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February 28, 2019

U.S. Environmental Protection Agency
Office of Ecosystem Protection
EPA/OEP NPDES Applications Coordinator
5 Post Office Square - Suite 100 (OEP06-03)
Boston, MA 02109-3912

Ref: Gris WWTP Nitrogen Removal Optimization

To Whom it May Concern:

On behalf of Barnhardt Manufacturing Company. Please find attached "Treatment Plant Optimization for Nitrogen Evaluation" as required by NPDES Permit No. MA0003697 Part 1.B.2.

An attempt to email this report to R1NPDES.Notices.OEP@epa.gov failed.

If you have any questions or need additional information, please feel to contact me or either Mr. Tom Robinson or Mr. Greg Morand at the numbers shown below.

Tom Robinson, Barnhardt Mfg., Phone: 704-376-0380

Greg Morand, Omni Environmental, Phone: 978-256-6766, Ext. 102

Sincerely,

W. Gilbert O'Neal

W. Gilbert O'Neal, Ph.D., P.E.
President

Cc: Greg Morand, Omni Environmental Group
Tom Robinson, Barnhardt Mfg.

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February 28, 2019

Mr. Tom Robinson
Director of Operations and Product Development
Barnhardt Manufacturing
1100 Hawthorne Lane
Charlotte, NC 28205

Delivered by EMAIL

Ref: Gris WWTP Nitrogen Removal Optimization

Dear Tom:

Please find attached my report regarding opportunities for operational changes that can be made to reduce the total nitrogen content in the effluent from the Gris Wastewater Treatment Plant located in Colrain, MA. This evaluation was required under the discharge permit MA003697 for discharge into the North River.

As explained in the report, the existing wastewater treatment system is being operating efficiently and no operational changes that would significantly reduce the concentration of effluent total nitrogen were identified. Attempts to establish anoxic conditions within the existing treatment system without proper mixing and control may compromise the treatment system efficiency with respect to both carbonaceous material removal and nitrification. To provide additional total nitrogen removal, significant capital expenditures would be required for denitrification.

Feel free to contact me if you have any questions or need additional information.

Sincerely,

W. Gilbert O'Neal

W. Gilbert O'Neal, Ph.D., P.E.
President

Cc: Greg Morand, Omni Environmental Group
Mark Thibodeau, Barnhardt Mfg.
Rebecca Israel, Barnhardt Mfg.
Susan King, MassDEP
USEPA, EPA/OEP NPDES Applications Coordinator
Keith Gammell, Barnhardt Mfg.
Larry Couch, Barnhardt Mfg.
Lewis Barnhardt, Barnhardt Mfg.
Kimberly Groff, MassDEP

Treatment Plant Optimization for Nitrogen Evaluation

Barnhardt Manufacturing Company
Colrain, MA

Prepared by:
Applied Technology and Engineering, PC.
W. Gilbert O'Neal, Ph.D., P.E.

February 28, 2019

Background

Barnhardt Manufacturing operates a cotton bleaching plant located at 247 Main Road, Colrain, MA, 01240. Wastewaters discharged from the facility and from the Village of Griswoldville are treated at Barnhardt's wastewater treatment plant (WWTP) using extended aeration biological treatment. The WWTP operates in accordance with the NPDES Permit No. MA003697 and discharges to the North River. Wastewater from the bleaching operation has a relatively high concentration of nitrogen with an annual average total nitrogen load to the receiving stream estimated to be 67.3 lbs/day.

The reissued permit, dated 3/1/18, requires that an evaluation be performed of the alternative methods of operating the existing WWTP to optimize the removal of nitrogen, and to submit a report to EPA and MassDEP documenting the evaluation. Recommended operational changes are required to be implemented in order to maintain the existing mass discharge loading of total nitrogen, which will be measured as an annual average. The report is to also include documentation of the annual nitrogen discharge load from the facility and how that load compares to previous years. This report is intended to address these requirements.

Description of the Existing WWTP

A flow schematic of the WWTP is provided in Appendix A. The WWTP was designed for a capacity of 1.3 million gallons per day (mgd). Wastewater from the Gris Plant, including bleaching, sanitary and other wastewaters, and wastewater from the Village of Griswoldville are combined and pumped through screens to remove fiber and other coarse solids. Screened wastewater flows to the extended aeration activated sludge plant which consists of two aeration basins and two secondary clarifiers. Each aeration basin provides a hydraulic capacity of around 1.65 million gallons (MG) and can be operated independently. Fine bubble diffusers are provided for aeration and mixing. Each clarifier has a diameter of 55 feet and can be operated in parallel or individually. Clarifier effluent flows are combined and pass through a metering station to the discharge point. A belt filter press is used for sludge dewatering.

Current Operating Performance

A summary of selected operating parameters is shown in Table I for the calendar year 2018. Flows and loadings to the WWTP are well below the design criteria with the effluent flow averaging only 0.323 mgd compared to the 1.3 mgd design flow. With respect to the biological system performance for carbonaceous materials, the average Chemical Oxygen Demand (COD) and Five-day Biochemical Oxygen Demand (BOD_5) concentrations are reduced by 87% and 99%, respectively. This represents a high level of treatment efficiency. Effluent TSS concentrations are well within permit limits averaging 24 mg/L. For nitrogenous materials, the total nitrogen percent removal was 39%. However, 74% of the Total Kjeldahl Nitrogen (TKN) was removed. The relatively high total nitrogen remaining is due to nitrification and an increase in nitrite and nitrates which represent 62% of the final effluent.

The concentrations of nitrogen compounds from influent sources and the final effluent are shown in Figure 1. The mass contributions are shown in Figure 2. Over 89% of the total nitrogen loading originates from the bleaching area. While the nitrogen concentrations from the Village are high, the flow is low contributing only 1% of the total influent nitrogen loading.

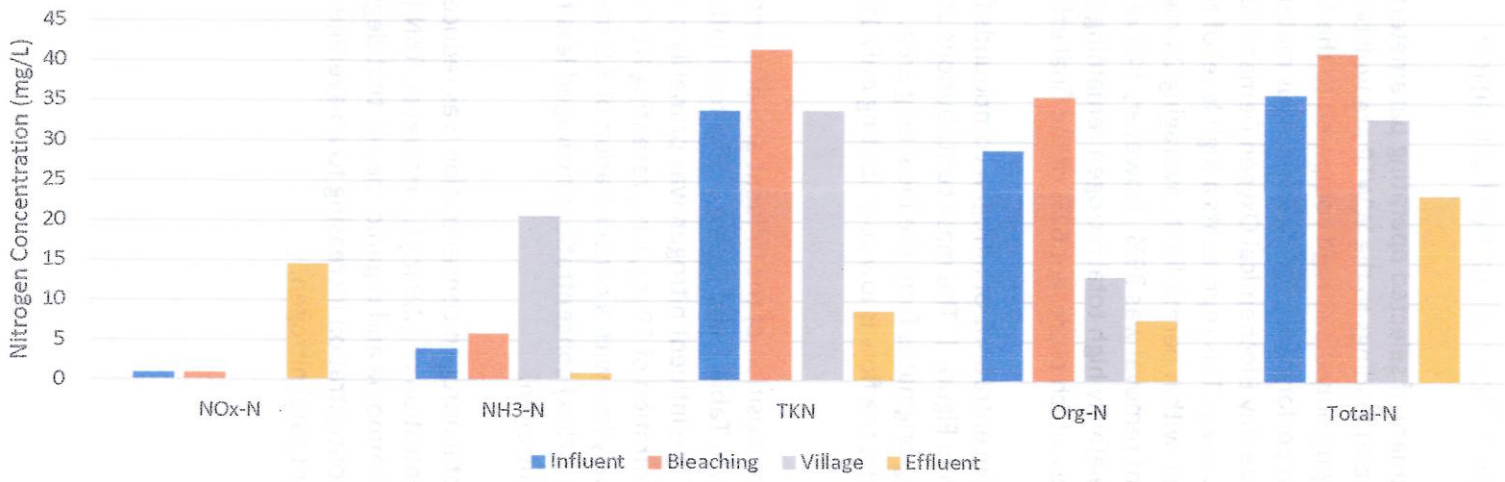
The composition of the influent and effluent nitrogen as a percentage of the respective totals is shown in Table 2 and Figure 3. The total influent nitrogen concentrations average 119 mg/L in 2018. The influent nitrogen was primarily present as organic nitrogen with an average concentration of 29 mg/L representing 81% of the total. Influent ammonia concentrations were relatively low with a concentration of 3.9 mg/L representing 11% of the total. Nitrite and Nitrate (NOx) concentrations averaged less than 1 mg/L representing only 3% of the influent total nitrogen.

The total nitrogen concentration was reduced by only 39% across the WWTP with an effluent concentration of 72.9 mg/L. However, TKN (ammonia plus organic nitrogen) was reduced by 74%. Ammonia and organic species that degrade to ammonia were nitrified with the effluent NOx concentration increasing to an average of 14.5 mg/L. NOx represented 62% of the final effluent total nitrogen.

Table I. Summary of Selected WWTP Operating Parameters

		Influent		Bleaching		Village		Effluent	
Parameter	Units	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Flow	mgd			0.182	0.407	0.005		0.323	0.757
COD	mg/L	1349	2480	2061	3350	234	978	176	334
BOD	mg/L	432	1200	523	1200	84	180	6	30
TSS	mg/L	28	88	30	80	99	960	24	119
NOx-N	mg/L	0.9	1.5	0.9	1.5	0.1	0.5	14.5	38.7
NH3-N	mg/L	3.9	12.1	5.8	9.1	20.6	46.2	0.9	6.3
TKN	mg/L	33.8	82.9	41.5	70.8	33.8	111	8.7	16.5
Org-N	mg/L	29	70.8	35.7	61.7	13.1	67.2	7.7	14.6
Total-N	mg/L	36	83.7	41.2	64.3	33	111.5	23.4	54.9
Total-N	lbs/d	119	262	106	172.3	1.4	4.6	72.9	202.3

Figure 1. Nitrogen Concentrations for Influent Sources and Final Effluent



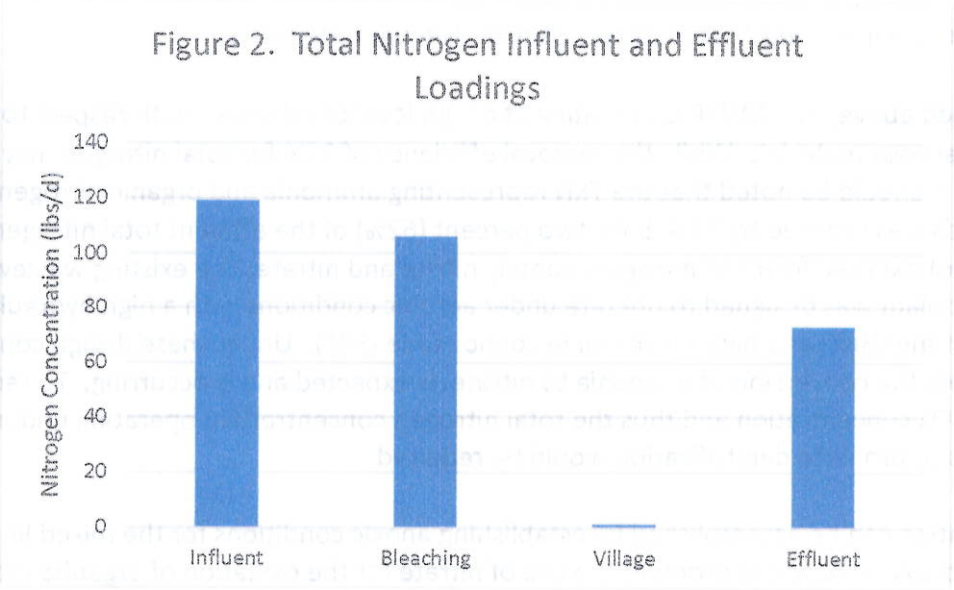
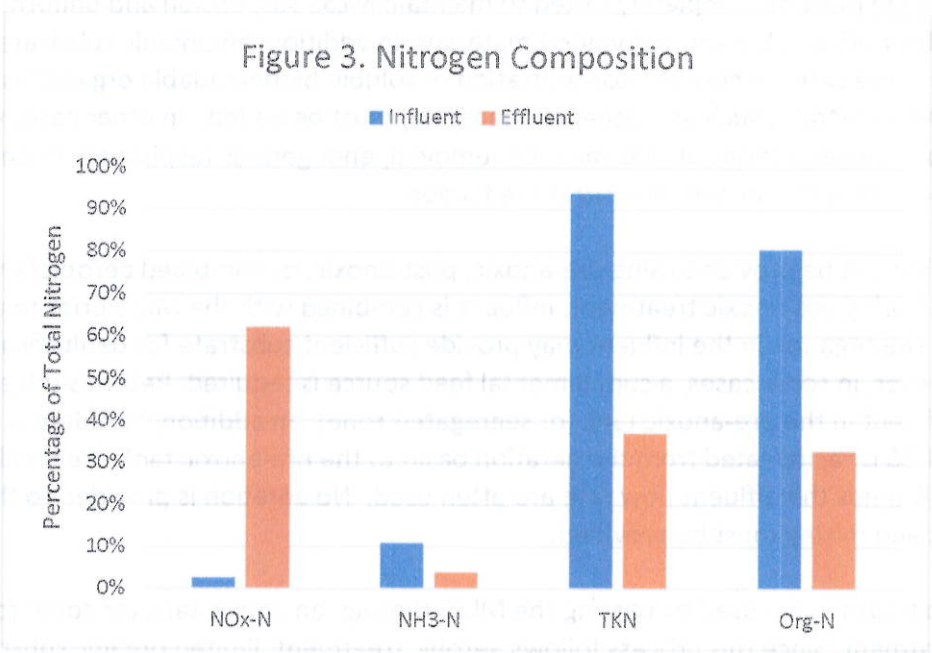


Table 2: Percent Composition of Nitrogen Species for Influent and Effluent

	Influent	Effluent
NOx-N	3%	62%
NH3-N	11%	4%
TKN	94%	37%
Org-N	81%	33%



Evaluation of Operating Methods to Optimize Nitrogen Removal

As discussed above, the WWTP is operating at a high level of efficiency with respect to removal of carbonaceous materials. While the removal efficiency of 39% for total nitrogen may appear to be low, it should be noted that the TKN representing ammonia and organic nitrogen compounds was reduced by 74%. Sixty-two percent (62%) of the effluent total nitrogen consisted of oxidized forms of nitrogen, namely nitrite and nitrate. The existing wastewater treatment plant was designed to operate under aerobic conditions with a high hydraulic retention time (HRT) and high mean cell residence time (SRT). Under these design conditions, nitrification, the conversion of ammonia to nitrate, is expected and is occurring. To reduce the effluent NOx concentration and thus the total nitrogen concentration, operating under anoxic conditions to promote denitrification would be required.

Denitrification can be accomplished by establishing anoxic conditions for the mixed liquor suspended solids (MLSS) to promote the use of nitrate for the oxidation of organics rather than oxygen.

During denitrification, nitrate is converted to nitrogen gas by heterotrophic bacteria. This is accomplished in an anoxic zone in which there are low oxygen conditions with dissolved oxygen concentrations less than 0.2 mg/L. This process is represented by the following simplified reaction:

$$NO_3 + \text{Organics} \rightarrow N_2(\text{gas}) + CO_2 + H_2O + OH + \text{New Cells}$$

The anoxic zone must be completely mixed to maintain MLSS suspension and uniform conditions for both soluble and suspended materials. In addition, an organic substrate must be present. In some cases, where the concentration of soluble biodegradable organics is low, a supplemental substrate, such as methanol or acetate, must be added. In other cases where relatively low concentrations of NOx must be removed, endogenous respiration, or cell decay, may provide sufficient substrate for nitrate reduction.

Denitrification can be provided using pre-anoxic, post-anoxic, or combined aerobic/anoxic processes. During pre-anoxic treatment, influent is combined with the MLSS prior to aerobic treatment. The organics in the influent may provide sufficient substrate for denitrification to occur. However, in some cases, a supplemental feed source is required. Return sludge is mixed with the influent in the pre-anoxic tank (or segregated zone). In addition, to enhance nitrate removal, MLSS is recirculated from the aeration basin to the pre-anoxic tank. Recirculation rates up to 4 times the effluent flow rate are often used. No aeration is provided to the pre-anoxic tank and mixing must be provided.

Post-anoxic treatment is used by passing the MLSS through an anoxic tank (or zone) following aerobic treatment. Since this process follows aerobic treatment, limited organic substrate is

available. In some cases, sufficient endogenous respiration occurs to allow limited denitrification. However, it is common to provide an organic supplemental feed source to improve nitrate removal. Again, no aeration is provided to the post-anoxic tank and mixing must be provided.

Denitrification has also been accomplished in combined aerobic and anoxic systems. This can be accomplished in sequencing batch reactors, oxidation ditches and completely mixed systems which are designed to expose the MLSS to cyclical aerobic and anoxic conditions. In completely mixed systems, dissolved oxygen and/or oxidation reduction potential (ORP) controls are provided to alternate the MLSS between aerobic and anoxic conditions. Mixing must be provided at all times during this process.

While sufficient volume is provided to establish anoxic conditions at the Gris WWTP, the EXISTING facilities do not provide sufficient mixing to maintain MLSS suspension without use of the diffused aeration system. In cases where high oxygen uptake rates are experience in the aeration basin, low airflow rates have been used to maintain mixing under anoxic conditions. However, the fine bubble diffusers installed in the WWTP aeration basins do not provide sufficient mixing under low airflow conditions. Even under normal aeration conditions, settling of solids can be observed in different areas of the aeration basins. Further, equipment for controlling blower speed and dissolved oxygen are not available. To provide anoxic treatment, additional equipment such as mixers, recirculation pumps for pre-anoxic treatment, chemical feed equipment for post-anoxic treatment and control systems will be required.

Reduction of ammonia and organic nitrogen could also reduce the effluent total nitrogen concentration. Ammonia concentrations are reduced through nitrification that converts ammonia to nitrate. In addition, some forms of organic nitrogen are converted to ammonia which is then nitrified. As presented above, the existing system is demonstrating nitrification through the removal of ammonia to and average concentration of less than 1 mg/L and the production of nitrate. More consistent nitrification of ammonia to concentrations less than 0.5 mg/L may be achievable, however, without the ability to denitrify, this would not result in a significant reduction of total nitrogen in the effluent. Additional reduction in organic nitrogen would also be difficult. Low effluent COD and BOD_5 concentrations indicate that even under long HRT conditions, the effluent organic fractions are not readily biodegradable. Removal of additional organics and organic nitrogen could likely be accomplished using chemical coagulation or other tertiary treatment processes. However, this cannot be accomplished with EXISTING equipment and would require significant capital investment.

Annual Nitrogen Discharge Load

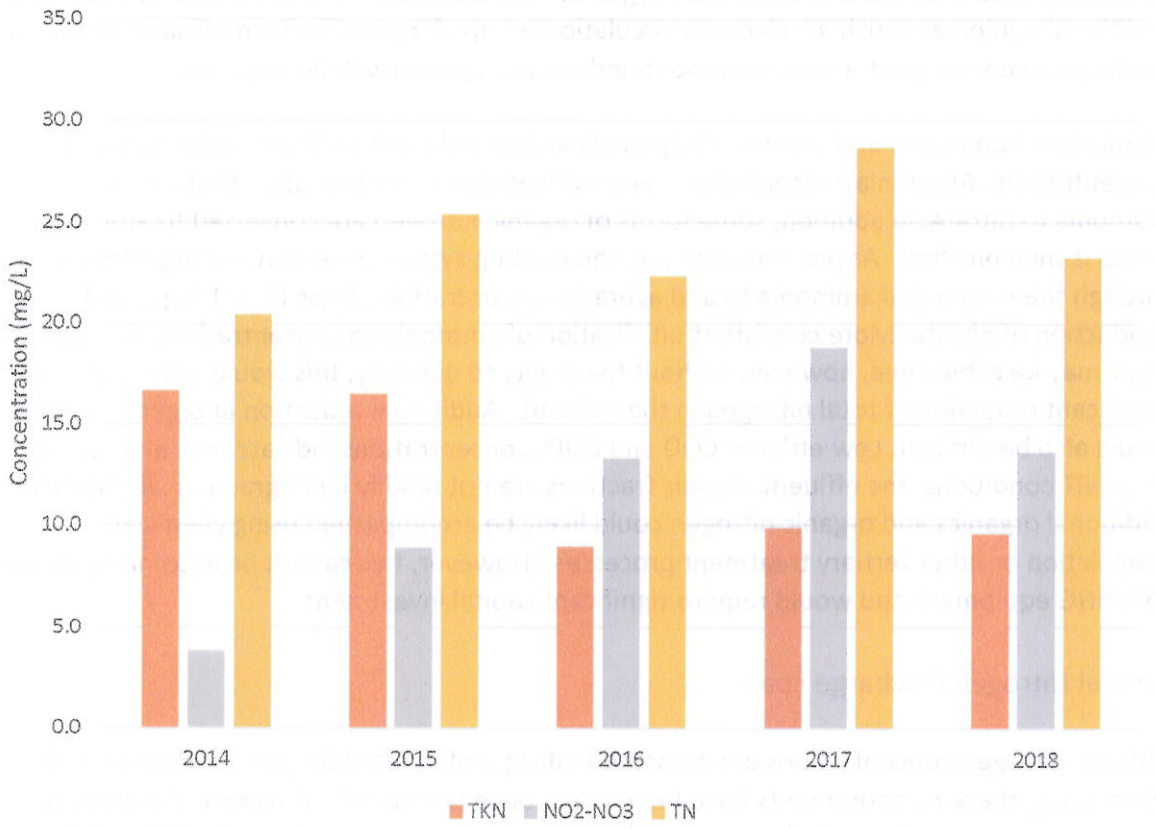
Effluent nitrogen concentrations are measured infrequently based on permit requirements. Historically, these measurements have been made once per month. However, the current month requires monitoring twice per month. The reported concentrations for TKN, nitrite-nitrate, and TN are shown in Table 3 for the period of 2014 through 2018. Total nitrogen is assumed to be the sum of TKN and nitrite-nitrate concentrations. Concentrations are also

shown in Figure 4. In 2016, an improvement in TKN removal was observed with concentrations being reduced from over 16 mg/L to below 10 mg/L. An increase in nitrate-nitrate concentrations was also observed, presumably due to an increase in nitrification. The average TN concentration for the 5-year period was 24 mg/L.

Table 3. Summary of Annual Average Nitrogen Concentrations

	Flow	TKN	NO2-NO3	TN	TN Mass
	Mgd	mg/L	mg/L	mg/L	lbs/day
2014	0.354	16.6	3.8	20.5	60.3
2015	0.405	16.5	8.9	25.4	85.7
2016	0.259	9.0	13.3	22.3	48.2
2017	0.224	9.9	18.8	28.6	53.5
2018	0.343	9.6	13.6	23.2	66.4
Average	0.317	12.3	11.7	24.0	62.8

Figure 4. Nitrogen Fractions

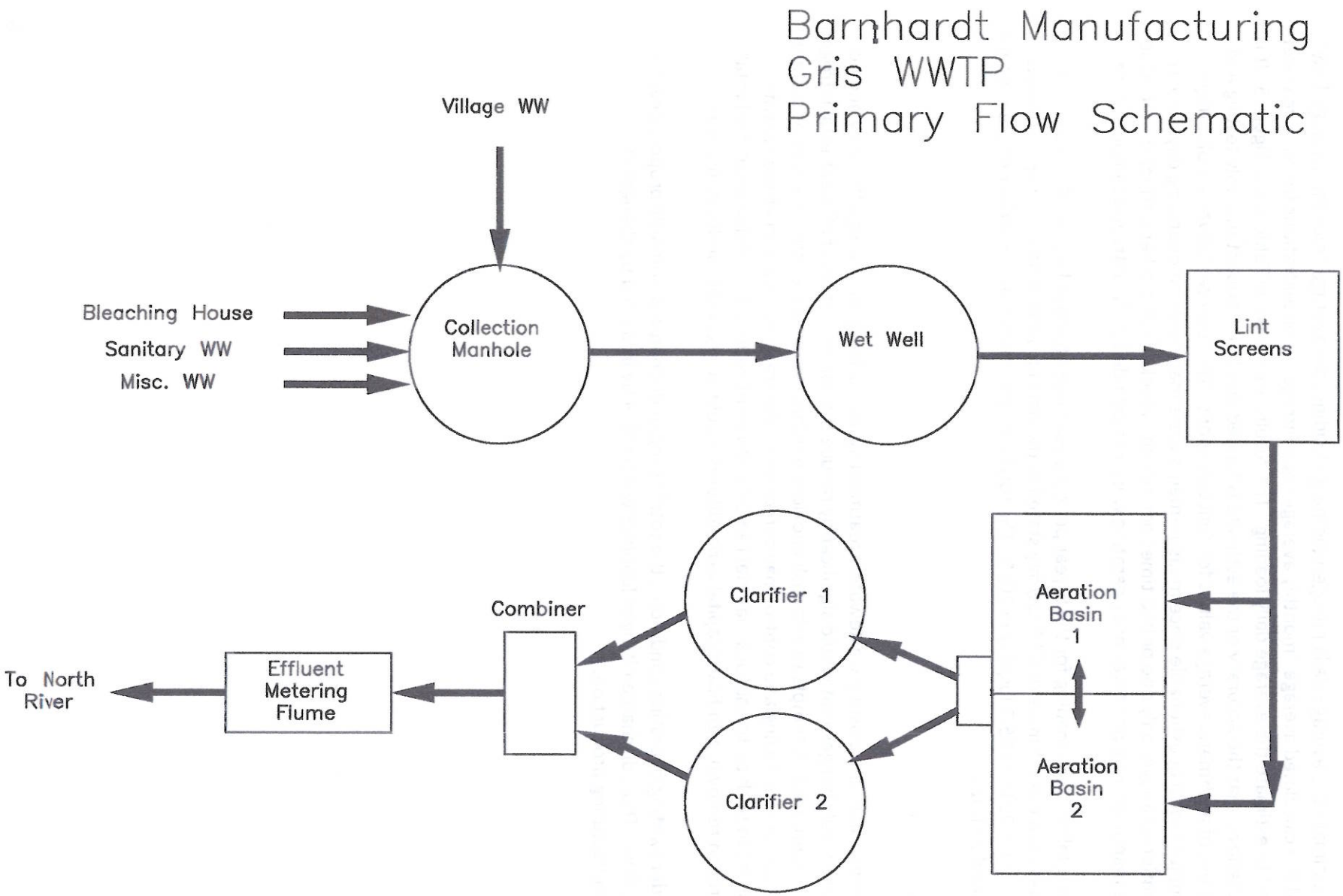


To estimate the average daily nitrogen discharge loading, the average "monthly average flow" and the calculated average "monthly average total nitrogen" concentrations for each year were used to estimate the average daily loading. The results are shown in Table 3 and Figure 5. It is recognized that the accuracy of the estimate is limited due to infrequent monthly testing and the use of arithmetic average values for concentrations. The representativeness of nitrogen samples is also questionable since measurements were made only on operating days and as mentioned above, only one or two times per month. Weekend and other periods during which the manufacturing plant was not operating were not included in the nitrogen sampling data.

The total nitrogen loading for the 5-year period is estimated to have been 62.8 lbs/day. This is lower than the estimate of 67.3 lbs/day stated in the permit. Annual values range from 48.2 lbs/day in 2016 to 85.7 lbs/day in 2015. The total nitrogen mass loading variations are primarily caused by flow.

Conclusion

In conclusion, the existing wastewater treatment system is being operating efficiently and no operational changes that would significantly reduce the concentration of effluent total nitrogen were identified. Attempts to establish anoxic conditions within the existing treatment system without proper mixing and control may compromise the treatment system efficiency with respect to both carbonaceous material removal and nitrification. To provide additional total nitrogen removal, significant capital expenditures would be required for denitrification.

Under existing operating conditions, the total nitrogen discharge is primarily proportional to the flow. Thus, discharge nitrogen loadings will be directly impacted by changes in manufacturing production.

Appendix A: WWTP Flow Schematic