interviews of operations staff at numerous wastewater treatment facilities and site visits to selected facilities.

#### **Publications and Presentations**

Bloom, G., “Mapping a Brighter Future,” *Water Environment & Technology*, July 1999.

Bloom, G., “A Technology Update on Anaerobic Digester Gas Cleaning and Use,” presented at Water Pollution Control Federation Annual Conference, 1986.

Bloom, G., “Brownville Junction, ME: A Case Study on the Design and Construction of a 65,000 GPD Subsurface Wastewater Disposal System,” presented at the Water Pollution Control Federation Annual Conference, 1991.

Bloom, G., “Developing a Plan to Control Energy Costs,” *New England Water & Wastewater News*, February 1995.

Bloom, G., “Lagoons - ‘Maine Communities’ Successful Solutions for Wastewater Treatment,” presented at the Water Environment Federation’s 68<sup>th</sup> Annual Conference, 1995.

Bloom, G., “The Impact of Partial Nitrification and Algae on Partial Mix Aerated Lagoon Effluent Quality,” presented at New England Water Environment Association Annual Conference, January 1996.

Bloom, G., “The New Lagoon,” *Operations Forum*, April 1996.

#### **Education:**

- B.S. Cornell University, Ithaca, NY 1977
- Graduate Coursework at Northeastern University.

# APPENDIX C

DeVries Dairy  
**Bion Nutrient Management System  
Sampling & Monitoring Program for  
Fate of Nitrogen & Phosphorus**



April 16, 2004

**James W. Morris, Ph.D., P.E. Chief Technology Officer**  
**George W. Bloom, P.E., Chief Engineer**  
*Incorporating edits and refinements from program Review Team.*

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1. PROJECT OVERVIEW.

1.1 Background Information.

The existing waste management facilities at the DeVries Dairy were modified to incorporate a high rate Bion Nutrient Management System (NMS). The Bion NMS waste management system is a biological nutrient removal process for removal of Nitrogen and Phosphorus from the waste stream. The system has been operational since July 2003.

This document outlines the sampling, monitoring and analysis of nutrients to determine the amount of nitrogen and phosphorous leaving the system as the solids and liquid streams generated by the full-scale high rate Bion NMS waste management system.

1.2 Goal

Determine the amount of nutrients leaving the Bion Nutrient Management System as solids in the effluent discharged, solids removed by solids separation units (presently screens) and as dissolved nutrients discharged, and compare these amounts to estimated nutrient loadings to the system during the period of program testing.

1.3 Project Approach

- Collect representative samples of the solid / particulate and soluble nutrients leaving the Bion system and the rates at which they are discharged.
- Compare the mass of nutrients discharged to their mass inputs.
- Establish operating parameters for the biological process that correlate to the air emissions generated during the sampling period.

1.4 General Overview.

The sampling and monitoring program under execution at the DeVries Dairy is collecting the data needed to assess performance of the Bion NMS waste management system with respect to nitrogen and phosphorus conversion and removal. Influent nutrient loadings will be determined. Effluent quality and harvested solids characteristics will be documented. Detailed design criteria and descriptions of the installed components are available in the Project Design Report.

The Bion Nutrient Management System installed at the DeVries Dairy has been retrofitted into a two lagoon system that has served this dairy for in excess of seventeen years. It is important to note that the design and operation of this full-scale retrofit system is under constraints imposed by current regulations. The testing project was allowed if the installation of the designed system left the total volume of the existing lagoon system intact, could not interrupt the function of the existing flush system, nor impact the current operating permit. The only way to accomplish this, in a short time frame and without substantial additional regulatory permitting, was to define the retrofitted Bion system reactor volumes using flexible fabric baffles and to use floating aeration / mixing equipment.

Lagoons 1 and 2 have had deposited solids removed once, more than ten years ago. Mixing in Lagoon 1 was sufficient to prevent solids from accumulating any more than from one to three feet depending on location over an average bottom depth of 14 to 15 feet. Initial startup saw the suspension of a portion of these solids. The potential for dramatic stirring or scouring of these deposited solids arise whenever water levels vary substantially and / or aerator positions are changed. This mode of additional solids and nutrient loading would not occur with solid wall basins as anticipated for permanent installations. However, this mechanism can be used to gradually remediate solid deposits in retrofitted systems.

1.4.1 Monitoring and loading

Performance monitoring has focused on the discharge points from the system and measures of nutrient loading to the system. The protocol reflects the specific operations and resulting practical constraints imposed by the on-going real-world running of this producing dairy and the required baffle design of this retrofit. The load to the system is a combination of gin trash bedding, manure and milkhouse wastewater. The manure and bedding is transported very well by the dairy's flush alley system. However, this mixture is extremely heterogeneous and varies spatially and temporally at different locations within the dairy waste collection system. This makes measuring system inputs a challenge. In addition, the flush lane configuration, use of mats in the lanes, and the tight geometry of the small premilking holding area combine to make the complete quantitative removal, volume measurement and sampling by scrapping and vacuuming the mix impractical.

An alternative is to consider a rations fed approach. Since the total weight variation of a production herd is insignificant, all P fed and significantly all N fed becomes manure

load to the system, less the amount removed in milk. The DeVries Dairy has very accurate numbers for dry matter intake (rations consumed by the cows) and of course milk production. If an allowance is made for the minor amount of feed spillage that also contributes to system load, on the order of 2% to 5% (Steve Martin animal nutritionist for DeVries Dairy – conversation 11/26/03), then this approach will provide a good measurement of system load. This approach is recommended by Lorimor, Jeff, et al. (2000), “Manure Characteristics – Manure Management System Series,” MidWest Plan Service, Ames Iowa, MWPS-18 Section 1, pp 19, 23.

Contributions from non-milkers are determined using the equations and tables presented in the recently proposed ASAE standards. The last significant load contribution is derived from bedding. The weight of bedding mixture used is determined and the mix is periodically analyzed for nutrient composition.

Minor contributions from cleaning agents and other potential sources may be estimated by the quantities purchased on an average basis. Thus far, these potential minor contributions have proven insignificant.

1.4.2 Design Compared to Installation / Operation

Loading to the retrofitted Bion NMS are substantially different than anticipated during design. System design inputs or parameter loads were established with information provided by the dairy and using 2001 ASAE D834.1 DEC99 standard values adjusted for the high producing herd at DeVries. Recent efforts by the agricultural engineering profession have been directed toward establishing animal manure standards that more closely reflect current practices in animal production operations. Considerable work has focused on dairy operations.

Though not officially adopted at this point, the result has been a Draft Proposed ASAE D834.1 standard dated and issued for review on September 2, 2003. For dairy manure production the standard is centered on a set of equations for each major parameter. These equations use the specific production situation (cow weight, ration consumption, milk production, etc.) as inputs to determine the expected load produced for each parameter. The proposed standard also provides a table of typical parameter values. The parameter loading values obtained from this standard are comparable to the values obtained from the ration less milk measurements approach discussed above.

Comparing the ration based or proposed ASAE standard for core parameters to the values used for design, it may be seen that current loadings are substantially higher. These represent an increased actual load compared to design values of approximately 55% TKN, 31% Tot-P, and 23% Total manure. Actual system hydraulic loading from the milk house is approximately 47,000 gallons per day or about 42 gal/cow-d. Typical design values for this type of operation are in the range of 15 to 16 gal/cow-d. With input from the dairy a design value of 26 gal/cow-d was used. Thus, the hydraulic loading is on the order of 60% greater than design (near 165% typical).

In addition, solids deposited on the bottom of the Bion system bioreactor during past operation of the lagoon exert an additional and variable load. This type of load is normal and expected for any normal lagoon retrofit installation. Removal and processing of these solids represents the remediation of the replaced system. Processing of these solids can be controlled in normal installations. In the present installation any long term solids should either be processed through the system or be present as deposited solids in areas where mixing intensity is low. As long as water levels hold steady or other activities that can alter bioreactor mixing are avoided, these deposited solids should slowly degrade placing an unknown but relatively small additional load on the system, with new materials introduced remaining in suspension.

The Bion system design, like that for any biological treatment system, anticipates load variation and allows for significant periods of high loading. Increases in the average operation loadings for key factors as indicated above and the system installed configuration have an impact on the facility. The effects are felt on aeration, solids handling and overall system efficiency.

1.4.3 Aerators

The stationary floating vacuum fed jet aeration and mixing system first installed has operated well from a mixing standpoint (please see design report for details). As designed this aeration system would not have been able to transfer the oxygen required by the substantial increase in loading experienced above design levels. In addition the system actually delivered only about half the design rated air flow (and thus half of the oxygen transfer rate) while otherwise appearing to be operating normally. Additional aeration capacity has been in the form of two 10 horsepower, pontoon mounted, blower fed, jet aerators.

Nozzles for the initial stationary system were designed to be approximately a foot above the original lagoon bottom. This location would suspend old accumulated solids in the nozzle header influence zone and provide sufficient mixing energy to keep new solids introduced suspended.

Three episodic events have caused the nozzle level to be substantially lowered. This has led to the suspension of large amounts of bottom solids and short-term increased solids and nutrient loads to the treatment system. Process response has seen good recovery of treatment and removals and indicative of steady operation.

1.4.4 Solids Separation

The existing Houle screen has been incorporated into the Bion system. Operation reliability of the Houle has required substantial improvements to the feed pumps, mixers and hydraulic configuration. During initial Houle screen operation, startup and installation of required upgrades, the coarse screening function was maintained but substantial periods of down time led to high loads when the screen came back on-line. The Houle system now operates well.

The overall increase in loadings over design values has also meant an increase in the amount of solids to be removed. A second Sweco screening unit has been added to enhance effluent solids removal and process control.

1.4.5 Precipitation Impacts

Rain events for a normal Bion installation would result in short term marginally higher flows but only those flows generated by runoff from exposed flush alley and open areas. These are typically small and readily accommodated. Since we are constrained to not altering the dairy footprint or geometry, substantial flows are generated during rain events. Specifically this flow is from open corals which drain into the Houle feed sump and thus the treatment system at this dairy. A bypass has been installed to deliver these high flows to the non-Bion portion of the existing lagoons to receive normal lagoon treatment (not treated through the Bion system).

If the bypass is not performed during a significant rain event, the abnormally high flow is directed into the Bion system. This flow also carries substantial organic solids, nutrients and inert soil solids. Two substantial rain events and their loads have been treated by the Bion system. Recovery was again as expected with steady, efficient operation in a short period. Operating protocols are presently in place to prevent this load from entering the Bion system.

2.0 SAMPLING AND MONITORING PROGRAM

2.1 Sample Locations.

A schematic of the system showing all waste management system components and sample locations is provided in Figure 1. Figure 2 offers a simplified process flow diagram indicating the sample locations that are the focus of this sampling program.

2.2 Sampling Procedures.

Samples are collected in a manner such that they are representative of the medium being sampled. For liquid and solids streams, samples are generally be “grab” type samples. Generally, a series of at least six grab samples will be taken over no less than a three hour period for each sampling event. The six grab samples for each location will be combined to create a composite sample for laboratory testing. Sampling taps will be provided on the various waste transfer piping. All samples will be collected and handled in accordance with the latest addition of Standard Methods and applicable laboratory test procedures.

Nitrogen and phosphorous as well as other parameter loads to the system are dominated by inputs from the actively milking portion of the herd. For N & P their load represents greater than 97% of that added by manure. The amount of manure N & P contributed by the milker category of the herd equals the N & P fed less the amount removed in milk.

DeVries Dairy has very accurate numbers for dry matter intake (rations consumed by the cows), and the composition of that ration, and of course milk production. If an allowance is made for the minor amount of feed spillage that also contributes to system load, on the order of 2% to 5% (Steve Martin animal nutritionist for DeVries Dairy – conversation 11/26/03), then this approach will provide a good measurement of system load. This approach is recommended by Lorimor, Jeff, et al. (2000), “Manure Characteristics – Manure Management System Series,” MidWest Plan Service, Ames Iowa, MWPS-18 Section 1, pp 19, 23. As a check, this mass balance ration and milk production approach for manure based N & P loading will be compared to values derived from the newly proposed ASAE manure standard equations and tables. This new proposed standard will also be used to determine other parameter inputs.

Two other categories of cows are responsible for manure loading to the system, dry pregnant cows and heifers. Their numbers and weight are known. Contributions from these non-milking category animals may be determined using the equations and tables presented in the recently proposed ASAE standards.

Bedding represents the final significant system load contribution, though minor (approximately 6% of total N and about 2% of total P). The weight of bedding mixture use is determined and the mix has been and will be periodically analyzed for nutrient composition as detailed below.

Process control parameter data including pH, ORP, temperature, and dissolved oxygen levels will be continuously monitored via probes in the bioreactors. This data will be transmitted to a computer for archiving, monitoring and analysis.

2.3 System Monitoring Parameters.

The sampling program centers on the determination of nitrogen and phosphorous leaving the system as discharged solids or soluble species. The discharge of nitrogen to the atmosphere in gaseous forms is addressed by the air sampling protocol. Figure 1 shows the location of all sampling points and flow meters for the installed Bion system. Figure 2 is a simplified process flow diagram with the sampling and flow monitoring points for this program indicated. High solids content or slurry discharges leave the process at sampling points 1, 2A, and 2B except when these fine 2B solids are not being returned to the Bioreactor. The solids removed or harvested by the Houle inclined plane screen are sampled at 1, samples collected from the coarse 350 µm screen Sweco 1 are normally harvested and sampled at point 2A. The finer solids removed by the 106 µm screen Sweco 2 are normally returned to the anaerobic volume of the bioreactor. Since these Sweco 2 solids normally do not leave the system, samples are not always taken at 2B and they are not part of the required process nutrient monitoring focus of this protocol.

The parameters to be monitored and tested for across the Bion NMS waste management system are identified in Table 1, System Monitoring Parameters, by sample location. Target parameters required by this protocol to determine the mass of phosphorous and nitrogen leaving the process other than by atmospheric nitrogen emissions are indicated

with “P”. When these target parameters vary by less than ±15% or 30 mg P/L or 50 mg N/L, which ever is greater, the system will be considered as under steady operation.

Table 1. System Monitoring Parameters.

Description		Houle Inclined Screen Solids	Harvested Solids	Recycle Solids	Anaerobic Volume	Anoxic Volume	Sweco 1 Effluent	Process Effluent	Lagoon 1 Effluent
Parameter / Sample Location Designation	Units	1	2A	2B	9A	9B	8A	8B	11
Flow*	gpd		F	F				F	F
Weight	lb/d	F	F						
Specific Gravity	lb/gal		S	S					
Bulk Density	gm/cm ₃	S	S						
Total Suspended Solids (TSS)	mg/L			S	S	S	S	P	P
Volatile Suspended Solids (VSS)	mg/L			S	S	S	S	P	P
Total solids (TS)	mg/kg	P	P	S					
Total volatile solids (VS)	mg/kg	P	P	S					
Oxygen Reduction Potential (ORP)**	mV				F	F		F	F
pH**	SU				F	F		F	F
Dissolved Oxygen (DO)**	mg/L				F	F			
Alkalinity	mg/L				S	S		S	S
Potassium	mg/kg	S	S	S					
Temperature (T)	C°				F	F		F	F
Soluble (Filtered Samples)									
Chemical Oxygen Demand (COD)	mg/L					S		S	S
Total Kjeldahl Nitrogen (Sol TKN)**	mg/l		S	S	S	S	S	P	P
Phosphorus (Total Soluble-P)**	mg/L		S	S	S	S	S	P	P
Potassium (Total Soluble-K)	mg/L					S		S	S
Total (Unfiltered Samples)									
Chemical Oxygen Demand (COD)	mg/L	S	S			S		S	S
Biochemical Oxygen Demand (cBOD ₅)	mg/L	S	S			S		S	S
Total Kjeldahl Nitrogen (TKN)**	mg/L	P	P	S	S	S	S	P	P
Nitrate Nitrogen (NO ₃ -N)	mg/L				S	S	S	S	
Nitrite Nitrogen (NO ₂ -N)	mg/L				S	S	S	S	
Ammonia (NH ₃ -N)	mg/L	S	S	S	S	S	S	S	S
Phosphorus (Total-P)**	mg/L	P	P	S	S	S	S	P	P
Potassium (Total-K)	mg/L	S	S	S		S		S	S

P – Protocol core laboratory analysis

S – Supplemental laboratory analysis for additional system operating data.

F – In-situ field measurements

* See schematic for flow meter locations

** Parameters to be tested for to determine when system performance stabilizes

It is recognized that removals of nitrogen loaded to the system may be accomplished through effluent nitrogen discharges, biological nitrification and denitrification (atmospheric discharge of inert nitrogen gas or N₂) with some conversion to biomass nitrogen, and / or atmospheric emissions of mostly ammonia. Quantitative verification that ammonia stripping is, or is not occurring, cannot be rigorously supported by this nutrient sampling protocol. Anecdotal evidence that there are no noticeable ammonia odors in the barns, flush alleys or lagoon areas are being semi-quantitatively verified with area whole-air sampling as specified in the air emissions protocol.

Though, significant nitrogen can leave similar biological processes in the form of nitrate and nitrite (measured here as mg NO₃-N/L and mg NO₂-N/L), the concentration of these nitrogen species has been less than 5 mg NO₃-N/L (but mostly less than 2 mg NO₃-N/L) and non-detect NO₂-N/L for 36 samples of the bioreactor anaerobic and anoxic volumes spanning the last three months. Supplemental samples will be taken throughout the protocol sampling period to determine the potential form soluble nitrogen discharges by this route.

The intricacies of internal unit operations and processes are beyond the scope of this program and protocol. As seen by the locations and parameters designated with a “P” or “F”, signifying protocol samples or field measurements required by the protocol in Table 1, the specific parameters and locations that are the focus of this program are tightly defined. However, supplemental data may also be collected in support of steady operation and as valuable input for future design and operation guidance.

2.4 Laboratory Procedures.

Laboratory test procedures to be utilized in analyzing the samples are summarized in Table 2. All analyses will be performed by independent, certified, outside laboratories. Periodic split samples will be run as a quality control check on laboratory work. Blind field spikes and blanks will be run for about every tenth analysis of critical parameters such as effluent Total P and TKN as a quality assurance measure (see Section 3.6).

2.5 Sampling Frequency.

Samples will be collected once per week, typically on Tuesday or Wednesday or more frequently during steady operation as indicated.

2.6 Field Quality Control Sampling Protocol

Use of field quality control (QC) procedures can be an effective method of monitoring both field activities as well as laboratory performance. Field QC parameters can include use of replicate samples, known check samples or spiked samples. One intent of the field QC is to provide samples to the laboratory that have known or theoretical amounts added or diluted, and since the laboratory does not know which sample is spiked or replicated, nor the level of spike/dilution added, the results can assist data quality reviewers in assessing the accuracy and precision of the laboratory tests.

Table 2. Laboratory Procedures and Process Monitoring.

Monitoring Parameter	Test Method
Total Suspended Solids	SM 2540-D/EPA 160.2
Volatile Suspended Solids	SM 2540 E/EPA 160.4
Alkalinity	SM 2320/EPA 310.1
Potassium	SW 846 6010/EPA 200.7
Settable Solids	SM 2540F/EPA 160.5
Total Chemical Oxygen Demand	SM 5220-C/EPA 410.1
Soluble Chemical Oxygen Demand	SM 5220-C/EPA 410.1
Total Carbonaceous Biological Oxygen Demand	EPA 405.1
Soluble Carbonaceous Biological Oxygen Demand	EPA 405.1
Total Kjeldahl Nitrogen	SM 4500NB/EPA 351.3
Soluble Total Kjeldahl Nitrogen	SM 4500NB/EPA 351.3
Total Ammonia Nitrogen	SM 4500NH3E/EPA 350.2
Soluble Ammonia Nitrogen	SM 4500NH3E/EPA 350.2
Soluble Nitrate Nitrogen	EPA 352.1
Soluble Nitrite Nitrogen	SM 4500NO2B/EPA 354.1
Total Phosphorus	SM 4500P/EPA 365.2
Ortho Phosphate	SM 4500P-E/EPA 365.2
Flow (Liquid)	Magnetic Flow Meters
Volume	Flow Differential, Measurement
Temperature	Probe & Meter
pH	EPA 150.1 & Probe
Conductivity	EPA 120.1 & Probe
Oxidative Reduction Potential	Probe, On-line Monitoring
Dissolved Oxygen	EPA 360.1 & Probe
Percent Total Solids	SM2540B/EPA 160.3
Volatile Percent Solids	SM2540B/EPA 160.5
Specific gravity	SM2710F
Bulk density	Gravimetric

Several items need to be taken into consideration when preparing field QC samples. If replicate/split samples are to be provided, it is imperative the original sample to be split is first of all representative of the sampling site and also the sample is homogeneous. To provide identical samples to two separate laboratories or two samples to the same laboratory, it is critical that steps be taken to ensure homogeneity between samples. Samples should be stirred, shaken, blended, or any method that provides a uniform sample aliquot. Because of the variability of sample matrix, the individual collecting the sample must be knowledgeable of the sample matrix and what precautions are needed to prevent stratification or heterogeneous sub-samples.

The use of spike samples also requires original sample preparation so the spiked sample and background sample are homogeneous. The preparation of matrix spike and matrix spike duplication requires the sub-samples to be homogeneous. Again, it is important for the sampling technician to plan how to prevent stratification or non-homogenous sample collection.

Another important criterion is to determine how much of a spike to add to the background samples. The spike should be between 50 and 150% of the background. If the spike level is too low, the background levels will over-shadow the spike levels, and the % Recovery will not allow adequate data review. If the spike is too high, the test cannot determine the effect the matrix has on the spike recovery.

Since each site and sample is different, it is important that the sampling technician know the background level prior to spiking. Table 3 details the proposed spiking levels for the Bion Project where nitrogen and phosphorous levels are being evaluated. The matrix spike will only allow evaluation of the “total” results and not the soluble parameters. Soluble parameters are determined by filtering through a 0.45 µm filter. The dairy does not have sufficient space, equipment and manpower to perform filtering on-site. The parameter present in the sample is therefore free to change from soluble to particulate or the reverse. Under the conditions experienced the solubilization of particulates would likely dominate and render spikes useless. Thus, since the soluble parameters are filtered at the laboratory and not in the field, and the soluble parameters are only a portion of the total, it is virtually impossible to spike and recover a field spike sample.

Midwest Laboratories, Inc. has provided the concentrated spike solution detailed in Table 3. To prepare the matrix spike, add 10 mL of the spiking solution to 1 liter of sample to achieve the spiking levels shown. Other amounts may be added to vary the level of spike as appropriate. Only the liquid samples are applicable for this method. There would be too much heterogeneity in the solid sample to allow for an adequate spike recovery.

Table 3. Concentrations of Parameters in the Concentrated Spike Solution provided by the Analytical Laboratory and Dosing Example.

Parameters	Concentrated Spike	Spike Level (10 mL in 1 Liter sample)
Ammonia	50,000 ppm	500 ppm
Total Kjeldahl nitrogen	50,000 ppm	500 ppm
Phosphate	10,000 ppm	100 ppm
Nitrate	2,000 ppm	20 ppm

The identity of the spike samples should be unknown; so a portion of the background sample and two spiked samples shall be included to allow determination of the background and then the precision and accuracy of the matrix spike and matrix spike duplicate (MS/MSD).

Another common field QC parameter is use of a blank. The field blank would be DI water. However, given the elevated levels historically detected across the Bion system, use of a field blank would not be applicable.

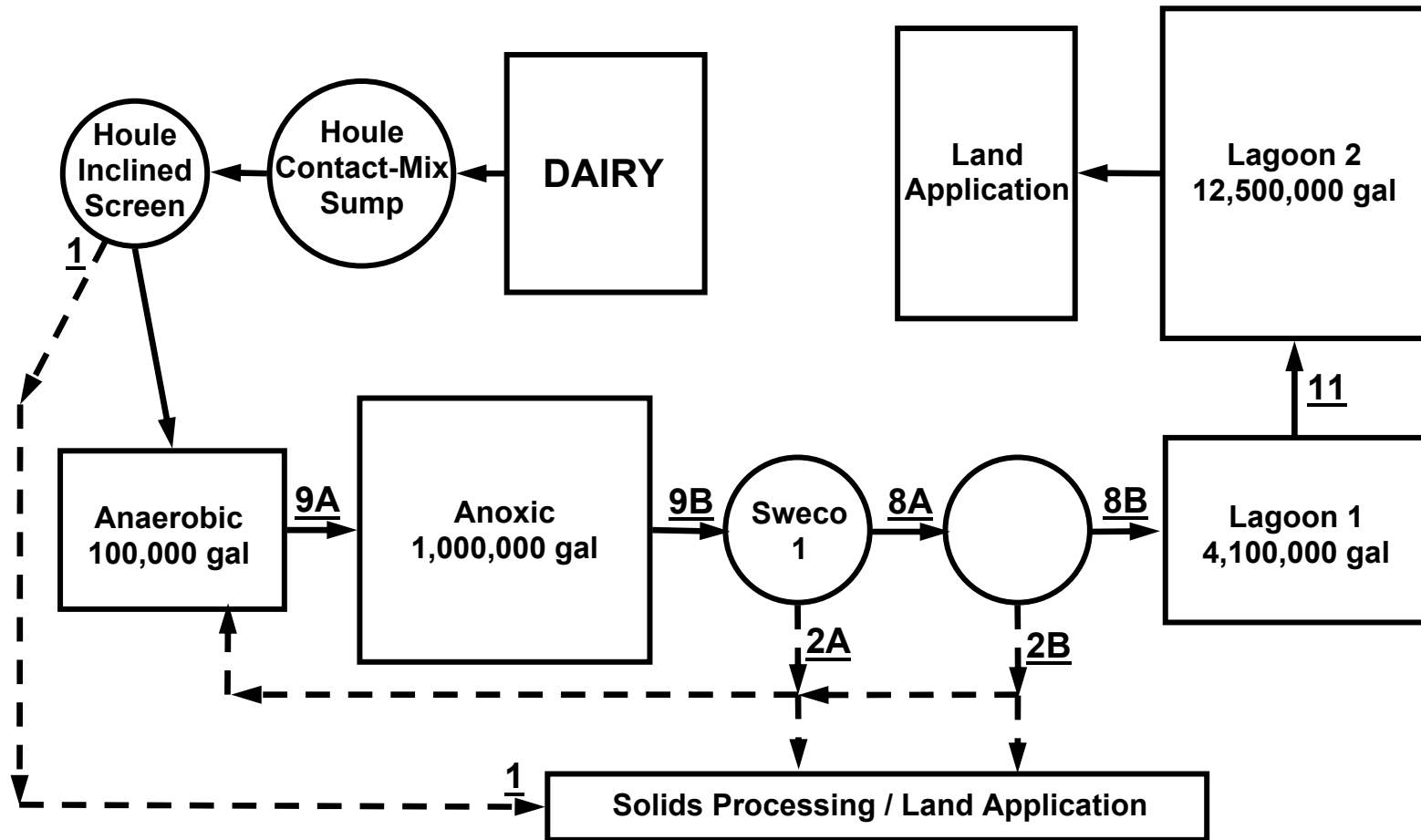


Figure 2. Process Flow Diagram with Sampling Points and Flow Meters (M).

3.0 ANALYTICAL APPROACH.

The essential point of nutrient management performance from a regulatory and manure management plan perspective centers on the mass of nitrogen and phosphorous remaining for land application. The effluent discharged from Lagoon 1 for this system provides a conservatively high estimate of that anticipated from a typical Bion system with storage for land application. The effective volume of the non-Bion reactor portion of Lagoon 1 is substantially smaller than the volume that would normally be available for a retrofit or a new installation. Thus, the mass discharge from Lagoon 1 (11) will be compared to system loading to determine overall performance. Likewise the performance of the biological process train in place with the current retrofit may be addressed with the same approach for the mass discharge from the second Sweco screen (8B).

3.1 System Load and Discharges

The daily nutrient loading to the Bion system is fairly steady. Cow numbers and ration intake do vary but fairly gradually. Water usage numbers are also stable on a weekly average basis. Rain events can increase flows and if not handled correctly by farm personnel can impose substantial short-term loads. As discussed above significant changes in lagoon water levels can produce large loads from the suspension of preexisting solids. The remediation of these solids is one of the goals of a system retrofit. From time to time, as biological activity and system mixing gradually remove accumulated solids, significant areas may release sending solids and dissolved nutrients into the mixed liquor contributing to another type of short-term load to the system. Finally, the potential always exists for components of the dairy's waste management system to experience downtime, which may also contribute to load variation.

These and other variations are the reality of a real-world facility receiving waste from an operating dairy. The situation is a dynamic one. Quantification of the various inputs from sources other than the baseline or near constant additions from manure, bedding and cleaning are problematic. Steady state or equilibrium modeling is simple but is inadequate if the situation addressed is a dynamic one. Significant unexpected inputs are beyond the control of this full-scale field system.

The analytical approach will be on a mass basis, measuring the baseline inputs to the system, removals in the form of harvested solids, discharges from the bioreactor through the final screens, discharges from Lagoon 1 and changes in the bioreactor for each parameter considered over a sampling period. When changes in the bioreactor inventory are small to insignificant the resulting analysis approaches one for steady operation. Even when inventory changes are experienced, mass removals and system operation will be characterized. The inventory change then becomes a system load component that expresses itself in changes in the removals measured. Thus, when the target nutrient parameters in the bioreactor vary by less than $\pm 15\%$ or 30 mg P/L or 50 mg N/L, whichever is greater, the system will be considered as under steady operation and analyzed as such.

Results may then be expressed as overall removal efficiency as a percentage or as a volumetric removal rate, mass removed per volume and time, lb P/1,000 bioreactor gallons-day.

APPENDIX D

**DeVries Dairy
Bion NMS Waste Management System
Sealed Process System Description for
Air Emissions Monitoring**



March 30, 2004

**James W. Morris, Ph.D., P.E. Chief Technology Officer
George W. Bloom, P.E., Chief Engineer**

Incorporating edits and refinements from program Review Team and air emission regulatory personnel.

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**1. PROJECT OVERVIEW.**

**1.1 Background Information.**

The existing waste management facilities at the DeVries Dairy were modified to incorporate a high rate Bion Nutrient Management System (NMS). The Bion NMS waste management system is a biological nutrient removal process for removal of Nitrogen and Phosphorus from the waste stream. The system has been operational since July 2003.

This document outlines the components that will be installed at the DeVries dairy for monitoring and documentation of air emissions from a full-scale high rate Bion NMS waste management system. A sampling and monitoring program for completing this work is also provided.

**1.2 Project Goal.**

Accurately monitor and quantify the major atmospheric emissions produced by an operating, full-scale high rate Bion NMS waste management system.

**1.3 Review of fundamental concepts**

Unlike many other agricultural waste management systems the entire liquid phase of the Bion system is complete mix as verified with TSS and DO readings across the system. Thus, the liquid and suspended solids reactor volumes are homogeneous.

There are alternatives for determining the emissions generated from full-scale process.

- A. Cover or otherwise totally enclose entire system for capture of all off-gasses for determination of quality and quantity of emissions. This is the most reliable and direct approach but is not practical for a retrofitted, large, open basin design like the subject system.
- B. Perform sampling on the surface of the open system. Even though the liquid and suspended solids phases of this system is homogeneous, gas phase releases are not. The points of release for the aeration bubbles induced by both subsurface aerators and floating aerators vary both spatially and temporally. If program surface coverage and the number of samples taken large

enough an experimental design may be able to overcome with some appreciable level of uncertainty the heterogeneous nature of surface releases.

- C. Isolate a discrete, enclosed reactor volume and directly measure the off-gas emissions from that sub-volume to provide a reasonable measure of emissions from the entire system.

#### **1.4 Project Approach.**

Install enclosed tanks that become process continuums of the anaerobic and anoxic bioreactor process environments. The enclosed tanks provide total containment, thereby allowing capture of air emissions from the bioreactor anaerobic and anoxic liquor. The bioreactor liquor in the two sealed process tanks behaves the same as in the full-scale unit processes, with biological and physical processes continuing uninterrupted, releasing process off-gasses at the same rate as the full-scale bioreactor anaerobic and anoxic treatment zones. Tank vent lines may then be monitored for the volume and composition of off-gasses from the bioreactor anaerobic and anoxic treatment zones. The emissions quantified from the enclosed tanks can then be multiplied by the ratio of enclosed vessels surface area to the open bioreactor surface area to obtain an accurate estimate for emissions from the open system.

#### **1.5 Design Concept.**

The enclosed process tanks are provided with very similar, if not identical, aeration and mixing levels as that used in the full-scale anaerobic and anoxic bioreactor treatment zones. Flow is pumped from the full-scale bioreactor anaerobic and anoxic treatment zones to the respective tanks. Transfer pump rates are sized to provide hydraulic retention times in the tanks that are a small fraction of those in the full-scale anaerobic and anoxic bioreactor treatment zones.

Due to the elongated geometry (10 feet wide by 160 feet long in the direction of flow), the bioreactor anaerobic treatment zone is similar to a plug flow unit process with gentle mixing sufficient to keep the 2% to 3% solids suspension mixed liquor from settling. Active gas generation from the liquor biomass escapes through the free liquid surface. Thus, the enclosed anaerobic zone process tank must have a surface area to volume ratio that is similar to that of the full-scale anaerobic treatment zone and be gently mixed at the same level (though higher mixing rates would encourage conservatively higher release rates if any effect were significant / measureable).

The bioreactor anoxic treatment zone is actively aerated and mixed by a jet-aeration and mixing system, and two floating surface aerators. The aeration and mixing system is controlled based on dissolved oxygen levels in the anoxic treatment zone. The predominant pathway of air emissions generation in the bioreactor anoxic treatment zone is by the stripping and transport from aerating and mixing the unit process. The enclosed anoxic process tank will be aerated and mixed similar to the full-scale anoxic treatment zone. Aeration and mixing rates in the tank will be adjustable to ensure maintenance of desired dissolved oxygen levels and mixing conditions similar to the full-scale system. The depth of aerated liquid will also be similar to that for the full-scale bioreactor anoxic treatment zone.

When these criteria are satisfied, the air emissions measured from the anaerobic and anoxic enclosed process tanks will provide an accurate qualitatively and quantitatively estimate of, or perhaps just greater than (thus conservatively high), those emissions occurring in the respective full-scale bioreactor anaerobic and anoxic unit processes being tested.

The emissions generated from the two enclosed tanks configured and operated as specified below will reasonably reflect the emissions from the full operating system. From a process engineering perspective these two tanks will function as operating sub-volumes of the anaerobic and anoxic zones of the open system. This similitude has been verified by the process experts on the review team and the team advisor.

Importantly, the use of the enclosed tank sub-volumes avoids the difficulties presented by other alternative approaches to accurately quantifying the estimated emissions from this biological process.

**1.6 Testing Protocol.**

Air emissions to be quantified include ammonia (NH<sub>3</sub>), hydrogen sulfide (H<sub>2</sub>S), volatile organic compounds (VOCs) with non-methane organic carbon (NMOC) also determined, carbon dioxide (CO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>) and methane (CH<sub>4</sub>). Proposed monitoring and testing protocols are provided hereinafter. These parameters and approach proposed have been reviewed by the cooperating engineers and scientists participating in this project or the Review Team and others as noted.

**2.0 DETAILED DESIGN DESCRIPTION OF THE ENCLOSED PROCESS SYSTEMS.**

**2.1 Design Approach.**

Figure 2.1 provides a schematic of the proposed sealed process systems for emissions monitoring. Descriptions of the installed systems follow.

**2.2 Bioreactor Anoxic Zone.**

Design criteria for the full-scale bioreactor anoxic zone are summarized in Table 2.1.

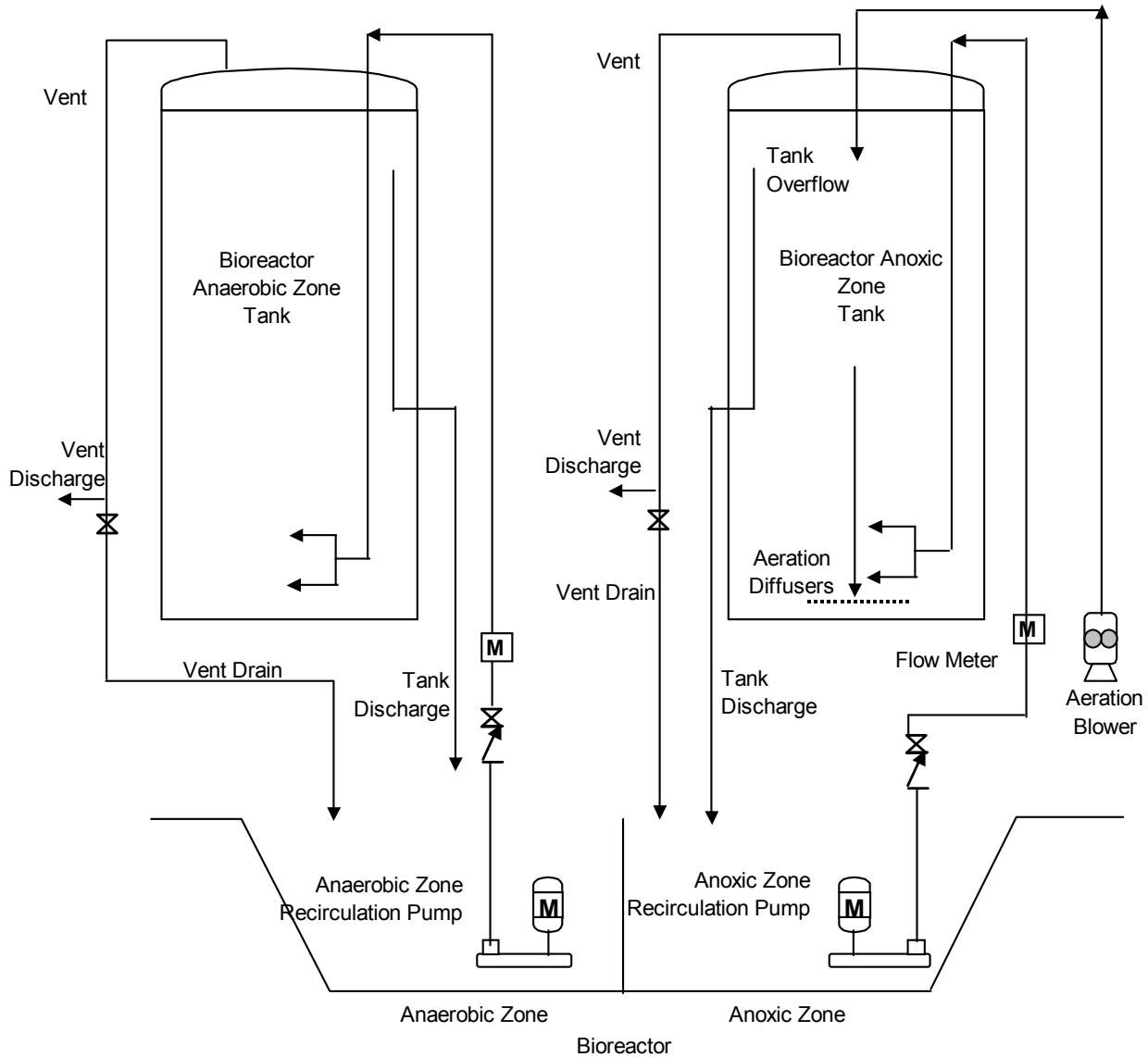
**Table 2.1. Full-Scale Bioreactor Anoxic Zone Design Criteria.**

| <b>Parameter</b>                                                           | <b>Value</b>  |
|----------------------------------------------------------------------------|---------------|
| <b><i>Bioreactor Anoxic Zone:</i></b>                                      |               |
| Volume, gals                                                               | 1,000,000     |
| Depth, ft.                                                                 | 12 to 14      |
| Surface Area, ft <sup>2</sup>                                              | 15,500        |
| Volume (ft <sup>3</sup> )/Surface Area (Ft <sup>2</sup> ) Ratio            | 8.6           |
| Hydraulic Retention Time, days                                             | 18 to 22      |
| Flush Recycle Rate (average), gpm                                          | 200 to 280    |
| Recycle Flow Retention Time, days                                          | 2.5 to 3.5    |
| <b><i>Aeration/Mixing System:</i></b>                                      |               |
| Aeration/Mixing Recirculation Rate, gpm                                    | 4,000 - 6,000 |
| Turnover - Recirculation Rate, minutes.                                    | 170 - 250     |
| Aeration Rate, scfm                                                        | 320 - 500     |
| Aeration Rate per 1,000 ft <sup>3</sup> Volume, scfm/1,000 ft <sup>3</sup> | 2.4 – 3.8     |

As shown in Figure 2.1, flow is pumped from the full-scale bioreactor anoxic zone and discharged into the bottom of an enclosed tank. The tank overflows by gravity discharging back into the bioreactor anoxic zone. The enclosed tank has a single vent through which all gasses introduced through aeration and generated by the process are discharged. The vent serves as the location for sampling, monitoring

and measurement of the off-gas discharge rate. The tank and aeration/mixing system has been sized to permit a variety of operating conditions that mimic conditions in the full-scale bioreactor anoxic zone.

**Figure 2.1 – Air Emissions Enclosed Process System Schematic.**



**2.3 Enclosed Anoxic Zone Emissions Testing Tank.**

**2.3.1 Anoxic Tank Geometry**

The anoxic zone sealed process tank is a 12,250-gallon polyethylene tank having a nominal diameter and overall height of 12-ft. and 17-ft., respectively. The tank overflow is configured to operate at a variety of volumes, depths and volumetric to surface area ratios as shown in Table 2.2.

**Table 2.2 – Anoxic Process Tank Operations Range Data.**

| Operating Volume | Liquid Depth | Surface Area        | Volume to Surface Ratio |
|------------------|--------------|---------------------|-------------------------|
| 6,000-gals       | 7.3-ft.      | 111-ft <sup>2</sup> | 7.2                     |
| 8,000-gals       | 9.6-ft.      | 111-ft <sup>2</sup> | 9.6                     |
| 10,000-gals      | 12.3-ft.     | 111-ft <sup>2</sup> | 12.0                    |
| 12,000-gals      | 14.7-ft.     | 111-ft <sup>2</sup> | 14.4                    |

**2.3.2 Anoxic Tank Aeration and Mixing System.**

Bioreactor process water is transferred to the enclosed anoxic zone process tank by a submersible pump. Flow to the tank is discharged into the bottom of the tank through two discharge nozzles thereby mixing the tank. Air is provided to the tank via a blower and submerged fine bubble diffusers.

- **Aeration Rate.** Air is supplied to the full-scale anoxic zone at a design rate of 320 to 500-scfm or 2.4 to 3.8-scfm/1,000-ft<sup>3</sup> of reactor volume. Aeration rate in the tank will be adjusted via a variable frequency drive on the blower such that steady operating dissolved oxygen levels in the enclosed tank are within ~ 0.3 mg DO/L. Table 2.3 provides aeration rates required in the enclosed process tank to mimic conditions in the full-scale bioreactor anoxic zone.

**Table 2.3 – Anoxic Process Tank Aeration Rates.**

| Operating Volume | Required Air Flow Rate, SCFM |
|------------------|------------------------------|
| 6,000-gals       | 1.9 to 3.0                   |
| 8,000-gals       | 2.6 to 4.1                   |
| 10,000-gals      | 3.2 to 5.1                   |
| 12,000-gals      | 3.8 to 6.1                   |

- **Recirculation Rate.** The contents of the full-scale anoxic zone are “turned over” approximately every 170 to 250 minutes by the aeration and mixing system. Similar design criteria are being used for sizing the pump that will transfer process water from the bioreactor into the enclosed process tank. Pump flow rate will be adjusted to provide appropriate mixing rates for the anoxic tank. Table 2.4 provides an estimate of the range of flow rates that will be required to turn over the contents of the sealed process tank every 170 to 250 minutes at various operating volumes. The design flow rate range required per Table 2.4 is between 25 and 75 gpm. The aeration mixing flows are inside the anoxic bioreactor volume from a process viewpoint. An internal system recycle is created by the flush return from the bioreactor. This recycle flush flows through both the anaerobic and anoxic bioreactor volumes. By pumping to the enclosed anoxic tank as detailed in Table 2.4, flow passes through this unit 14 to 30 times while each recycle flush flow occurs, and from 100 to 190 times for each process hydraulic retention time. This assures that the liquid in the enclosed anoxic tank for air emissions testing and the anoxic bioreactor mixed liquor are essentially an enclosed subset or sub-volume of each other.

**Table 2.4 – Anoxic Process Tank “Turn Over” Rates.**

| Operating Volume | Flow Rate Required to Turn Over Tank Contents Every 170 to 250 minutes, gpm |
|------------------|-----------------------------------------------------------------------------|
| 6,000-gals       | 24 to 35                                                                    |
| 8,000-gals       | 32 to 47                                                                    |
| 10,000-gals      | 40 to 59                                                                    |
| 12,000-gals      | 48 to 71                                                                    |

**2.4 Bioreactor Anaerobic Zone.**

Design criteria for the full-scale bioreactor partial mix anaerobic zone are summarized in Table 2.5.

**Table 2.5. Open Bioreactor Anaerobic Zone Design Criteria.**

| Parameter                                                       | Value      |
|-----------------------------------------------------------------|------------|
| <b><i>Bioreactor Anaerobic Zone:</i></b>                        |            |
| Volume, gals                                                    | 100,000    |
| Depth, ft.                                                      | 12 to 14   |
| Surface Area, ft <sup>2</sup>                                   | 1,550      |
| Volume (ft <sup>3</sup> )/Surface Area (Ft <sup>2</sup> ) Ratio | 8.6        |
| Hydraulic Retention Time, days                                  | 1.8 to 2.2 |
| Flush Recycle Rate (average), gpm                               | 200 to 280 |
| Recycle Flow Retention Time, hours                              | 6 to 8.4   |
| <b><i>Mixing System:</i></b>                                    |            |
| Mixing – Three 0.5 hp Paddle Mixers, hp/1,000-ft <sup>3</sup>   | 0.1        |

As shown in Figure 2.1, flow is pumped from the full-scale bioreactor anaerobic zone and discharged into the bottom of the enclosed process tank. The enclosed process tank overflows by gravity, discharging back into the full-scale bioreactor anaerobic zone. The enclosed tank is equipped with a single vent through which atmospheric discharges are sampled, monitored and measured. The enclosed process tank is sized to permit a variety of operating conditions. The tank is mixed via a jet mixing system (no aeration) to provide hydraulic retention time and mixing intensity similar to those in the full-scale bioreactor anaerobic zone.

**2.5 Enclosed Anaerobic Zone Emissions Testing Tank.**

**2.5.1 Anaerobic Emissions Testing Tank**

The anoxic zone sealed process tank is a 12,250-gallon polyethylene tank having a nominal diameter and overall height of 12-ft. and 17-ft, respectively. The tank overflow is configured to operate at a variety of volumes, depths and volumetric to surface area ratios as shown in Table 2.6. The transfer pump and mixing system are similar to that for the anoxic zone tank. Pump flow rate may be varied to provide appropriate hydraulic retention times and mixing rates.

**Table 2.6 – Anaerobic Process Tank Operations Range Data.**

| Operating Volume | Liquid Depth | Surface Area        | Volume to Surface Ratio |
|------------------|--------------|---------------------|-------------------------|
| 6,000-gals       | 7.3-ft.      | 111-ft <sup>2</sup> | 7.2                     |
| 8,000-gals       | 9.6-ft.      | 111-ft <sup>2</sup> | 9.6                     |
| 10,000-gals      | 12.3-ft.     | 111-ft <sup>2</sup> | 12.0                    |
| 12,000-gals      | 14.7-ft.     | 111-ft <sup>2</sup> | 14.4                    |

**2.5.2 Anaerobic Emissions Testing Tank Mixing and Hydraulic Retention.**

The contents of the full-scale anaerobic zone are replaced approximately every 6 to 8 hours by influent flow to the system. Similar design criteria were used for sizing the pump that transfers process water from the bioreactor into the sealed process tank. The full-scale anaerobic zone is also mixed at a rate of 0.1hp/1,000-ft<sup>3</sup> of volume. This mixing rate is very low and only serves to inhibit short-circuiting of the

anaerobic zone by influent flow. Since the mixed liquor is at concentrations between 2% to 3% that does not settle significantly even over a quiescent 24 hour period, mixing energies normally associated with biological systems are not required. Settleometer tests reveal settling of less than 5% over the standard 30 minute time period and only a maximum of about 10% when left for 24 hours. Given the small amount of mixing energy used in the full-scale system, the transfer pump flow rate will be adjusted to provide appropriate detention times and mixing rates for the anaerobic tank. Table 2.7 provides an estimate of the range of flow rates that will be required to replace the tank volume every 6 to 8 hours. The transfer pump will be designed to transfer flow to the anaerobic zone tank at rates up to 50-gpm.

**Table 2.7 – Anaerobic Process Tank “Turn Over” Rates.**

| <b>Operating Volume</b> | <b>Flow Rate Required to Turn Over Tank Contents Every 6 to 8 hours, gpm</b> |
|-------------------------|------------------------------------------------------------------------------|
| 6,000-gals              | 13 to 17                                                                     |
| 8,000-gals              | 16 to 22                                                                     |
| 10,000-gals             | 21 to 28                                                                     |
| 12,000-gals             | 25 to 33                                                                     |

### **2.5.3 Anaerobic Emission Testing Tank Headspace Ventilation**

Emission rates from process occurring in the anaerobic emission testing tank could be well below 1 ft<sup>3</sup>/hr. At such low anaerobic tank emission rates there is potential for the elevated partial pressures that may occur (gas concentrations in the headspace) to suppress the rate of evolution compared to the full-scale system which is open to the atmosphere. Henry’s law would indicate that both the liquid dissolved equilibrium concentrations and rate of emissions may impact the quantity emitted. By providing ventilation of the headspace with ambient atmospheric gas, this issue may be resolved.

A ventilation fan has been installed with the capacity to provide 12 turnovers per hour, (or more), of the headspace volume. However, the flow rate will be adjusted to much lower turnover rates, perhaps in the range of two to four turnovers per hour. The rate selected for the sampling runs will be determined by the concentrations and quantities obtained for the various parameters over a period of at least two liquid volume turnovers in the emissions testing tank, or as directly advised by the Review Team air emission specialists. The desired rate would be low enough to allow maximum parameter concentrations to enhance the accuracy of emissions measurements and high enough to minimize or significantly negate any suppression of emission rates.

## **3. SAMPLING AND MONITORING PROGRAM.**

### **3.1 General approach**

Primary emissions quality and quantity will be determined using rigorous laboratory analysis of composite samples for parameter concentrations and hot wire anemometers for quantities. Samples shall be collected in a manner such that they are representative of the off gas streams generated. All off gas samples are to be collected in accordance with applicable air quality management district requirements and / or standard protocols. The system as a whole contains approximately 1.1 million gallons of process liquid. The system hydraulic retention time is around 20 days with an internal recycle of nearly 10:1. The number of cows does change somewhat but very gradually. The monitored parameters for

the liquids and solids discharged from such a large slow rate system with regular loading remain fairly constant and do not change rapidly during steady operation. It is anticipated that air emissions will also be steady.

Supplemental in-situ grab samples will be taken to establish a baseline for on-site monitoring, provide some measure of emission variability, and provide a rough check to laboratory analysis results. These samples will always be collected in parallel to the laboratory composite sampling. Based upon the results from emissions monitoring at Bion's pilot scale facility, Table 3.1 presents the anticipated concentration ranges for the various parameters.

**Table 3.1 – Anticipated emission concentrations expected.**

|                                    |                          |
|------------------------------------|--------------------------|
| Ammonia                            | 30 ppm                   |
| Oxygen                             | 19.13%                   |
| Carbon dioxide                     | 1.41%                    |
| Combustible gas (pentane standard) | 2.67% of LEL             |
| NOx                                | Non-detect               |
| Hydrogen sulfide                   | Non-detect to 101.12 ppm |

### **3.2 Sampling for Laboratory Analyses**

#### **3.2.1 Weekly sampling**

Samples will be collected following USEPA standard operating procedure 1704 (USEPA/SOP # 1704) for samples collected as whole ambient air samples collected in Summa passivated stainless steel canisters. Two six-liter Summa canister 24-hour composites will be collected normally from Monday  $\pm 1600$  to Tuesday  $\pm 1600$  to Wednesday  $\pm 1600$ .

#### **3.2.2 Inspection sampling**

One one-liter Summa canister 3 hour composite taken within the 24-hour canister period that is observed by team and / or regulatory personnel during inspection visits.

#### **3.2.3 Area whole air samples**

On a single designated sampling day **four additional samples** shall be collected to determine air quality influenced by the circulating process water or recycled flush water.

**1 & 2)** Active flushing and draining of alleys occurs on approximately 30-minute cycles.

Twenty-minute canister grab samples shall be taken at two locations along an actively flushing alley for two separate sampling weeks

**3)** A one-hour canister grab sample shall be taken below the rim of the coarse screen sump or contact / mixing tank at an elevation one foot above the maximum flush water elevation. Flow from this sump travels over an elevated inclined coarse screen. The vertical down-flow effluent pipe from this screen produces a continuous vacuum draw through the screen. These gasses are

released in the flow splitter box adjacent to the fine screens. 4) A one-hour grab canister will be sampled from the splitter box headspace during active coarse screen flow.

### **3.3 In-Situ Sampling & Analysis**

#### **3.3.1 Emission Quantification**

The quantity of emissions being produced from each emissions testing tank shall be determined at least twice at four-hour intervals on the canister sampling days using a hot wire anemometer inserted directly into the vent to determine flow rate.

#### **3.3.2 Supplemental on-site analysis**

Grab samples are to be collected from vents and other locations. Vent grabs are to be taken at least twice during the two canister sampling composites. On-site air analyses will be obtained using the instruments and protocols outlined in Section 4. These samples are to provide on-site checks and additional data to augment the more rigorous canister sample laboratory analyses.

## **4. LABORATORY PROCEDURES**

Time composite samples (24, 3, 1 and 0.5-hour canisters) of gasses discharged from the vents of both enclosed vessels will be collected two times per week, with collection of additional area whole air samples (as detailed in Section 3 above) then all will be analyzed for the following parameters. All analyses will be performed by an independent commercial laboratory using the collected gas from the Summa canisters and following the specific protocols noted in Section 4.1. Test procedures to be utilized in analyzing the samples are summarized in Table 4.1. **All Summa canister evacuation, cleaning, parameter measurement calibration, parameter QA/QC and certification of meters will comply with USEPA TO15.**

**Table 4.1. Laboratory Procedures and Process Monitoring.**

| <b>Monitoring Parameter</b>         | <b>Test Method</b>                                 |
|-------------------------------------|----------------------------------------------------|
| In-situ Process Monitoring          |                                                    |
| Air & Vent Flow Rate                | Hot wire anemometer                                |
| Temperature                         | Probe & Meter                                      |
| Laboratory Procedures               |                                                    |
| Hydrogen Sulfide (H <sub>2</sub> S) | EPA EMC Method 18                                  |
| Volatile Organic Compounds (VOC's)  | EPA EMC Method 18                                  |
| Nitrogen Oxides                     | OSHA approved Drager sample tubes<br>ASTM-SP D4913 |
| Methane                             | EPA EMC Method 18                                  |
| Carbon Dioxide (CO <sub>2</sub> )   | EPA EMC Method 18                                  |
| Ammonia (NH <sub>3</sub> )          | OSHA approved Drager sample tubes<br>ASTM-SP D4913 |

The above procedures and analyses will be performed on all Suma canisters collected. Table 4.2 summarizes the dates, locations and composite duration time for the samples to be taken.

**Table 4.2 Laboratory Sampling Summary**

| Location / Dates           | Laboratory Summa Canisters, hours composite |      |     |      |      |      |      |      |      |
|----------------------------|---------------------------------------------|------|-----|------|------|------|------|------|------|
|                            | 3/31                                        | 4/6  | 4/7 | 4/14 | 4/15 | 4/20 | 4/21 | 4/27 | 4/28 |
| <b>Anaerobic tank vent</b> |                                             |      |     |      |      |      |      |      |      |
| <b>Normal</b>              | 24                                          | 24   | 24  | 24   | 24   | 24   | 24   | 24   | 24   |
| <b>Inspection</b>          |                                             |      |     |      | 3    |      |      |      | 3    |
| <b>Anoxic tank vent</b>    |                                             |      |     |      |      |      |      |      |      |
| <b>Normal</b>              | 24                                          | 24   | 24  | 24   | 24   | 24   | 24   | 24   | 24   |
| <b>Inspection</b>          |                                             |      |     |      | 3    |      |      |      | 3    |
| <b>Flush alley loc 1</b>   |                                             | 0.33 |     |      | 0.33 |      |      |      | 0.33 |
| <b>Flush alley loc 2</b>   |                                             | 0.33 |     |      | 0.33 |      |      |      | 0.33 |
| <b>Mix / contact sump</b>  |                                             | 1    |     |      | 1    |      |      |      | 1    |
| <b>Splitter box</b>        |                                             | 1    |     |      | 1    |      |      |      | 1    |

The figures shown indicated the composite time for sampling in hours.  
*Potential second inspection samples.*

## **4.1 Ammonia**

### **4.1.1 Laboratory**

A 100 ml sample of whole air drawn from the Summa canisters will analyzed using Drager Sample Tubes (following ASTM Standard Practice D 4913 for Determining Concentration of Hydrogen Sulfide by Direct Reading, Length of Stain, or Visual Detectors). This is an OSHA approved method with a color change appearing along a graduated scale. Unlike electronic instrumentation, reaction stoichiometry negates requirement for calibration. Two ranges and sensitivities will be available. The low concentration range is 0.2-5.0 ppm ( $\pm 10\%$  of reading as measured) for a minimum accuracy of 0.5 ppm; and an upper range of 2-50 ppm ( $\pm 8\%$  of reading as measured) for a minimum accuracy of 4 ppm.

### **4.1.2 In-situ**

A digital CMS Detector Chip Analyzer will be used (following ASTM Standard Practice D 4913 for Determining Concentration of Hydrogen Sulfide by Direct Reading, Length of Stain, or Visual Detectors). The sample variability of this method is expected to be on the order of 5% to 10% with sample resolution of 1 ppm or better anticipated. Two sensitivity ranges of CMS chips will be available for use. The low range of 0.2 – 5.0 ppm (10% of reading as measured) has a minimum accuracy of 0.5 ppm and an upper range of 2-50 ppm (8% of reading as measured) for a minimum accuracy of 4 ppm.

## **4.2 Hydrogen Sulfide**

### **4.2.1 Laboratory**

Using whole air from a summa canister and EPA method 18, instrumentation involves use of Gas Chromatography, Mass Spectroscopy, Flame Induced Detection and Total Carbon Detections. Accuracies of better than 1 ppb are expected.

#### **4.2.2 In-situ**

A digital CMS Detector Chip Analyzer will be used (following ASTM Standard Practice D 4913 for Determining Concentration of Hydrogen Sulfide by Direct Reading, Length of Stain, or Visual Detectors). This is a chemical method with a color change appearing along a graduated scale. Unlike electronic instrumentation, reaction stoichiometry negates requirement for calibration gases. CMS chips with a range of 20-500 ppm range ( $\pm 8\%$  of reading as measured) will be used. Accuracies of better than 4 ppm are expected.

### **4.3 Volatile Organic Compounds**

#### **4.3.1 Laboratory**

Whole air samples from a Summa canister will be used following EPA method 18, instrumentation involves use of Gas Chromatography, Mass Spectroscopy, Flame Induced Detection and Total Carbon Detection. A lump sum or non-specified VOC figure will be provided, however, data will be stored in a manner such that the VOCs may be specified if desired. Minimum accuracies in the 1 part per billion (ppb) range are expected with method and equipment employed.

#### **4.3.2 In-situ VOC**

No in-situ VOC measurements are to be performed during this program. The quantity of VOC emissions determined from the laboratory composite sampling performed will be used to consider whether supplemental in-situ grabs samples are needed.

### **4.4 Carbon Dioxide**

#### **4.4.1 Laboratory**

Whole air samples from a Summa canister will be used following EPA method 18, instrumentation involves use of Gas Chromatography, Mass Spectroscopy, Flame Induced Detection and Total Carbon Detection. Minimum accuracies in the 1 part per billion (ppb) range are expected with method and equipment employed.

#### **4.4.2 In-situ**

A Telaire 7001 Carbon Dioxide monitor will be employed with a 1PPM sensitivity and a  $\pm 50$ PPM accuracy. In addition, a CMS Detector Chip Analyzer will be used for concentrations greater than one percent following procedures described in ASTM D 4599 Standard Practice for Measuring the Concentration of Toxic Gases or Vapors Using Length-of-Stain Dosimeters.

## **4.5 Nitrogen Oxides**

### **4.5.1 Laboratory**

A 100 ml sample of whole air drawn from the Summa canisters will be analyzed for nitric oxide (NO) and nitrogen dioxide (NO<sub>2</sub>) using Drager Sample Tubes (following ASTM Standard Practice D 4913 for Determining Concentration of Hydrogen Sulfide by Direct Reading, Length of Stain, or Visual Detectors). This is an OSHA approved method with a color change appearing along a graduated scale. Unlike electronic instrumentation, reaction stoichiometry negates requirement for calibration. Accuracies of better than 4 ppm are expected on all samples. Two ranges and sensitivities will be available. The low concentration range is 0.5-10 ppm ( $\pm 15\%$  of reading as measured) for a minimum accuracy of 1.5 ppm; and an upper range of 2-100 ppm ( $\pm 8\%$  of reading as measured) for a minimum accuracy of 8 ppm.

### **4.5.2 In-situ**

A digital CMS Detector Chip Analyzer will be used (following ASTM Standard Practice D 4913 for Determining Concentration of Hydrogen Sulfide by Direct Reading, Length of Stain, or Visual Detectors). This is a chemical method with a color change appearing along a graduated scale. Unlike electronic instrumentation, reaction stoichiometry negates requirement for calibration gases. A CMS chip will be used with a range of 0.5 – 15 ppm ( $\pm 8\%$  of reading as measured) for NO<sub>2</sub> and NO giving an expected minimum accuracy of 0.6 ppm.

## **4.6 Methane**

### **4.6.1 Laboratory**

Whole air samples from a Summa canister will be used following EPA method 18, instrumentation involves use of Gas Chromatography, Mass Spectroscopy, Flame Induced Detection and Total Carbon Detection. Minimum accuracies in the 1 part per billion (ppb) range are expected with method and equipment employed.

### **4.6.2 In-situ**

An LEL MSA Solaris detector will be used to determine methane concentrations in off gases. This detector complies with 30CFR part 22 for methane detection in mining operations. This instrument will be calibrated weekly with 50 percent LEL certified methane standard. Resolution is 0.05% CH<sub>4</sub> LEL or 500 ppm methane.