DRAFT

SYSTEM ASSESSMENT

LSB EL DORADO WASTEWATER

B&V PROJECT NO. 417160
B&V FILE NO. 40.2000

PREPARED FOR

LSB Industries

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BLACK & VEATCH

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1.0 Purpose

The purpose of this report is to summarize Black & Veatch observations from the site visits and present related recommendations to improve the operation of the natural uptake of nitrogen (ammonia and nitrate) in the pond system located on the property to meet permitting requirements.

2.0 Background

On April 31, 2023, professionals from Black & Veatch, Andrew Shaw and Dan Scott, visited the El Dorado Facility to assess the discharge limitations, operational processes, and testing data associated with nitrogen treatment performed in the on-site pond system used for this purpose. Discussions were held with the LSB personnel and a walkdown of the system and ancillary equipment was performed. Black & Veatch discussed initial findings prior to departure.

The observations and recommendations presented within this memorandum are derived from these visits and discussions. The observations were made while onsite by Black & Veatch and supplemented with observations shared by the LSB operating personnel at the site.

3.0 Observations

Black & Veatch was made aware of communications from the State department of environmental quality indicating they were aware of over 100 discharge violations under existing permits and requesting mitigation plan of action to resolve the problems.

The discharge permits can largely be separated into 2 categories: direct discharge and combined discharge. The direct discharge is not limited on volume but are more stringent in terms of concentrations of contaminants such as heavy metals. In addition, direct discharge varies in nitrogen concentrations seasonally even listing 0 lb/day during certain times of the year. By contrast the combined discharge is limited to 2 MGD but is in general less stringent in terms of concentrations.

Rain events produce much more than could be discharged under the 2 MGD combined discharge and on some level will need to utilize the direct discharge permits and get into compliance. However, given the immediate needs, these discussions were not well developed and are no recommendations are given here to address this long-term reality.

Nitrogen levels in excess of 100 mg/L of ammonia and nitrate are currently being measured in the 160-million-gallon Lake Kildeer and that when rain events occur the site must drain contaminated water into the outfall. Some steps to including a small aerator and biological feed system have been included to try and enhance natural uptake of nitrogen which have shown some success but are insufficient to prevent discharge violations. Some steps have also been taken to limit the amount of nitrogen that discharges from the other ponds (Lake Lee and 004 Pond) such as including an air stripper and caustic feed to strip a small amount of ammonia to the air. However, this stripper needs to be limited to ~20% removal to avoid violating the facilities air permit.

4.0 Commentary and Discussion

The LSB site personnel had already investigated numerous ideas prior to engaging Black & Veatch to enhance natural uptake of nitrogen in the existing ponds, reduce washdown of nitrogen from the plant, or install equipment to remove nitrogen from either the high concentration Pond 004 or Lake Kildeer

directly. These efforts as well as ideas presented to LSB by Black & Veatch are summarized in the table in the Appendix.

During the discussion on site the site expressed that the long-term goal should be to reduce loading by making improvements to the AN loading area to make it zero discharge, and the final polishing of nitrogen should be via the existing Lake Kildeer or other ponds. Understanding that this long-term goal may take some time (potentially a few years) to accomplish, there is also a desire to consider temporary solutions for reducing the risk of discharge violations with the existing conditions. Because of these short- and long-term goals, the concepts discussed have been broken out into these categories and Black & Veatch are recommends pursuing both as separate but complimentary goals.

The following subsections provide a narrative description and Black & Veatch's recommendation of each concept discussed. How each recommendation can be implemented is included conceptually but many warrant a detailed investigation and analysis prior to implementation.

4.1 Pond Baffling (Long-Term Objective)

LSB Personnel showed Black & Veatch dye studies showing that Lake Kildeer flow patterns are short-circuiting and therefore the volume of Lake Kildeer is not well utilized. Black & Veatch agreed that if this can be mitigated it would likely enhance nitrogen uptake by improving effective retention time. While the design looked reasonable on the surface, modeling Lake Kildeer would provide more certainty by providing analysis that could be used to make decisions about the design.

Black & Veatch believes the value of baffling on its own is likely small, but when combined with other pond improvements such as addition of alkalinity and additional aeration and/or mixing would provide LSB with a more robust and reliable pond polishing system. LSB has indicated costs for the baffles would be ~$200k which is a low relative to other improvements and so is recommending proceeding with this improvement.

It is not known at this time how fast or slow the deployment timeline for this concept would be.

4.2 Alkalinity Addition (Long-Term Objective)

During the discussions, data on alkalinity and pH was presented to Black & Veatch. These data were significantly below normal targets for nitrification bioreactors and was identified as the most likely inhibitor to natural nitrification within the ponds. Any engineered system for nitrification will require a dosing system to add alkalinity in significant quantities.

Some potential risks are associated with the addition of alkalinity. Firstly, if the chemical added primarily increases pH rather than bicarbonate or carbonate concentrations, ammonia is likely to air strip in any aeration systems with the potential of an air permit violation. Secondly, ammonia becomes more toxic at high pH when speciation favors NH3 rather than NH4. This added toxicity in the ponds may end up inhibiting some of the existing biological activity already occurring. Microorganisms are particularly sensitive to changes in pH, so whatever existing biology has developed may not survive the transition. Alkalinity addition in the existing pond should include monitoring and adjustment based on information in order to minimize the impacts of these potential risks.

While adding alkalinity to the existing pond may have a short-term impact on nitrogen levels, a permanent alkalinity addition system should be incorporated into long term system design if Lake Kildeer is to operate as a nitrogen polisher as the final solution. While the O&M cost of this concept are

high (it could require over $1M per year at existing ammonia loads depending on chemical cost), it is an absolute requirement in any system that depends on biological nitrification.

Lake Kildeer could have the alkalinity adjusted for ~$200-$500k in about 1-3 months and Black & Veatch recommends proceeding with this concept.

4.3 Additional Aeration (Long-Term Objective)

LSB conducted a study of Lake Kildeer to measure the dissolved oxygen (DO). The results of this study indicate there could be large portions of the pond that get insufficient aeration and mixing to perform biological nitrification reliably. While some low DO areas may be facilitating denitrification, this method (nitrification and denitrification in the same pond) for nitrate removal is not possible to get reliable results given lack of control. Nitrification requires relies on slow growing microorganisms, and as such are easily "washed out" when conditions vary outside of a relatively tight range. This is particularly true with DO.

Black & Veatch was told that surface aerators that are solar powered can be acquired for ~60k each and given the minimal effort in installing and running them, Black & Veatch is recommending LSB purchase 3 units to install in Lake Kildeer (one for each baffled zone).

Black & Veatch could assist in performing modeling of Lake Kildeer to assist in the selection and location of aerators to compliment baffle designs which would provide more confidence in the existing plan as well as a troubleshooting tool after implementation.

Black & Veatch believes this concept could be performed for ~180k. The lead time for these aerators is unknown currently.

4.4 Attached Growth Media (Long-Term Objective)

Direct observation of Lake Kildeer indicates that there are not significant suspended bacteria in the pond. Any sludge retention (if it is happening) are likely happening in the sediment at the bottom and sides of the pond. By adding media for attached growth, a more reliable sludge retention mechanism could be established.

Black & Veatch does not have direct experience with attached growth media designed for pond applications and believes there will be engineering and operational challenges with this approach.

No cost or schedule evaluation was done for this option.

4.5 Conversion of Lake Lee to Activated Sludge (Long-Term Objective)

Based on Black & Veatch experience, pond treatment for nitrification and denitrification is not typically recommended, is these biological processes require precise conditions to produce reliable results. While we believe it could be done, a properly engineered and designed activated sludge system is the best technical solution for nitrate removal. Lake Lee could be used as the basin for anoxic mixing, carbon addition, and effluent recirculation and be fitted with fixed film media and a solids liquid separation device (typically clarifier or DAF). With proper analysis and operation, nitrate removal could be reliably achieved via denitrification.

This option is less of a "band-aid" and therefor has a more typical project development cost and timeline. Black & Veatch would take a phased approach to advance through conceptual design, front end engineering, detail design, procurement, and construction related engineering services in line with industry standard.

Black & Veatch expects based on the size that the total cost for a project like this would be in the $10s of Millions of dollars and take 1-2 years to complete, though a "fast-tracked" approach could reduce this to 6-12 months.

Analysis should be done to quantify the source mitigation efforts underway with LSB and determine a conservative but realistic design basis for total nitrogen loads to Lake Kildeer. If this analysis shows that nitrate removal will still be a problem after all other mitigation efforts have been made, Black & Veatch recommends that this option be pursued.

4.6 Cation/Anion Exchangers (Short-Term Objective)

Some time was spent discussing ion exchange for ammonia removal (cation exchange) and/or nitrate removal (anion exchange). This could work as a temporary way of discharging from Lake Kildeer under the permits, but it is not a viable long-term strategy as it produces chemical regeneration waste that is difficult and costly to dispose of, and certainly could not be discharged from the site.

Black & Veatch experience from working with ion exchange and RO systems is that ROs are cheaper in both CAPEX and OPEX. Since packaged rental units are available for both technologies at similar flow rates, using ion exchange will not add any advantage to an RO system, and is likely to be more expensive. No further analysis was done on this option.

No cost or schedule evaluation was done for this option.

4.7 Reverse Osmosis (Short-Term Objective)

Several ideas were presented during the discussion about the potential use of reverse osmosis (RO). LSB had been considering RO for the high strength pond 004 and had been told by other parties that this shouldn't be considered because the off the shelf RO units are not designed for high concentrations, and recovery would be low. There is also the problem of what to do with the concentrated brine that the RO produces since there is no nitrogen removal, so blending is not an option.

Black & Veatch suggested that instead LSB should consider an RO on Lake Kildeer water as a way of ensuring compliance on discharge water regardless of the conditions in the lake. While a single packaged unit wouldn't be able to achieve 2 MGD, the flow rates would be significantly better than a packaged biological unit and risk of discharge non-compliance from an RO is very low. While the RO would require an ultrafilter pre-treatment, those units are also available off the shelf and as rental units.

Further analysis suggested a 500-600 gpm system could be secured for a rental cost of $70k per month. After chemical and operator costs and deployment costs, the total expense would be in the range of $2-$3 Million over a 2 year period while long term solutions are developed. Additional ROs could be secured at similar pricing, so an analysis should be done to determine how many would be required to

definitively have the capacity to discharge all water as RO permeate over this period and costs adjusted accordingly.

Given the high cost of this option and the fact that it does not impact any long-term goals of the site, it is the recommendation of Black & Veatch that LSB consider and quantify in dollars the risk of short term (2 year) failure to meet discharge requirements for the facility. If after this analysis the likely cost of this temporary RO system is small by comparison, it is Black & Veatch recommendation to proceed with securing it because it is the most likely short-term solution to ensure discharge with compliance over that period.

4.8 Packaged Biological Units (Short-Term Objective)

Deploying a packed wastewater system (or several) was discussed because of the benefits associated with ease of deployment. Because of the large volumes typically required for biological processes, and the small size of packaged units due to shipping constraints, it was understood by the group that this would be a short-term solution and not a long-term solution for the full load. The value however of a properly designed bioreactor is appealing though even if small due to the ability to control important parameters necessary for reliable operation.

Black & Veatch identified through previous project connections 2 packaged biological units that could be acquired for the cost to ship and refurbish.

Further analysis has shown these units can treat ~60,000 gallons per day which appear to be inline with other packaged units' hydraulic rate. More analysis would be required to determine an expected nitrogen removal rate, but back of the envelope numbers show this approach would take several years to reduce the current load of Lake Kildeer.

These units would require minor modifications and some site preparation in order to deploy, but Black & Veatch believes it could be done for $200k-$500k which includes all costs over a 2-year operating period. Deployment would likely require 3-5 months. Given the relatively low cost and known availability, Black & Veatch recommends proceeding with this option as it is the most reliable approach to reducing nitrogen loads in the near term.

4.9 Composting Operation (Other)

One out of the box idea was discussed to use the water in Lake Kildeer for a composting operation. The idea would be to source a low nitrogen biomass (wood waste) and use the high nitrogen water to compost it, producing a potentially saleable product.

Further analysis by Black & Veatch indicates that the scale of this type of operation for all the nitrogen in Lake Kildeer is unrealistic. Typically, 1 part nitrogen should be paired with 30 parts carbon for composting. Because of the large amount of nitrogen, this means something like ~4,000 tons of wood waste would need to be sources and a similar amount of compost sold for the existing nitrogen load in Lake Kildeer. No further analysis has been done for this concept.

No cost or schedule evaluation was done for this option.

4.10 Breakpoint Chlorination (Other)

Some time was spent discussing the possibility of using chlorine for breakpoint chlorination. Technically this converts ammonia contamination into several disinfection byproducts known as chloramines. Given the permit references measures that do not detect chloramines, this may be a way to transform chemically the ammonia and discharge it without violating the permits.

It was noted however, that even though this theory holds up for discharge of nitrogen compounds, this would cause any sample for toxicity to fail. In addition, toxicity would likely disrupt any biological nitrogen removal already occurring downstream of the injection of the chlorine. Given the risk that this option could cause more problems than it solved, it was not evaluated further.

No cost or schedule evaluation was done for this option.

5.0 Conclusion

The assessment covered in this memorandum has shown that by installing systems to improve conditions for biological nitrogen removal in the existing ponds, polishing of nitrogen can be achieved. In addition, solutions exist to reduce discharge violations using temporary equipment which could be used to bridge the gap until the source mitigation and pond improvements are completed.

6.0 Recommendations

For next phase in this process, Black & Veatch would like to propose the following engineering services to assist LSB in achieving their goals of improving Lake Kildeer for nitrogen polishing and in the near term reduce risk of discharge violations.

1. Environmental modeling of Lake Kildeer
2. Design recommendations for baffling, aerating, and alkalinity addition in Lake Kildeer
3. Assistance in securing and deploying temporary treatment equipment

Black & Veatch can provide a change order estimate to the current Purchase Order for this level of effort for this next phase upon the request from LSB.

Appendix