H2Ohio Technology Assessment Program (TAP)

Final Report

Assessment of Nutrient Management Technology Submission

Nutrient Regeneration (Regen)

January 2022

TETRA TECH

EXECUTIVE SUMMARY

Kurtz Brothers, Inc. (Kurtz) of Independence, Ohio has submitted a technology proposal for Nutrient Regeneration (Regen) to Ohio Environmental Protection Agency's (Ohio EPA) H2Ohio Technology Assessment Program (TAP) for the purpose of addressing the Lake Erie algal blooms and associated nutrient loading. Regen directly addresses 4 of the TAP objectives and one indirectly. Regen's potential is tied to a regional systems approach that is based on the principles of converting agricultural manures and other biomass sources into bulk commodity products. These products are stable forms of organic nutrients and valuable soil amendments (e.g., organic nutrient pellets, compost, biochar, topsoil, etc.). Regen's proposed technology is not necessarily more complex than other technologies evaluated through the TAP, but it seeks to address root causes of nutrient cycle impairment within the Lake Erie basin while providing multi-beneficial solutions that reduce the need and importation of synthetic fertilizers, improve farmland soil health (i.e., increased soil organic carbon, more effective nutrient/water cycling), and ultimately support economic viability of both Ohio farms and farm communities.

The foundation of the Regen approach is a constructed "Regen Facility" strategically centered around supporting swine and dairy farms that is capable of handling both processed and unprocessed manures as the main input, but also designed to handle other "waste" sources within the region (e.g., municipal biosolids, food waste, carbon waste, dredged river sediment). The direct outputs from the facility are marketed back to regional farms as organic fertilizers and soil amendments, but also can be sold within urban markets to improve hydrologic function of urban landscapes (parks, lawns) while also reducing synthetic fertilizer inputs. Kurtz Bros. has presented supporting documentation and pro forma business plans that could make adoption of Regen preferable to the status quo for farm enterprise budgets currently using synthetic nitrogen (N) and phosphorus (P) and with low soil organic matter (SOM) in their farm fields.

Regen is cost effective, especially when the financial assistance available from the USDA Natural Resources Conservation Service (NRCS) and other sources for its planning, design, and capital construction is considered. Potential crop yield increases may be an indirect and distributed benefit. There are possible NRCS financial assistance programs such as Conservation Innovation Grants that will cover up to $5 million of the planning, design, and implementation costs of a Regen Facility.

This report evaluates Regen against a suite of criteria identified by the TAP using information provided by Kurtz Bros. and obtained elsewhere. Tetra Tech determines that Regen is very likely to be effective at reducing nutrient loading to Lake Erie, in direct proportion to the volume of nutrients intercepted from manures and to the reduction of synthetic fertilizer applications on agricultural fields. No negative impacts associated with environmental risks, supply chain limitations, or community perception were identified. The estimated total costs are about $0.0125 per pound (/lb.) for nitrogen and $0.0615/lb. for phosphorus, which are low compared to other similar agricultural best management practices (BMP). The biggest potential barrier to applying Regen at a scale large enough to make a significant impact is farmer willingness to have P removed from manure onsite although processing manure at farm locations to reduce the phosphorus would be a benefit to farmers and give them more manure disposal options. This could be addressed through financial support provided by H2Ohio or NRCS incentives to use compost and biochar. A demonstration project targeting widespread adoption of Regen

within one or more Lake Erie subbasins could evaluate the ability of financial incentives to spur landowners to use this technology and could also provide more detailed data about nutrient load reductions, crop yield increases, and potential constraints to using Regen within the Lake Erie drainage basin.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
$/lb.	Dollars per pound
AES	Applied Environmental Solutions
BMP	Best management practice
CWA	Clean Water Act
EQIP	Environmental Quality Incentives Program
FTE	Full-time equivalent
HAB	Harmful algal bloom
K	Potassium
Kurtz	Kurtz Brothers, Inc.
lb.	pound
lbs.	pounds
N	Nitrogen
NPDES	National Pollutant Discharge Elimination System
NPS	Non-Point Source
NRCS	Natural Resources Conservation Service
O&M	Operation and maintenance
Ohio EPA	Ohio Environmental Protection Agency
P	Phosphorus
PPP	Public-private partnership
QA/QC	Quality assurance/quality control
Regen	Kurz Bros. Nutrient Regeneration
RFT	Request for technologies
SOM	Soil organic matter
TAP	Technology Assessment Program
USDA	United States Department of Agriculture
WWTP	Wastewater treatment plant

1.0 INTRODUCTION AND BACKGROUND

H2Ohio (http://h2.ohio.gov) is Ohio Governor Mike DeWine's comprehensive, data-driven water quality plan to reduce Harmful Algal Blooms (HABs), improve wastewater infrastructure, and prevent lead contamination. Governor DeWine's H2Ohio plan is an investment in targeted solutions such as :

- Reducing phosphorus runoff through increased implementation of agricultural best management practices and the restoration of wetlands;
- Improving wastewater infrastructure;
- Replacing failing home septic systems; and
- Preventing lead contamination in high-risk daycare centers and schools.

HABs have been a concern in Lake Erie for decades, and the State of Ohio has a long history of developing solutions to address them. In support of these efforts, state agencies are often presented with new approaches for addressing HABs. These approaches often involve technologies and products that are typically innovative, can be proprietary, and span multiple scientific disciplines. To evaluate these proposals for their efficacy and feasibility, the Ohio Environmental Protection Agency (Ohio EPA) worked with the Ohio Lake Erie Commission to create a public advisory council—the Technical Assistance Program (TAP) Team. The H2Ohio TAP Team is comprised of representatives from the private sector, public sector, trade associations, and non-profit companies. The H2Ohio TAP team is conducting an evaluation of technologies designed to treat, control, and reduce HABs in the Lake Erie watershed. H2Ohio initiated the TAP to solicit and evaluate technologies that support one or more of the following five goals:

1. Reduction of nutrient loading to rivers, streams, and lakes;
2. Removal of nutrients from rivers, streams, and lakes;
3. Reduction of the intensity or toxicity of algal blooms;
4. Recovery of nutrients from animal waste; and
5. Improvement of nutrient removal in wastewater treatment systems.

The H2Ohio TAP Team worked to solicit and prioritize technology proposals for further review. A Request for Technologies (RFT) was developed and issued by Ohio EPA in November 2020 (H2Ohio TAP, 2020). The H2Ohio TAP conducted a thorough evaluation of the 40+ proposals received in response to the RFT and selected 10 technologies for further evaluation. The developers of these 10 technologies were given an opportunity to provide additional information and supporting data to allow an independent evaluation of their technology by a third party, Tetra Tech.

As a contractor to the Ohio EPA, Tetra Tech conducted an independent third-party evaluation of the 10 technologies selected by the H2Ohio TAP team. The goal of the evaluation was to provide a general assessment of the potential effectiveness, implementability, readiness, and cost of deploying each technology. Select technologies may eventually be demonstrated in the field under future H2Ohio programs.

2.0 PURPOSE

The primary purpose of the technology assessment and evaluations was to conduct a comprehensive scientific evaluation of the selected technologies to determine if and how they could be utilized to address HABs in Lake Erie.

Based on input from Ohio EPA and the H2Ohio TAP team, Tetra Tech established primary (P1 & P2) and secondary (S1 & S2) objectives for the third-party evaluation program. The primary objectives are critical to the technology evaluation and involve conclusions regarding technology performance that are based on quantitative and semi-quantitative data. The primary objectives for the evaluations of the participating technologies are as follows:

- P1: Effectively assess the performance, cost-effectiveness, and reliability data gathered from each vendor with regard to one or more of the 5 H2Ohio goals:
    - Reduce nutrient loading to rivers, streams, and lakes:
    - Remove nutrients from rivers, streams, and lakes:
    - Reduce the intensity or toxicity of algal blooms
    - Recover nutrients from animal waste:
    - Improve nutrient removal in wastewater treatment systems, specifically with small (e.g., lagoon) and decentralized systems
- P2: Ensure that the evaluations are completed by appropriate personnel using a documented, consistent approach and level of detail, to include:
    - Proof of concept review
    - Fatal flaw analysis
    - Review of previous implementation of the technology or similar technologies
    - Review of data quality objectives
    - Review of quality assurance/quality control procedures and reports
    - Evaluation of scalability
    - Information gap evaluation
    - Evaluation of cost; both total and by unit, such as nutrient reduced/removed
    - Feasibility review for a proposed demonstration project
    - Feasibility review for full scale implementation
    - Statement of probability of success

The secondary objectives pertain to Tetra Tech's approach to assessing and presenting the information and thus support the primary objectives.

The secondary objectives for Tetra Tech's evaluation are as follows:

- S1: Prepare Comprehensive Scientific Assessment and Recommendations Reports for each technology that will support potential users' ability to make sound judgements on the applicability of the technology to a specific site and to compare the technology to alternatives.

- S2: Ensure that project deliverables follow consistent format and similar levels of detail. Each report will contain:
    - A summary of the technology and results of past uses of the technology;
    - Results of conceptual model review, fatal flaw analysis, and information gap evaluation;
    - A statement of probability of success and scalability of the project;
    - Verification of cost estimates at various implementation levels;
    - Results of the feasibility review for a potential demonstration project and full-scale implementation of the technology;
    - Verification of claims made by applicants.

The technology evaluation consisted of the (1) collection; (2) evaluation; and (3) summarizing and reporting of data on the performance and cost of each technology. These data provided the basis for meeting the primary objectives.

Most data supporting these evaluations were provided by the technology developers and Tetra Tech attempted to verify it using independent sources, when available. Tetra Tech focused its verification efforts on key aspects of the technology (e.g., effectiveness, cost) as well as any claims that seemed questionable. Otherwise, Tetra Tech assumed information provided by the vendor to be accurate. Instances where Tetra Tech is unsure of a claim being made by the vendor are noted in the report. In some cases, information was also obtained from the peer-reviewed scientific literature. Tetra Tech worked with each developer to obtain the data necessary to meet the primary and secondary evaluation objectives.

Tetra Tech then completed an independent evaluation of the data provided by each developer and prepared separate reports for each technology evaluation, following a consistent report format. This report provides a summary of our review of Regen.

3.0 TECHNOLOGY OVERVIEW

"Regen" stands for Nutrient Regeneration and is nonpoint-source (NPS) nutrient management, a proven conservation practice supported by a specific United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) conservation practice standard called Nutrient Management (Practice Standard Code 590). NRCS practice standards are non-enforceable, state-specific guidance and BMPs intended to facilitate compliance with state and federal regulations. Point sources are regulated under the Clean Water Act (CWA) National Pollutant Discharge Elimination System (NPDES). Nonpoint and point sources from farmers and producers are the primary source of nutrients that make HABs possible (Ohio EPA, 2020). Regen can be considered a watershed-scale, non-structural agricultural BMP. Such BMPs have a nutrient removal cost effectiveness that is typically orders-of-magnitude less than point-source management or structural practices (USDA, 2006).

Kurtz Brothers, Inc. (Kurtz) states that Regen meets all five TAP Objectives. Nutrients are converted from manure waste streams into more stable fertilizer/soil amendments, thereby reducing nutrient loading to rivers, streams, and lakes (TAP Objective 1). Regen products such as biochar and filter socks can be deployed in rivers and streams for direct removal of nutrients (TAP Objective 2). Meeting Objectives 1 and 2 will result in reduction

of HABs not by removing the bloom but systemically through nutrient reduction. A multi-disc roller separator component (e.g., KDS brand) helps dewater swine and dairy process manures from waste lagoons for subsequent processing and nutrient recovery (TAP Objective 4), and municipal wastewater treatment plant (WWTP) biosolids can be incorporated into Regen composting (TAP Objective 5).

Regen manages nutrients from participating producers by processing manure sources at the individual farms prior to land application, thereby removing a concentrated form of phosphorus (P) and diverting P concentrate to a regionally based central facility where other organic and/or nutrient-rich feedstocks (municipal biosolids, food wastes, carbon wastes) and inorganic (dredged sediments, degraded fill) materials are added to produce a range of products and in-direct outputs. These products, which drive the economic viability of the Regen approach, include organic nutrient pellets, concentrated high-nitrogen (N) fertilizer, compost soil amendments, topsoil, biochar, stormwater control filter socks (which include both biochar and compost products), renewable heat and energy sources, and carbon and renewable energy credits that can be sold on the open marketplace.

Kurtz proposes that providing a regional source of organic fertilizer and soil amendments has a two-fold benefit for water quality management. First, it displaces the importation and use of more environmentally-mobile synthetic fertilizers into the Lake Erie basin, thus reducing nonpoint nutrient pollution from agriculture lands and managed urban pervious areas (e.g., lawns). These products are more stable, portable, and storable than traditional land application of wet or dewatered manures and chemical fertilizers. At the same time, these organic inputs help increase soil organic matter (SOM) , which is directly linked to increased nutrient and water holding capacities while also improving soil drainage and healthy soil structure. Compost and biochar enhance soil biological health that increases natural mineralization of soil nutrients, which further reduces agronomic requirements for nutrient inputs. Although H2Ohio does not consider increased soil health to categorically reducing non-point-source pollution, Regen products are considered a tool to increase overall soil health, thereby potentially reducing nonpoint-source nutrient releases to waterbodies. Regen's approach is to remove high P loads from land applied manures, create new stable forms of nutrient sources for regional farmers, distribute these products to reduce the need for synthetic fertilizers, and improve soil health through their applications which help provide protection from fertilizer mobility from land application. It is important to note that projected N and P load reductions are based on removal from manures only. Although some unpublished Ohio State University research (Studer, 2021) indicate greater P loss with increase SOM, other published sources indicate general reductions in nutrient loss when SOM is increased in the watershed (Mengel, 2012)(Ohio EPA, 2013). Kurtz believes that the largest reductions of nutrient pollution will come from improved soil health and even a marginal reduction in synthetic fertilizer use.

4.0 TECHNOLOGY EVALUATION

This section of the report addresses each of the criteria identified by Ohio EPA to be included in the independent evaluation process.

4.1 CONCEPTUAL MODEL REVIEW

Kurtz Bros.' provided the following description of conceptual model for Regen. Evaluation of the features in the model are found in Sections 4.2-4.15.

The Regen process includes processing liability biomass through a collection of different treatment technologies, working together in a systematic fashion, to convert raw manure or partially treated biosolids into finished marketable goods. The primary technological components of Nutrient Regeneration include high solids separation, state of the art compost stabilization, heat dryers, gasification systems, and pelletizers. If waste-to-energy and onsite clean green bioenergy is desired, Regen facilities can be equipped with waste-to-energy anaerobic digesters.

The process of Nutrient Regeneration is done throughout a watershed by the establishment of strategically located Nutrient Regeneration facilities. Each Regen facility houses different technological components of the treatment system and serves as an outlet for locally generated biomass sources. The treatment technologies incorporated into the system include both front-end and back-end treatment components. The front-end operation, where nutrient removal and solidification takes place, incorporates solids separation technology with intricate solids stabilization systems. Solids separation of raw livestock manure is done through the use of Quick Wash™ and KDS Rotating Disc Separation technology. This system is a tested and verified system that processes commonly found livestock manure into a nutrient concentrate. This technology is able to extract upwards of 94% of target P from manures with a focus on processing the most problematic manure sources such as swine and dairy. The captured nutrients are stabilized through a proprietary composting operation that reduces moisture content while binding up free mobile nutrients into stable forms of slow-release organic nutrients. Once the stabilization has occurred, the concentrate is treated on the back end of the Regen process where different finished goods are produced for market use.

The back end of the Regen process involves processing of the stabilized biomass to create a high-quality soil amendment, fertilizer pellet, or biochar. All of these products involve high heat treatment of the stabilized organics to further reduce moisture content and stabilize the nutrients into a finished good. The back-end technology of the Regen process includes specialty composting equipment, pelletizers, and a biochar pyrolysis system. The biochar system includes a rotary dryer, biofilter, and all ancillary equipment used for the production of biochar. All of these components are represented by commercially available equipment with a proven history and track record of distribution.

A Regen Facility has many components and moving parts. While none of these components are very cumbersome to operate, they do require a certain level of operational competence and upkeep. The major equipment components will require routine annual upkeep and maintenance. The overall infrastructure of a Regen facility can support a long lifespan of well over 20 years. A routine facility maintenance plan and budget

should be dedicated to the entire upkeep of the system. Complex equipment components such as industrial dryers and the pyrolysis systems require routine maintenance and a repair and a replacement plan for high-wear items. Annual downtime for inspection and repair is built into the annual operations plan for the facility. With proper routine maintenance, even these complex equipment components can have operational life spanning 20 - 30 years (Kurtz, 2021).

Figures 1 through 5 present various representations of Regen's processes and conceptual model provided by Kurtz (Kurtz, 2021).

Figure 1 – Example Regen Facility and it's Features

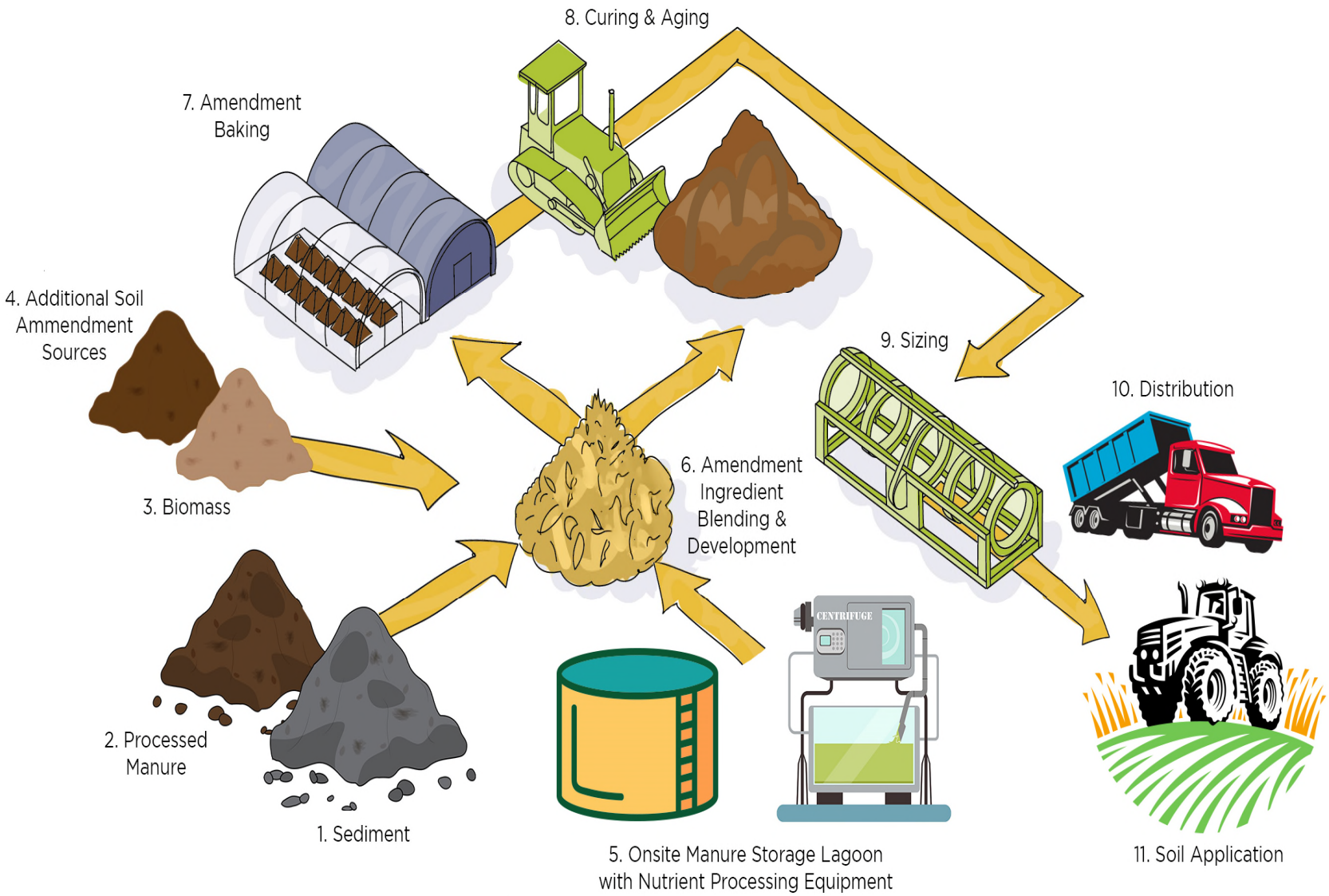

Figure 2 - Regen Inputs and Outputs

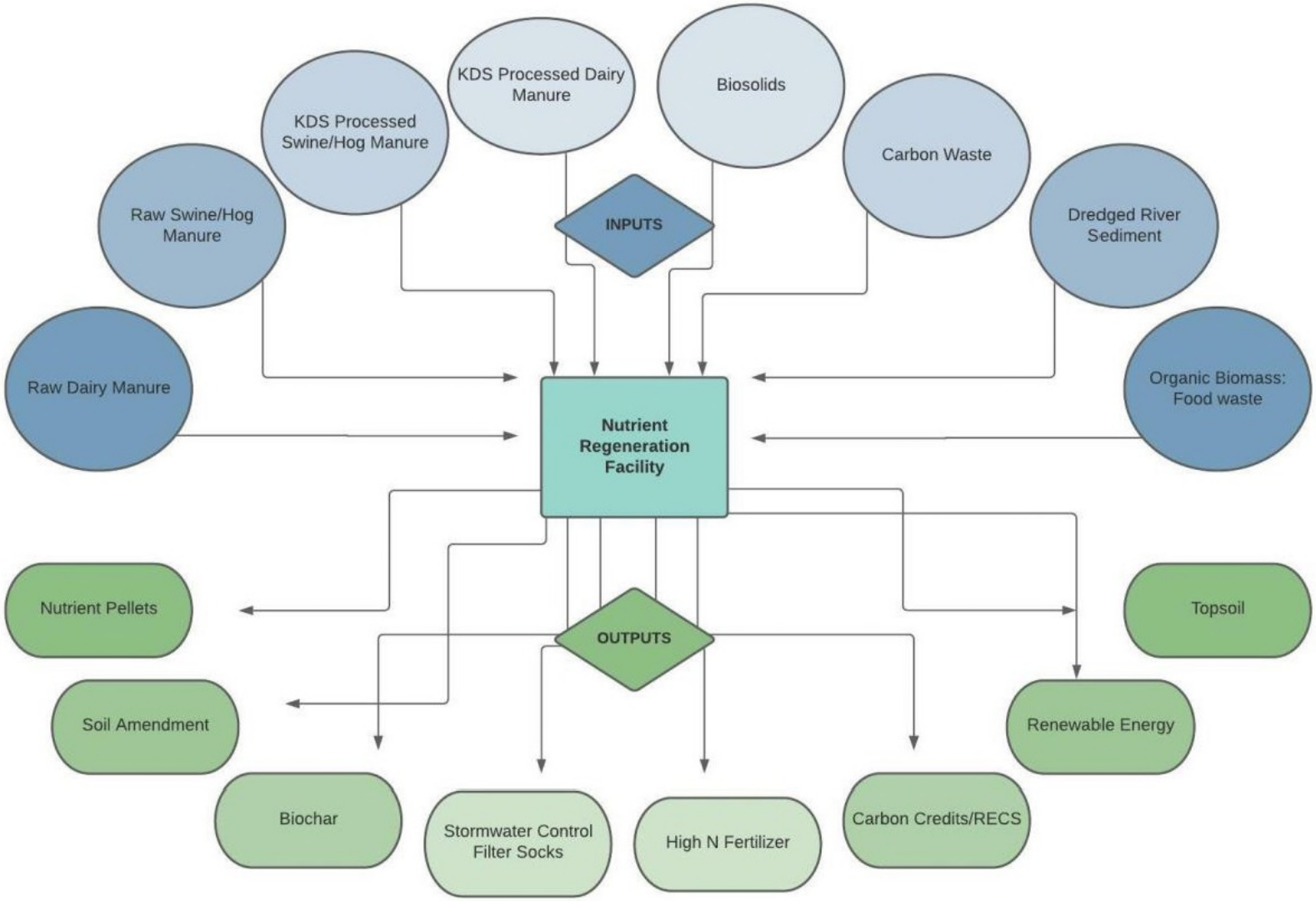

Figure 3 - Regen Process Flow Diagram

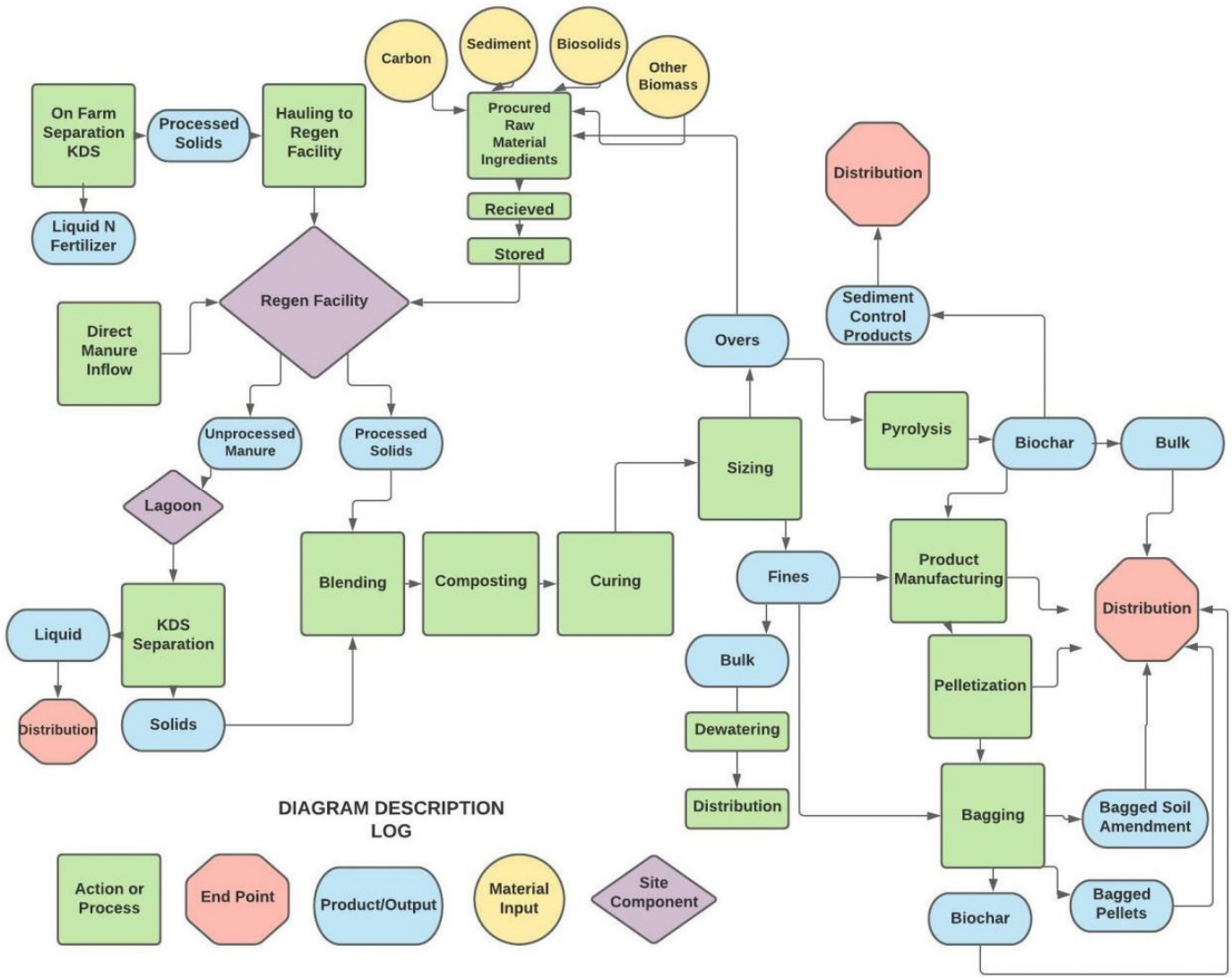

Figure 4 - Rendering of a Regen Facility

Figure 5 - Examples of Fertilizer and Soil Amendments

Note: Amendments made from concentrated manure in the form of (L-R) biochar, pellets, and compost

In summary, Regen is an assembly of existing processes and equipment, namely, KDS dewatering separators, Ohio EPA Class II composting, green waste recycling, pyrolysis/gasification (biochar), anerobic digestion, screening/pelletization/bagging systems, and soil/sediment/sand/aggregate construction material handling equipment.

4.2 FATAL FLAW ANALYSIS

There are no obvious fatal flaws with Regen. However there are several challenges outside the immediate operational boundary of the facility and that could impact the success of Regen. The potential challenges include a) the cost of capital and b) market forces for Regen products such as biochar, compost, and soil amendments. Market forces include the consumer demand for products, their pricing, and their sale.

The Regen Facility and some associated infrastructure such as bins, bulldozers, tarps, and fencing will require a startup capital investment, with the return on investment capable of paying back creditors over time. The time from startup to marketable commodities coupled with the cost of money is a combination that could make Regen unviable. The cost of money is defined as the interest payments on any borrowed money or due date of cost-share grants, for example. The perceived "flaw" is a common feature of any capital investment and there are many ways to mitigate its risk. These include private equity, public-private partnerships (PPP), and state or federal grants, cost-share, or royalty business models. However, the risk that a suitable source of capital could not be found or that, once constructed, Regen could not experience cash flow or profit, appears low.

The second potential challenge is a lack of demand in the marketplace for Regen products. Kurtz Bros. currently produces and markets an extensive array of landscape, engineering, and agricultural materials in the Great Lakes region, so infrastructure to market and experience promoting new products already exists. The potential "flaw" is the unknown success of a rather significant public education and marketing campaign that demonstrates the need and efficacy of switching from synthetic fertilizer to Regen products, despite the known detriments of synthetic fertilizer use. These include lower nutrient availability, higher nutrient solubility, higher mobility in the soil, and depletion of SOM. Projected near-record high fertilizer prices (Brownfield Ag News, 2021) may hasten farmers' switch to other sources. Although adoption is key, Kurtz Bros. recognizes that choice of organic fertilizer over synthetic is a complex one and some farmer habits may not change. Kurtz Bros. proposes generally that shifting from synthetic to organic fertilizer will have a measurable effect on nutrient pollution in the watershed. Kurtz Bros. reports that, for example, market demand exists for organic composts, biochar, and fertilizers in the Western Basin but distributors are not present to meet that demand. Compost and biochar can be applied by most row crop and livestock farmers using existing agriculture equipment with Regen products.

Regen involves several conventional industrial processes and the extensive use of electromechanical equipment. Breakdown and parts replacement of this equipment are not considered fatal flaws and are instead elements of routine maintenance common to this type of equipment. In particular, the efficacy of the KDS roller separator is key to isolating P from N and solids from liquid manure, respectively. The P in solids from manure (KDS output) is the starting point of the Regen process.

4.3 REVIEW OF PREVIOUS IMPLEMENTATION OF REGEN

The Regen is not a new technology – only an innovative systems approach developed to meet the needs and specific context of the Lake Erie basin. As described in Section 4.1, Regen is an assembly of existing processes and equipment, namely, KDS dewatering separators, Ohio EPA Class II composting, green waste recycling, pyrolysis/gasification (biochar), anerobic digestion, screening/pelletization/bagging systems, and soil/sediment/sand/aggregate construction material handling equipment. Pilot scale implementation of the comprehensive Regen outlined in the TAP proposal has not yet occurred, but below is a brief description of the already-proven components.

Deployment of the KDS separation equipment is reported to be greater than 500 units (mostly in Asia) and further details can be found in Applied Environmental Solutions' (AES) proposal. AES' QuickWash® was also a finalist for the H2Ohio TAP program.

The composting operation Regen proposes to use is modeled after Andre Farms in Wauseon, Ohio. Its operation spans over 25 years in Ohio's agricultural sector and includes an Ohio EPA Class II and III compost operation, custom soil distribution, manure management services, as well as nutrient management services. The trajectory of market demand of manure-based compost products continues to be strongly positive, suggesting that there is strong market demand for similar products

Finally, Kurtz Bros. itself has a 73-year track record of developing, processing, packaging, distribution, and marketing of organic waste streams and landscape, construction, and agricultural materials. The Regen operation essentially utilizes their existing materials handling expertise. Kurtz Bros. currently operates large scale organics production facilities throughout the State of Ohio and develops "end markets". An "end market" is where consumers purchase and use the product for value-added compost products. Over the past 30 years, over 6,000,000 tons of yard waste was diverted away from disposal in landfills and converted into value-added compost that was sold as compost, mulch, and as an organic matter component of blended soils. The Kurtz Bros. organics recycling operations are located throughout the state with some of their largest facilities located in Cleveland, Canton, and Columbus. Every year the Kurtz Bros. companies distribute about 300,000 cubic yards of compost and compost-based products. Kurtz Bros. is directly responsible for receiving, processing, marketing, and distribution of these products. Current production sites are many times the size of the proposed Regen operation.

4.4 COST EVALUATION

Kurtz Bros. presented capital and operation and maintenance (O&M) costs for a single pilot model Regen facility, but also a proposed full-scale deployment of five regional Regen facilities. The full-scale deployment is estimated to reduce the P load entering the Ohio Lake Erie watershed by 18 percent (equivalent to about 46% of Ohio's reduction goal). A single pilot facility could service 180 million gallons of manure per year, which could yield a reduction of 206 tons of Total P and 991 tons of Total N excluding the further reductions of N and P from land applied Regen products within the watershed. This estimated load reduction from a single Regen facility could account for 9% of the total P load reduction for the entire Lake Erie watershed. Scaling Regen operations is based more on annual manure availability from local farmers versus end-product marketing (which can expand beyond the region as needed).

Inherent to the Regen nutrient load calculations is the assumption that the KDS separators remove most of the phosphorus in the swine and dairy manure with the solids-separation, while the high-nitrogen liquid portion remains on the farmer for application to crop fields. Under the status-quo model, farmers would continue to supplement crop fertility needs with imported synthetic fertilizers. However, these volume reduction estimates are conservative since they only account for the initial load reduction via the solids separation, and do not account for the following potential factors:

- Reductions in synthetic fertilizer use being offset with Regen products that have more stable forms of N and P (e.g., compost, organic nutrient pellets)
- Increase in nutrient holding capacities through use of Regen products that increase soil organic matter

- Improved nutrient cycle and mineralization within cropland soils through increased soil organic matter and improved soil biological health
- Nutrient reductions from implementation of biochar filter socks that would be generated by the Regen facilities

Note that additional nutrient reduction factors were not included in the baseline estimate since they rely on behavior and production changes by local farmers (which are beyond direct control Kurtz Bros.) and the adoption of these factors do not alter Regen's proposed economic model since facility products can be marketed outside of the Lake Erie basin.

Table 1 displays Kurtz Bros.'s estimated costs for both the single facility and full-scale Regen scenario. Note that the cost evaluation includes not only costs, but anticipated revenue from the products produced by the Regen facility. The anticipated revenue offsets over 75 percent of the annual O&M cost for a single installation and returns a profit for multiple installations. By inspection, it is apparent that no public financial support would be needed after capital costs have been paid for up front. Over time, these too would be paid back from the self-sustaining profit from the system. Furthermore, Kurtz Bros. cites the NRCS Environmental Quality Incentives Program (EQIP), Conservation Innovation Grants, the carbon credit market, and other external grant sources to enhance the business proposition of Regen. At the time or writing, Kurtz Bros. was not able to include detailed costs or a draft business plan as public information. To compare the combined effect of capital cost, periodic (O&M) costs, and service life, a service life of 20 years and a discount rate of 3 percent were selected to attain an estimated present value.

Table 1 - Estimated Business Proforma: Regen Installation & Operation

Component	Quantity per Installation	Cost Per Installation ($M)	Cost for Full-Scale Deployment ($M)[1]
Capital Cost Rollup		**$14.029**	**$59.623**
KDS Manure Separation Systems[2]	6		
On-road Semi Truck Transportation	1		
Transportation Roll-off Containers	10		
Property/Land, acres	10		
Building, 10,000 sq ft	1		
Undercover Storage- 15,000-yard storage capacity	1		
Lagoon, 1 million gallons	2		
Front End Loader	1		
McClosky Screen Plant	1		
Windrow Turner	1		
Pellet Mill	1		

Component	Quantity per Installation	Cost Per Installation ($M)	Cost for Full-Scale Deployment ($M)[1]
Complete Biochar System	1		
Automated Bagging Plant	1		
Annual O&M Rollup		**$3.237**	**$14.566**
Full-time Labor	9		
Fuel, power, water, taxes, permits, packaging, etc.	1		
Revenue	1	$(4.146)	$(20.73)
Net Annual		**$(0.909)**	**$(6.163)**
Present Value (capital cost + 20 years of net profit at 3%)[3]		**$0.51**	**$(32.07)**

Notes:
1. Full-scale deployment is five regional Regen facilities throughout the Ohio Lake Erie watershed. Capital and O&M costs have been reduced by 15 percent for full-scale deployment.
2. Installations of KDS equipment on 5 participating farms per Regen regional facility is included.
3. A negative present value cost indicates positive cash flow; a positive present value cost indicates negative cash flow.

It is assumed that processed manure effluent (containing P) will not be sold and will not be paid for since KDS byproducts are both an asset and a liability. Each Regen facility would receive the processed manure portion of effluent from the KDS system. In volumetric terms, the system would handle the equivalent of 180 million gallons per year of raw liquid swine or dairy manure. The separated solids equate to an estimated at 46,000 cubic yards per year and is included in transport costs. The Regen facility would require an additional carbon feedstock of 92,000 yards for composting that would be sourced from regionally available waste streams or from purchased carbon sources. The costs of carbon have been included in the Kurtz Bros. model. Hauling of manure solids and green waste to the Regen facility are accounted by Kurtz Bros. as cost items.

Similarly, dredged sediment from Lake Erie port authorities is assumed to be a zero-cost reuse (except for transport), relieving some burden from ports to dispose of dredged sediment. Finally, the potential for anaerobic biogas to offset energy demands onsite has not been estimated.

Kurtz Bros. calculated the removal rate of N, P, and potassium (K) from a single Regen facility processing manure solids representing 180 million gallons of raw swine/dairy manure. In Table 2, the present value costs presented in Table 2 are divided into the removal rates to arrive at a cost per ton of N, P, and K removed for both a single instance of a Regen facility and full-scale deployment (five facilities) in the Ohio Lake Erie watershed. Note that as the number of facilities increases, the cost per ton becomes negative, indicating net profit from the enterprise.

Table 2 - Annual Estimated Cost Per U.S. Ton for Nitrogen, Phosphorus, and Potassium Reduction

Constituent Removed	Single Installation U.S. tons/year	Full-scale Deployment U.S. tons/year	Single Installation $/U.S. ton[1]	Full-scale Deployment $/U.S. ton[1]
N as N	991	4,955	$25	($324)
P as P	206	1,030	$123	($1,557)
P as P_2O_5	471	2,355	$54	($681)
K as K	472	2,360	$54	($680)
K as K_2O	571	2,855	$44	($562)

Notes:
1. Costs presented are based on the present value of capital cost and annual net profit over a 20-year time period (see Table 1).

Kurtz Bros. points out that N, P, and K are separated from the manure waste streams with the KDS system, with P yielding the highest recovered ratio compared to amount in the raw manure source. Typically, all three nutrients are land applied when spreading manure on-farm, resulting in overapplication of some nutrients (particularly where soils already have high P indexes). Without KDS, manure contains N, P, and K and often results in nutrient application greater than agronomic rates. With KDS, manure contains N and K sought after by crop farmers but without the P. Regen composted organic products can be manufactured with varying concentrations of nutrients to meet a farmer's agronomic requirements while building water- and nutrient-holding capacity in the soil. At the lower end of P concentration, Regen-processed manure typically contains less than 1 percent P. At the upper end of P concentration, the recovered P can be processed and marketed as P concentrate.

Still, the recovered nutrients and soil amendments containing the recovered nutrients (as estimated in Table 2) can be exported outside the watershed and nutrients literally removed from the watershed. However, crop farmers within the Lake Erie basin may choose to utilize Regen products as fertility inputs once these become available locally. Although this factor doesn't change the economic model for the Regen facility, local distribution can help solidify relationships with local livestock farmers for feedstock sources, as well as yield some of the subsequent benefits to nutrient reductions described previously (e.g., increase SOM, higher nutrient/water holding capacities, reduced importation of synthetic fertilizers, etc.). Due to their form and structure, the nutrient in the Regen products will not mobilize or leach like synthetic or manure fertilizer; it has a negative mobility factor helping to further retain other more mobile forms of fertilizer.

4.5 SCALABILITY EVALUATION

Regen is scalable with some economies of scale experienced for more installations or larger installations. For example, a network of three Regen facilities can save around $1.1 million in capital costs when mobile resources are shared by the conglomerate. These savings at scale are also apparent in Tables 1 and 2 which compare a single Regen facility with five.

The minimum deployment size is a single pilot, full-scale plan occupying 10 acres, as described in Table 1. A facility of that size requires local manure inputs of at least 180 million gallons per year. Scaling up depends more on the manure sources as feedstock than the market demand for Regen products. Depending on manure sources, a region could have one or many Regen facilities. Even just five Regen facilities in a single subwatershed (Northwest Ohio) could achieve 46 percent of the US Action Plan reduction goal for P in Lake Erie and 59 percent of the reduction goal for the Maumee River.

At a larger scale of five or more Regen facilities around the state, all five TAP objectives will experience synergistic benefits. As described above, nutrients are removed from manure waste streams thereby reducing nutrient loading to rivers, streams, and lakes (TAP Objective 1). Regen products such as biochar and filter socks can be deployed in rivers and streams for direct removal of nutrients (TAP Objective 2). Meeting Objectives 1 and 2 will result in reduction of HABs not by removing the bloom but systemically through nutrient reduction. The KDS component recovers and separates nutrients from animal waste lagoons (TAP Objective 4) and municipal wastewater treatment plant biosolids can be incorporated into Regen composting (TAP Objective 5).

4.6 INFORMATION GAP EVALUATION

Kurtz Bros.' submittal was very thorough. Each component of Regen was more fully described with appendices of data and evaluations (Kurtz Bros., 2021). Kurtz Bros.' own size and history in materials handling further supports a key part of Regen – the packaging, distribution, and marketing of Regen products.

Minor information gaps are regarded as follows:

- Kurtz Bros. provided "Northwestern Ohio Swine and Dairy Calcs" in its appendices. The dry matter percent phosphorus before KDS separation was 0.74 and in Regen composts 0.63. On the surface, it appears that 0.11 percent is retained in the liquid portion of manure onsite, but not stated explicitly. Also, in the calculations, 0.63 percent phosphorus in dry compost is shown equivalent to 0 tons per year. These data may be contained in AES' Quick Wash TAP proposal but was not included in Kurtz Bros.'s response to data request.

- Little information was given regarding waste streams of the Regen process requiring final disposal such as landfilling. There may be none, as the entire operation can be broadly regarded as a waste-as-resource enterprise.

- Detailed cost spreadsheets were not made available for proprietary concerns. However, calculations by Tetra Tech of available numbers did nearly match the summary data presented by Kurtz Bros., both with regards to quantity and value.

- Present value was not calculated by Kurtz Bros. but was estimated by Tetra Tech to aid in the comparison to other TAP vendors.

- Some information regarding the nutrient filter sock was also withheld. Tetra Tech's evaluation therefore simply recognized the probable reduction of nutrients in water bodies by adsorption, but claims could not be confirmed. Also, the effect of filter socks on reductions of nutrients in water bodies

was not fully described. Since the biochar and nutrient filter socks are an added benefit to the Regen system, this data gap is not considered significant.

4.7 FEASIBILITY FOR LARGE-SCALE TECHNOLOGY DEMONSTRATION

Regen's process model starts with feedstocks suitable for processing and about 10 acres of land co-located in a region with swine or dairy CAFOs. The likelihood of locating swine or dairy CAFOs producing a total of about 180 million gallons of manure annually appears high in many watersheds, especially in the Maumee River watershed. Other elements of the Regen process are easily acquired, installed, and operated with conventional modes of transportation, purchases from equipment vendors, and labor. Renting or purchasing 10 acres of land appears more feasible since the producer could experience benefits from manure handling, processing, and reduction. Further, a profit-sharing arrangement could be formed that may benefit all parties.

As noted, capital costs would need to be financed through grants and loans, however these are not necessarily sunk costs because Regen facilities experience revenue.

4.8 FEASIBILITY FOR FULL-SCALE IMPLEMENTATION

Five Regen facilities are the basis of Kurtz Bros.'s full-scale implementation and appears feasible even in a single watershed. However, clusters of facilities in watersheds with adequate feedstock would justify even wider scale implementation. There appears to be little difference in feasibility between technology demonstration (a single Regen facility) and full-scale implementation (five or more Regen facilities). Regen facilities should be in the agriculture communities that they wish to service so they can access waste materials and end-use markets for the products that they produce. Regen facilities could be added incrementally as land is acquired and the enterprise budget allows for more debt, investment, and capital expenditures for additional facilities.

4.9 PROBABILITY OF SUCCESS

Because the Regen process model works at a watershed scale, it appears to be able to address all TAP goals significantly. As a systemic solution to nutrient pollution in waterbodies, its process appears promising because it ultimately addresses the root causes of HABs which is the overapplication of nutrients and their leachability in the low-SOM soils characteristic typically found in farm soils within the Ohio Lake Erie watersheds.

In addition, the Regen process includes a host of secondary benefits beyond the TAP objectives. These include higher agricultural crop yields (from increased SOM); waste-to-energy (from onsite anaerobic digestion); solid waste diversion (from organics recycling); carbon credits; and soil amendments supporting organic agriculture.

In summary, because of Kurtz Bros.'s size, expertise, and presence in the marketplace, few ingredients are necessary to make Regen a success and a reality.

4.10 FINANCIAL VIABILITY

Kurtz Bros. has annual revenues of over $35 million in Northern Ohio and nearly $100 million amongst 13 landscape supply centers, 9 production sites, 1 waste-to-energy site, and 3 erosion and sediment control plants. Kurtz Bros. employs over 350 full-time employees in Northern Ohio, with another 180 additional employees throughout the collective companies. It appears to be well positioned to construct and operate Regen facilities.

It is Tetra Tech's opinion that this information demonstrates the financial viability of Kurtz Bros. to support term implementation of this technology.

4.11 QAPP

Kurtz Bros. provided some raw data to support the technology evaluation but no quality assurance project plan (QAPP), per se, was provided. As described in Section 4.6, few data gaps were found. A significant amount of data was from third parties including peer-reviewed academic journals and equipment vendor literature. The underlying data are therefore assumed to be of high quality. In addition, Kurtz Bros. indicated that a QAPP and quality assurance/quality control (QA/QC) features would be established prior to a demonstration project following the regulatory guidelines provided by Ohio EPA based around compost and material distribution. QA/QC features would include the following:

1. Inflow and outflow loads to and from the compost facility are inspected to assure that materials received for composting such as feedstocks and bulking agents are free of contamination and solid wastes or unapproved materials for composting and that regulatory requirements are met for finished compost.

2. Finished compost data will be collected and compared to the regulatory limits and stabilization standards by management staff prior to release of finished compost from the site and the collected information will be used to generate daily, monthly, and annual reports for the Ohio EPA.

3. Daily compost pile temperature collection by hand or by computer-based electrode continuous collection of data.

4. Analysis and evaluation of the collected temperature data for operational and regulatory purposes.

5. Turning of piles as necessary to keep the composting process active to produce finished compost.

6. Use of a written plan for use of equipment to assure that the equipment used on raw incoming feedstocks is either not used on finished compost or that the equipment cleaned between uses to assure that fecal coliform is not reintroduced into finished compost.

7. Collection of representative samples of processed compost for shipment to third party labs for pathogens, regulatory metals, and stability indicators.

4.12 DATA VALIDATION

While Kurtz Bros. does not specifically have any clear 'third-party' review of its organics management experience, the company instead brings over three decades of experience and operating knowledge for large scale compost and organics management facilities and product commoditization. These data are considered unvalidated by third parties but are in-house and first-hand. Other data used to prepare this evaluation were provided by parties other than Kurtz Bros., and the data are considered to be validated.

4.13 SUPPLY CHAIN

The Regen process is an assembly of off-the-shelf equipment and sub-processes. Establishing a Regen plant would be the same as opening another recycling facility that would need to be staffed and staged just like any other production facility. The risk from supply chain disruptions for capital construction is considered low. During the operation and maintenance phase, a robust maintenance program would need to be implemented because of the many electromechanical components. Spare part inventory would need to be kept up to date. In addition to the feedstock processed manure, the proposed pilot scale Regen facility has a projected requirement of 46,000 yards of carbon, in various forms, per year so land and feedstock would have to be ensured through contract and contingency. In the event of a disruption, little consequence to the process or environment would occur until operations could return to normal.

4.14 ENVIRONMENTAL RISKS

Environmental risks for the Regen process can be characterized as similar to a large-scale compost operation on 10 acres. Because the setting is agricultural and near CAFOs, noise, dust, and odor impacts would be similar to them and go mostly unnoticed. An incremental increase in truck traffic on county, state, and federal highways would occur. Also, similar to a livestock operation, any facility that manages waste manure, biosolids, or organics will present a relative level of odor. Noise, dust, and odors can all be mitigated with locating the Regen facility in a location with the proper zoning, space, and wind direction.

Kurtz Bros. would create a spill prevention and response plan that can be implemented in the rare instance that an accident occurs onsite or on the road. The elevated emissions from truck traffic associated with the Regen facility can be qualitatively offset by the reduction in synthetic fertilizer use, onsite waste-to-energy production, and fixing carbon (carbon credits).

Finally, the facility itself would largely be regulated by Ohio EPA as a Class III composting facility and using its siting criteria. Following these criteria would mitigate many potential environmental impacts.

Kurtz Bros. did not present any data on waste streams. The products of Regen are composed of upstream waste streams, however a certain amount of unusable feedstock and impurities to be disposed in a landfill would be expected and minor.

As described above, numerous beneficial, waste-as-resource byproducts are an important feature of the Regen process. These include higher agricultural crop yields (from increased SOM); waste-to-energy (from onsite anaerobic digestion); solid waste diversion (from organics recycling); and soil amendments supporting organic agriculture.

4.14.1 Health & Safety

A Regen facility would involve large equipment such as front-end loaders, conveyors, horizontal grinders, and screeners. Also, manure contains fecal coliform and other potentially harmful bacteria. Kurtz Bros. maintains a health and safety plan for all its workers to address these hazards. The plan includes the following:

- Statement of Health & Safety
- KBI – Safety Culture
- Training
- Drug and Alcohol Policy
- Accident Reporting
- KBI Safe Work Rules
- Personal Protective Equipment
- Fire Extinguishers and How to Use
- Job Hazard Analysis
- Material Handling and Storage
- Mechanized Equipment
- Conveyor Belt Safety / Hazards
- Fall Protection / Hazards
- Lock-Out / Tag-Out Safety
- Electrical Safety
- General Trenching & Excavation Rules
- Hazard Communication

The Regen soil amendment products have no unique health and safety hazards and would be similar to the use of any other compost, including dust and stockpiling.

4.15 COMMUNITY PERCEPTION & DISPROPORTIONATE IMPACT

The Regeneration model was not constructed in a vacuum by Kurtz Bros. alone, but instead represents a collective approach to problem solving that helps provide opportunities from challenges and creates a win-win model for stakeholders affected by the State's desire to reduce nutrient pollution in Lake Erie. Kurtz Bros. has invested hours consulting with stakeholders. Kurtz Bros. utilizes local labor at all their existing facilities. A regional Regen facility would employ at least 9 full-time equivalent (FTE) jobs. Because of this, the prospect of community resistance is considered low.

As described in Section 4.14, Kurtz Bros. would utilize best management practices to mitigate environmental impacts. Kurtz Bros. has experience working with communities and neighbors to be good stewards and establish a mutual good neighbor policy.

Kurtz Bros. presented a letter of support from a Soil and Water Conservation District within the agriculture region of Northwest Ohio as well as a letter of support from one of the premier family farms operators in Ohio.

5.0 FINDINGS AND OPINIONS

Based on our review of the available information and discussions with Kurtz Bros., Tetra Tech has reached the following conclusions regarding Regen:

- Regen is an example of a systemic solution to HABs in Lake Erie. While efficacy in reducing the occurrence of HABs is an elusive metric, Regen functions at the causal level, that is, nutrients released from soil, coursing through the watershed, and entering Lake Erie.
- Regen's solution to HABs is watershed-wide. While it cannot make a HAB event disappear from a particular lake or bay, it reduces the likelihood of it occurring in the first place.
- Regen's business model relies heavily on other players and factors and necessitates multi-lateral agreements, contracts, and market participation. This is in contrast to other technologies that can be deployed unilaterally by a single farm or jurisdiction.
- Not unlike other technologies, Regen relies on up-front capital to construct its facilities. If that capital is borrowed in a typical business loan, the time required to sell product may challenge the ability to pay back principal and interest. Under a different business scenario, for example, using grant funding or long loan terms, there should be no barriers to business viability.
- Regen's nutrient removal rates are significant and the cost per ton of nutrient is efficient.
- Regen operates at a scale commensurate to the problem.
- Regen requires a long-term commitment to detect and associate any reductions of HABs in Lake Erie to Regen. However, the business model appears to sustain itself.

6.0 REFERENCES

Brownfield Ag News. (2021). Near-record high fertilizer prices projected for 2022. August 4. Accessed online at: https://brownfieldagnews.com/news/near-record-high-fertilizer-prices-projected-for-2022/

H2Ohio Technology Assessment Program (H2Ohio TAP), Lake Erie Algal Bloom. (2020). Request for Technologies.

Kurtz Brothers, Inc. (Kurtz). (2021). "Request for Technologies, Technology Assessment Program (TAP) Lake Erie Algal Bloom," submitted by Jason Ziss January 14, 2021

Kurtz. 2021. "Nutrient Regeneration: Protecting Lake Erie Water Quality While Servicing Midwest Agriculture." presented to Tetra Tech by Jason Ziss July 23.

Mengel, D. (2012). *The Value Of Soil Organic Matter*. No-tillfarmer.com. Retrieved in December 2021 from https://www.no-tillfarmer.com /articles/1851-the-value-of-soil-organic-matter

Ohio EPA. (2013). Ohio Lake Erie Phosphorus Task Force II Final Report. Table 5-1. Accessed online at: https://www.motherjones.com/files/task_force_report_october_2013.pdf

Ohio EPA. (2020). Nutrient Mass Balance Study for Ohio's Major Rivers 2020. Division of Surface Water Modeling and Assessment Section. December 24, 2020.

Studer, Kip. (2021). Personal communication November 4, 2021. Mr. Studer is a representative from the Ohio Department of Agriculture and member of the H2Ohio TAP Team.

U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS). (2006). Best Management Practices to Minimize Agricultural Phosphorus Impacts on Water Quality. July. Accessed online at: https://www.ars.usda.gov/is/np/bestmgmtpractices/best%20management%20practices.pdf