Brown AND Caldwell

carollo

701 Pike Street
Suite 1200
Seattle, WA 98101

T: 206.624.0100

Technical Memorandum

Prepared for: City of Bellingham Public Works Department

Project Title: Post Point WWTP Biosolids Project Phase 3 – Biosolids Facility Plan and Nitrogen Removal Impact Study and Phase 4 – Preliminary Design

Project No.: 154154 Phase 4 Task 327/10550A00

Technical Memorandum No. 15

Subject: Struvite Management

Date: November 15, 2021

To: Steven Bradshaw, Superintendent of Plants

From: Mike Thorstenson, Brown and Caldwell Project Manager

Copy to: Brian Matson, P.E., Carollo Senior Vice President

Digitally signed by Cameron D. Clark
Contact Info: Carollo Engineers, Inc.
Date: 2021.12.16 16:15:42-08'00'

CAMERON D. CLARK
STATE OF WASHINGTON
49936
REGISTERED
PROFESSIONAL ENGINEER

Prepared by: ______________________
Cameron D. Clark, P.E., Carollo Engineers, Inc.,
Washington License 49936, Exp.: 12/8/2023

Reviewed by: ______________________
Susanna Leung, P.E. Carollo Engineers, Inc.,
Washington License 40845, Exp.: 5/8/2023

Reviewed by: ______________________
Steve Krugel, P.E., Brown and Caldwell,
Washington License 42043, Exp.: 11/12/2022

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List of Abbreviations

$Al_2(SO_4)_3 \bullet 14H_2O$	aluminum sulfate
AO	anaerobic-oxic
City	City of Bellingham
ferric sulfate	$Fe_2(SO_4)_3$
vivianite	$Fe_3(PO_4)_2 \bullet 6H_2O$
$FeCl_3$	ferric chloride
lb	pound(s)
mgd	million gallon(s) per day
PAO	phosphorus accumulating organism
PO_4^{3-}	phosphate
Post Point	Post Point Resource Recovery Plant
Project	Post Point Biosolids Project
struvite	$Mg^{2+} + NH_4^+ + PO_4^{3-} + 6\ H_2O \text{ -> } MgNH_4PO_4 \bullet 6H_2O$
TM	technical memorandum
TPAD	Temperature-Phased Anaerobic Digestion
W3	plant water
WAS	waste activated sludge
WWTP	wastewater treatment plant

Section 1: Executive Summary

Struvite is a common precipitate at wastewater treatment facilities. The likelihood of nuisance struvite formation at the Post Point Resource Recovery Plant (Post Point) will increase after the biosolids upgrade because nutrient concentrations in the thickening and dewatering return streams will also increase. However, it is difficult to accurately predict the location or quantity of struvite formation at Post Point. Struvite formation is a complicated process affected by the concentrations of key constituents (magnesium, ammonia, phosphorus), equipment geometry, temperature, pH, and the activity of other ions in solution. Therefore, struvite mitigation planning is often based on empirical observations of struvite formation in the field.

The severity of nuisance struvite formation varies by facility. When struvite precipitates within an anaerobic digester and is beneficially incorporated as part of the biosolids, there are minimal adverse impacts. In these circumstances, preventative engineering methods and reactive maintenance are often the preferred struvite maintenance strategies. However, if struvite precipitates in piping or rotating equipment, it can result in expensive and time-consuming maintenance demands. Chemical management or dedicated unit processes are often employed to control nuisance struvite precipitation.

This technical memorandum discusses struvite management strategies as they apply to Post Point. Because the extent of struvite formation is unknown at this time, a struvite management plan is proposed that minimizes short-term capital costs and allows the City of Bellingham (City) to adaptatively address struvite formation in the future:

1. Following the biosolids project: Monitor struvite formation in pipes and equipment. Employ preventative engineering and reactive maintenance approaches.
2. A chemical management option will be provided as part of the biosolids upgrade. Chemicals such as iron salts, alum, or others can be used to manage struvite formation in the digesters and downstream processes.
3. If nuisance struvite becomes a wide-spread challenge: Compare continued use of reactive maintenance and chemical management technologies to controlled precipitation technologies to determine the appropriate long-term solution.

Section 2: Introduction

The City is in the planning process to evaluate options for long-term biosolids management and beneficial reuse opportunities for the wastewater residual solids recovered from Post Point.

The Post Point Biosolids Project (Project) planning process has followed a phased approach, including Phases 1, 2 and 3, to consider all possible alternatives and narrow down options to a preferred biosolids and energy management alternative. The City's phased planning and project implementation process includes Phase 1 – Preferred Conceptual Alternative Selection, Phase 2 – Final Alternative Selection, Phase 3 – Biosolids Facility Plan and Nitrogen Removal Impact Study, Phase 4 – Preliminary Design, Phase 5 – Detailed Design, and Phase 6 – Construction.

Phase 1 included the initial identification of all potential biosolids and energy alternatives, screening to identify viable alternatives for further evaluation, and the selection of a preferred conceptual alternative. In February 2019, the results of Phase 1 were summarized in Technical Memorandum (TM) No. 1 (TM 1) – Preferred Conceptual Alternative Selection. Phase 2 further developed the preferred conceptual alternative and evaluated specific processes for biosolids treatment, biogas end uses, and other processes. In

May 2019, TM 2 – Final Alternative Selection summarized the results of Project planning Phase 2. Phase 3 further refines the selected alternative technical requirements and documents the planning effort within the Biosolids Facility Planning Report (Biosolids Facility Plan) and is an update to the City's existing, comprehensive 2011 Wastewater Facility Planning Report (Carollo, 2011).

This TM No. 15 was prepared as part of Project planning Phase 3 and documents struvite management considerations for the Project. Struvite is a chemical precipitate of magnesium, ammonium, and phosphate that often forms at wastewater treatment facilities. the wastewater treatment process tends to concentrate the key constituents, increasing struvite formation kinetics. Since 2007, the City has enhanced solids settleability in their secondary treatment process by encouraging the growth of phosphorus accumulating organisms (PAOs) at Post Point. Post Point's anaerobic – oxic (AO) activated sludge basins encourage the growth of PAOs by providing alternating anaerobic and aerobic conditions. PAOs release phosphorus under anaerobic conditions in the anaerobic zone and then accumulate excess phosphorus in the presence of oxygen in the aerobic or oxic zones. PAOs store excess phosphorus in storage granules that are then wasted as part of the waste activated sludge (WAS).

As part of the Project, the solids handling process will be converted from solids incineration to anaerobic digestion. When PAOs are exposed to the anaerobic environment inside the digester, stored phosphorus will be released in the form of soluble ortho-phosphate. Soluble phosphorus remains in solution after dewatering and is recycled to the headworks in the dewatering return stream. Phosphorus returned to the liquid stream is re-acquired by the PAOs, creating a phosphorus loop between the liquid and solid treatment process. Many utilities have found that the combination of biological phosphorus removal and anaerobic digestion increases nuisance struvite formation because of elevated phosphorus concentrations cycled between the two processes.

Nitrogen and phosphorus—both critical to the formation of struvite—are generally at higher concentrations in the solids treatment processes, particularly dewatering sidestreams. Phosphorus released during digestion is mostly in the phosphate form, which remains soluble and is conveyed back to the secondary treatment process rather than being removed in the biosolids. Therefore, addressing nutrients in the solids streams and sidestreams can have the additional benefit of reducing nutrient loadings to the secondary treatment process.

Struvite impacts on maintenance vary depending on the location and severity of formation. Struvite can be particularly problematic when it forms within piping, rotating equipment, or other critical plant processes. Figure 2-1 shows nuisance struvite formation within piping. Struvite formed as a rough precipitate along pipe walls, reducing the pipe diameter, increasing the pipe friction coefficient, and reducing the pipe capacity. Figure 2-2 shows nuisance struvite formation within a centrifuge. Struvite formed between the bowl and casing, causing scoring of the bowl as it rotated. Scoring can result in premature wear of the bowl, unequal weight distribution, and noise or vibration issues during operation. Left unchecked, struvite could prevent the centrifuge from performing as designed. Struvite commonly forms on the inside of heat exchangers that cool digested solids from thermophilic to mesophilic temperatures, such as those planned for the temperature-phased anaerobic digestion (TPAD) process at Post Point.

In contrast, struvite can also be a beneficial precipitate if it is formed within the digester and remains in the biosolids. When retained in the biosolids, struvite can be a valuable fertilizer that increases the nutrient content of the biosolids product, a benefit to the resource recovery process.

Figure 2-1. Nuisance Struvite Formation within Piping

Figure 2-2. Nuisance Struvite Formation within Centrifuges

It is impossible to accurately predict the severity of struvite formation at Post Point after the biosolids upgrade. Biological and chemical wastewater treatment models have not been shown to be effective at accurately predicting the fate and behavior of metals like magnesium. Dedicated struvite precipitation models are available, but require field measurements of nutrient concentrations, which won't be available until after the digesters are installed. Even if struvite formation potential could be accurately predicted, discerning between nuisance struvite formation and formation in the biosolids would likely not be possible.

This TM discusses potential struvite mitigation strategies and establishes a framework for addressing struvite precipitation if it is shown to be a nuisance at Post Point.

Section 3: Struvite Formation Fundamentals

The governing chemical reaction for struvite precipitation is shown in the following equation:

$$Mg^{2+} + NH_4^{+} + PO_4^{3-} + 6\ H_2O \rightarrow MgNH_4PO_4 \bullet 6H_2O\ (\textit{struvite})$$

Struvite precipitation frequently occurs at locations where flow turbulence is high, which strips carbon dioxide from solution and increases the pH. This happens, for example, in process piping locations where pressure drops occur, such as piping, pump impellers, and post-digestion dewatering equipment. Struvite precipitation potential peaks around pH 10, thus struvite is more likely to precipitate as pH increases. Struvite precipitation is often magnesium-limited, so minimizing magnesium concentrations is a common struvite mitigation strategy. The preventative engineering strategies discussed in this section focus on minimizing turbulent piping or minimizing magnesium concentrations (usually by dilution). The reactive maintenance methods focus on addressing struvite formation after it has formed in process equipment. The chemical management and controlled precipitation technologies are dedicated processes to actively control struvite formation and minimize plant impacts.

Section 4: Struvite Management Alternatives

This section discusses process that have been used to control struvite within wastewater treatment plants (WWTPs), including rough space requirements and relative costs.

4.1 Preventative Design Measures

4.1.1 Description

Preventative control incorporates struvite mitigation design features such as:

1. Design/modify piping so that turbulent areas are avoided. The piping design should use long radius elbows, wyes instead of tees, and large pipe diameters.
2. Design piping, drop structures, overflow boxes, etc. to avoid locations of significant pressure drop, turbulence, and gas release.
3. Use smooth pipe materials such as glass-lined or plastic piping.
4. Minimize solids pumping wherever possible. Pumping can create a turbulent environment and also creates another location where struvite can form on mechanical equipment.
5. Reduce flow rates in piping to laminar regimes. If the flow is pumped on a timer, it may be possible to increase the pumping period and decrease the flow rate in the piping.
6. Design process piping to accommodate struvite cleanout. Redundant piping can be provided to allow for cleanout of one pipe while maintaining service.
7. Recirculation loops can also be used to effectively loosen and remove struvite in pipes that experience nuisance struvite formation (see below for further discussion of struvite cleaning chemicals).

4.1.2 Advantages

Preventative design measures have a proven history of successful implementation at wastewater treatment facilities. WWTPs that retroactively implement preventative design techniques have shown a reduction in struvite-related maintenance costs. For Post Point, preventative measures will be incorporated into the design of new biosolids facilities.

4.1.3 Disadvantages

Nuisance struvite formation may still occur despite preventative design measures. Depending on the level of nuisance struvite formation observed after the biosolids upgrade, additional struvite control measures may be required.

4.1.4 Implementation at Post Point

In general, preventative design measures are considered best engineering practice and will be used in the new biosolids facilities. For example, redundant solids pipes will be provided between the solids handling buildings and the digester facilities. These redundant pipes will allow maintenance of one pipe for struvite removal while maintaining the system in service. Piping design will incorporate minimal turbulence (low pipe velocities), optimal geometry (no sudden drops), and appropriate materials for the application. In addition, upgrades to existing piping and processes that could result in improved performance will be identified during detailed design.

4.2 Reactive Maintenance

4.2.1 Description

If struvite forms in process equipment or piping, it can be removed as part of Post Point's maintenance protocol. The reactive maintenance process generally involves isolation of the affected pipeline followed by chemical and/or physical removal:

1. Chemical removal involves the use of proprietary chemicals such as those manufactured by Jenfitch, RYDLYME, or others. The chemicals are recirculated through the isolated pipe section to loosen or dissolve struvite. Depending on the chemical, this process can re-dissolve struvite deposits or loosen struvite deposits and facilitate manual removal. Anti-scalants and anti-struvite agents are proprietary chemicals and are therefore relatively expensive. Usually, they treat struvite buildup by chelating magnesium, which can re-dissolve struvite into the process stream to be flushed out or moved downstream in the process. There are numerous chemicals available on the market, so selection of the preferred chemical should consider history of successful use at wastewater treatment facilities, biodegradability, storage life, dose requirements, chemical handling requirements, and availability, among other factors.
2. Physical removal requires opening the affected pipeline or equipment and either jetting out the struvite deposits with high-pressure water or manual removal using mechanical tools. This removal mechanism is space-, labor-, and time-intensive. For reference, a facility in the Midwest incurred reactive struvite maintenance costs up to $350,000 per year. The facility has a similar maximum rated flow as Post Point and also employs biological phosphorus removal. The cost was primarily for pipe disassembly and removal with hand tools. However, the costs for this reference facility may represent the high-end of maintenance costs. Post Point may incur considerably lower struvite maintenance costs.

4.2.2 Advantages

Reactive maintenance requires minimal capital cost and does not consume site footprint during normal operations. If nuisance struvite is a minor issue at the facility, reactive maintenance is a low-cost and effective method of control.

4.2.3 Disadvantages

If reactive maintenance demands are excessive, space and labor demands can become exorbitant. Removing pipes for physical removal can require extensive equipment downtime. Removing large quantities of struvite can also require lots of building footprint for struvite staging before being removed from the facility. When nuisance struvite issues become excessive, dedicated struvite control technologies can reduce reactive maintenance problems.

4.2.4 Implementation at Post Point

Reactive maintenance is the default nuisance struvite control mechanism if chemical or physical control methods are not implemented. It is possible that struvite will not be a major concern at Post Point, thus it is prudent to wait until struvite behavior as a result of the biosolids upgrade is understood. Until that time, a reactive maintenance protocol is recommended.

4.3 Chemical Management

4.3.1 Description

There are several chemical control techniques available to minimize or prevent struvite formation within the facility. These techniques generally involve reducing the concentration of one or more ions required for struvite formation.

1. Add iron salts such as ferric chloride ($FeCl_3$) or ferric sulfate [$Fe_2(SO_4)_3$]. Iron salts can be added to primary clarifiers as a form of chemically enhanced primary treatment or directly to the digesters. Iron reacts with the phosphate ion to form insoluble ferric phosphate precipitates. Iron salts also reduce the pH of the liquid stream, which inhibits struvite formation. In addition to struvite control, adding iron salts can reduce hydrogen sulfide concentrations in the digester gas and can improve solids dewatering performance by increasing cake solids. However, iron salts can be relatively expensive and large chemical doses are often needed. Iron salts increase the risk of forming nuisance vivianite [$Fe_3(PO_4)_2 \bullet 6H_2O$] deposits in process equipment and piping. Nuisance vivianite has similar concerns and maintenance requirements as nuisance struvite, so careful control and consideration of iron salt dose are important. Iron salts create safety and corrosion issues due to chemical handling. The iron precipitation reaction consumes alkalinity, which need to be offset by alkalinity supplementation in the sidestream treatment process. Iron increases the weight of the biosolids product, which may increase the number of truck trips required to transport biosolids from the facility.
2. Add aluminum sulfate [$Al_2(SO_4)_3 \bullet 14H_2O$], commonly known as alum. Although aluminum sulfate does not pose the safety and corrosion issues of ferric chloride, the resulting hydroxide precipitate can have adverse effects on the dewaterability of the sludge. Alum is rarely used on sludge applications and may require additional chemicals to function properly. Alum also consumes alkalinity, which would require supplementation in a sidestream treatment process.
3. An innovative approach to chemical struvite management is the use of rare earth chloride solutions that preferentially target phosphorus to form a precipitate. These chemicals have experienced growing popularity in recent years because they are not corrosive, safer to work with than iron- and aluminum-based chemicals, and produce significantly less chemical sludge than iron- and

aluminum-based chemicals. To date, this solution has primarily been used for liquid stream treatment to assist plants in achieving very low concentrations of phosphorus in plant effluent. Additional research on these chemicals would be needed to determine their suitability for application at Post Point.

4. Diluting sidestreams with process water is a method that has been tried with mixed success. A connection point for plant water (W3) could be provided upstream of pipelines affected by nuisance struvite formation and a continuous stream of water provided into the pipeline. Dilution reduces the concentration of all three important ions, but it increases pumping and therefore power consumption. Dilution would also increase the size of the sidestream treatment process because of the ion concentration reduction and process liquid temperature decrease.
5. Lower the pH with acid to increase the solubility of struvite. An acid line could be provided directly into the solids or sidestream pipeline and a continuous stream of acid provided. Sulfuric, hydrochloric, nitric, or other acid would likely be acceptable for this purpose. Sometimes, spent acid from industrial manufacturers can be obtained cheaply, but the number of additional truck trips required for chemical delivery and concentrations of contaminants in the acid should be evaluated. Acidifying upstream of dewatering is not expected to substantially impact dewatering performance, but corrosion and reduced alkalinity returned to the headworks or sidestream treatment processes may be an important consideration. Reduced alkalinity in the sidestream process would increase supplementation requirements.

4.3.2 Advantages

Chemical management strategies require minimal footprint and operator oversight is simple. Footprints can be as small as what is needed for chemical totes and delivery pumps. Adding chemicals to treatment processes can have additional benefits, such as improved phosphorus removal in primary clarifiers, reduced hydrogen sulfide concentrations in digester gas, and improved dewaterability.

4.3.3 Disadvantages

Chemical management may increase oversight demands for chemical ordering, handling, storage, and cleanup. Other disadvantages for each chemical management approach are discussed above.

4.3.4 Implementation at Post Point

A chemical management method will be included in the design of the new digester facilities. The ability to add struvite management chemicals will reduce nuisance struvite, with an additional advantage of reducing hydrogen sulfide concentrations in the digester gas. Additionally, if iron salts are used for chemically enhanced primary treatment in the future, iron salt demands in the solids processing system would decrease.

If excessive chemical demands are observed after the biosolids upgrade project, controlled precipitation technologies should be evaluated to determine if they are a cost-effective alternative to continued chemical management strategies.

4.4 Controlled Precipitation

4.4.1 Description

Controlled precipitation refers to the process of intentionally precipitating struvite in a dedicated reactor. Currently, there are several companies with proprietary technologies for struvite management. The most well-known are offered by Ostara and Centrisys. DHV, Paques, and NuReSys also offer struvite management technologies, but have fewer installations and less experience with struvite management on biosolids systems in the United States. For this project, the Ostara and Centrisys systems were evaluated because they reasonably represent the range of options available to the City and because they are applied to different points in the treatment process. The Ostara process is applied to sidestreams from thickening and/or dewatering, while Centrisys is applied directly to digested solids.

The Ostara technology does not treat digested solids, so dewatering equipment and digesters may be at higher risk of nuisance struvite formation compared to the Centrisys technology without a mitigating technology such as WASSTRIP. The WASSTRIP process was developed by Clean Water Services, a wastewater agency near Portland, Oregon, and is marketed by Ostara as a method to protect digesters and dewatering equipment from nuisance struvite formation. The process relies on the presence of PAOs in the WAS, meaning the process is best suited for WWTPs that undergo biological phosphorus removal. The WASSTRIP process is essentially a WAS fermentation tank upstream of digestion that provides a short anaerobic retention time. Depending on the availability of readily biodegradable carbon, the retention time could be between 12 and 24 hours. While in the WASSTRIP reactor, PAOs release their accumulated phosphorus into a soluble form without undergoing significant decay or digestion. The sludge is then thickened, with the filtrate combined with the dewatering recycle flow and sent to the Pearl reactor. The reduced phosphorus load to digestion helps protect the digester by reducing struvite precipitation both within the digester and in the feed and discharge lines. Because the level of treatment needed at Post Point is unknown at this time and because the Post Point plant has limited available space, a WASSTRIP process was not included in this analysis, but could be evaluated in the future.

4.4.1.1 Ostara Pearl® Process

A diagram of the Ostara Pearl® Technology is shown in Figure 4-1. The process promotes the controlled precipitation of struvite from sidestreams within a specially designed reactor and produces a dried fertilizer product. The reactor system is comprised of vertically oriented columns that increase in diameter stepwise from bottom to top. Liquid is fed into the columns and flows upward through the system, allowing struvite pellets to form. Depending on the type of system provided by Ostara, a recirculation process may also occur.

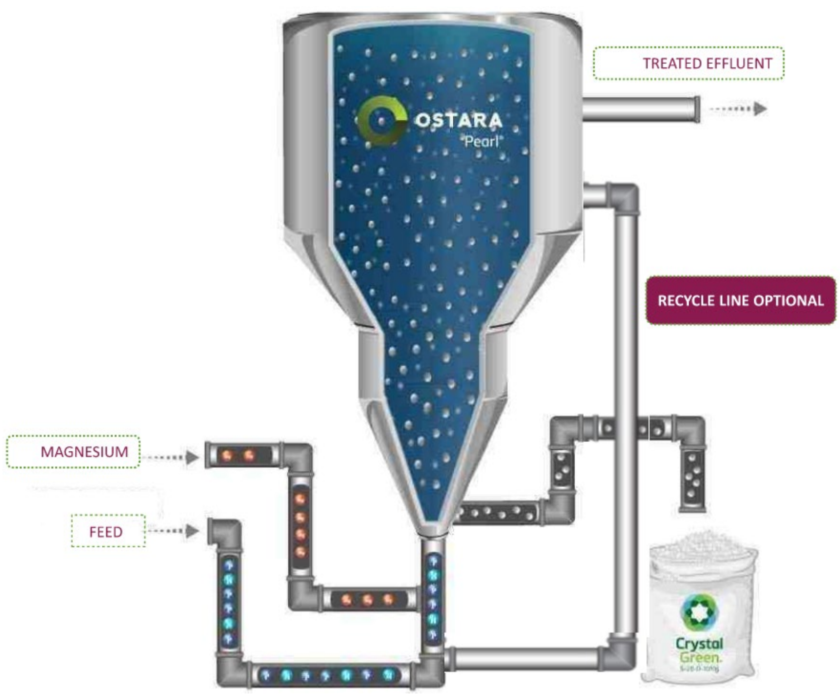


Figure 4-1. Ostara Pearl® Process Flow Schematic

Super-saturation levels for struvite are achieved by adding magnesium until a stoichiometric optimum is achieved. If needed, an alkaline solution can also be added to raise the pH. Typical removals for phosphorus range from 80 to 90%of the sidestream loading rate. Precipitated struvite is harvested from the bottom section of the reactor system and dewatered using a cyclone. The dewatered product is then thermally dried before being packaged, stored, and shipped. The precipitate product is a slow-release fertilizer substitute known as Crystal Green® (Figure 4-2). Crystal Green® is a shiny, hard, white pellet, about 2 to 3 millimeters in diameter. The Ostara Crystal Green® product is automatically bagged into approximately 2,000 pounds (lb) super sacks for ease of transport and storage. These bags can be stored nearby, or transported to a remote location.

A preliminary evaluation of an Ostara system was performed for Post Point. The 520 Building was identified as a potential location for controlled precipitation equipment after the existing incinerator is removed. One Pearl FX reactor tank and associated equipment will fit within the existing 520 Building (see Appendix A). Further refinement of equipment sizing and layout would need to be performed in the future once flows and nutrient concentrations are known.

The Ostara Pearl® process has been used in municipal wastewater treatment applications since 2007. There are currently at least 14 full-scale installations in operation in the United States. Most of Ostara's installations are located in North America at wastewater treatment facilities ranging in capacity from 15 to 1,200 million gallons per day (mgd).

Figure 4-2. Crystal Green® Product Produced at the Ostara Pearl® Installation in Edmonton, AB

4.4.1.2 Centrisys MagPrex™

Figure 4-3 shows a diagram of the Centrisys MagPrex™ process. The MagPrex reactor is an aerated crystallization reactor where struvite recovery and removal occur simultaneously. The entire digested biosolids flow is processed through the MagPrex system. In addition to removing struvite, controlled precipitation of the digested solids provides dewatering benefits through the removal of phosphates. The benefits include a reduction in polymer consumption and an improvement in the cake total solids concentration. The manufacturer reports reductions in polymer consumption of 20 to 30% or an increase in cake total solids between 2 and 3 percentage points, but results vary by location.

Magnesium chloride is provided to achieve super-saturation levels of struvite. Air is introduced into the reactor to provide mixing and to strip carbon dioxide, which increases the pH and enhances struvite formation. Typical observed phosphorus removals are between 80 and 90% of the load to the reactor. With MagPrex, it is possible to simply precipitate struvite into the biosolids stream, for ultimate distribution with the bulk biosolids. If desired, struvite can be separated from the biosolids stream at the bottom of the reactors and conveyed to product storage bins for separate handling. Note that the MagPrex system discharges a relatively wet product that may contain traces of biosolids. The air-stripping process will also generate gaseous methane and monitoring protocols are required to remain below explosive levels. The struvite grains can be used as an agricultural soil amendment or fertilizer.

The MagPrex technology has six full-scale installations in the United States. MagPrex is based on a European technology (AirPrex) that has several more installations in Europe.

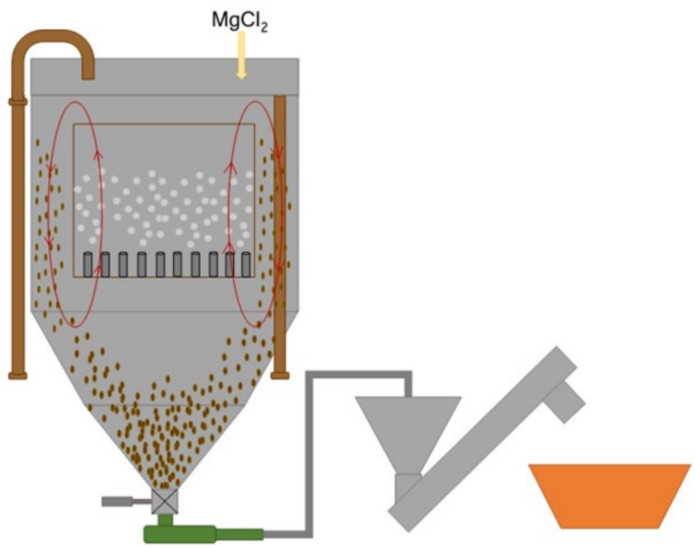


Figure 4-3. MagPrex Process Flow Schematic Showing Optional Struvite Recovery

A preliminary evaluation of the MagPrex system was performed for Post Point. The MagPrex reactor tank is about as tall as the 520 Building and would require building modifications to fit a single tank within the building. The roof of the 520 building would require an opening to accommodate the tank. As part of the building modifications, the roof would act as a service platform at the top of the tank. Alternatively, two shorter tanks could be installed. The shorter tanks would fit inside the 520 building but the capital cost would be higher, Both layout options are presented in Appendix B and Appendix C.

4.4.2 Advantages

Controlled precipitation can effectively remove large quantities of struvite that may otherwise create nuisance precipitation issues. When nuisance precipitation requires exorbitant labor or building space for maintenance, controlled precipitation technologies provide a dedicated unit process to minimize struvite costs. Depending on the technology, the struvite can be recovered and beneficially used as a fertilizer.

4.4.3 Disadvantages

Controlled precipitation technologies substantially reduce nuisance struvite within the plant, but nuisance struvite can still form, particularly in areas upstream of the control technology. The technologies also require space for the struvite management equipment. In particular, controlled precipitation technologies are tall and require special construction planning. Capital and operational costs can also be significant. Note that if struvite recovery is implemented, the recovered product can often be sold to offset operational costs.

4.4.4 Implementation at Post Point

The site footprint and potential locations for Ostara and Centrisys technologies are discussed above. If excessive reactive maintenance is observed after the biosolids upgrade project, controlled precipitation technologies should be compared to continued use of ferric to determine which option is preferable.

Key items to consider with controlled precipitation technologies include the size of the trucks required for struvite transport (if recovery is implemented), truck traffic considerations for chemicals and struvite, odor production, and space requirements.

There are a variety of contract models available for controlled precipitation technologies that provide cost flexibility for the following issues:

- Financing the capital cost of the treatment system.
- Staffing and maintaining the system.
- Designing, constructing, and operating the process.
- Marketing and distributing the struvite fertilizer product.

Because struvite control technologies are relatively new, there is not a standard contract model across all manufacturers. Nearly all manufacturers are willing to negotiate these logistical issues with the client to ensure that a mutually beneficial contract can be arranged. However, there are popular contract models that tend to be favored by municipal wastewater treatment facilities. Most contracts fall under the category of "capital purchase." In that model, the client is responsible for financing, constructing, and operating the system, which includes providing maintenance, power, and caustic (if necessary). The manufacturer would provide technical consultation and magnesium chloride. The manufacturer would also pay the owner for every ton of struvite fertilizer product and would be fully responsible for transporting the product from the treatment plant.

A less common alternative is a "treatment fee" agreement, where the manufacturer is responsible for the design, construction, and operation of the sidestream treatment system, while the owner pays a fee that can be negotiated based on volume of fluid treated, pounds of phosphorus removed, etc. This option is less popular because many municipalities dislike the possibility of sharing treatment responsibilities with an additional entity. In general, however, most contract mechanisms may be negotiated to achieve the best total solution for both parties.

Section 5: Summary and Recommendations

This section summarizes struvite control mechanisms and proposes a plan for struvite management after the biosolids upgrade. These control mechanisms with their description, relative cost, and recommendation are presented in Table 5-1.

Table 5-1. Comparison of Struvite Control Mechanisms

Technology	Description	Relative Cost	Recommendation
Preventative Design	Design piping and other equipment to minimize nuisance struvite formation	$	Include in biosolids upgrade project
Reactive Maintenance	Remove nuisance struvite from affected piping and equipment after it has formed	$-$$$, depending on severity	Perform reactive maintenance until the impacts of struvite formation can be characterized
Chemical Management	Manipulate chemical characteristics of process fluid to minimize struvite formation	$-$$$	Include chemical management techniques in biosolids upgrade project
Controlled Precipitation	Dedicated struvite precipitation reactor	$$$	Consider use if nuisance struvite formation is substantial

Struvite formation potential at Post Point after the biosolids project is unknown at this time. Therefore, it is prudent to establish a struvite management plan that will match the severity of nuisance struvite. Preventative engineering measures will be incorporated into all stages of the biosolids upgrade design, including the following items:

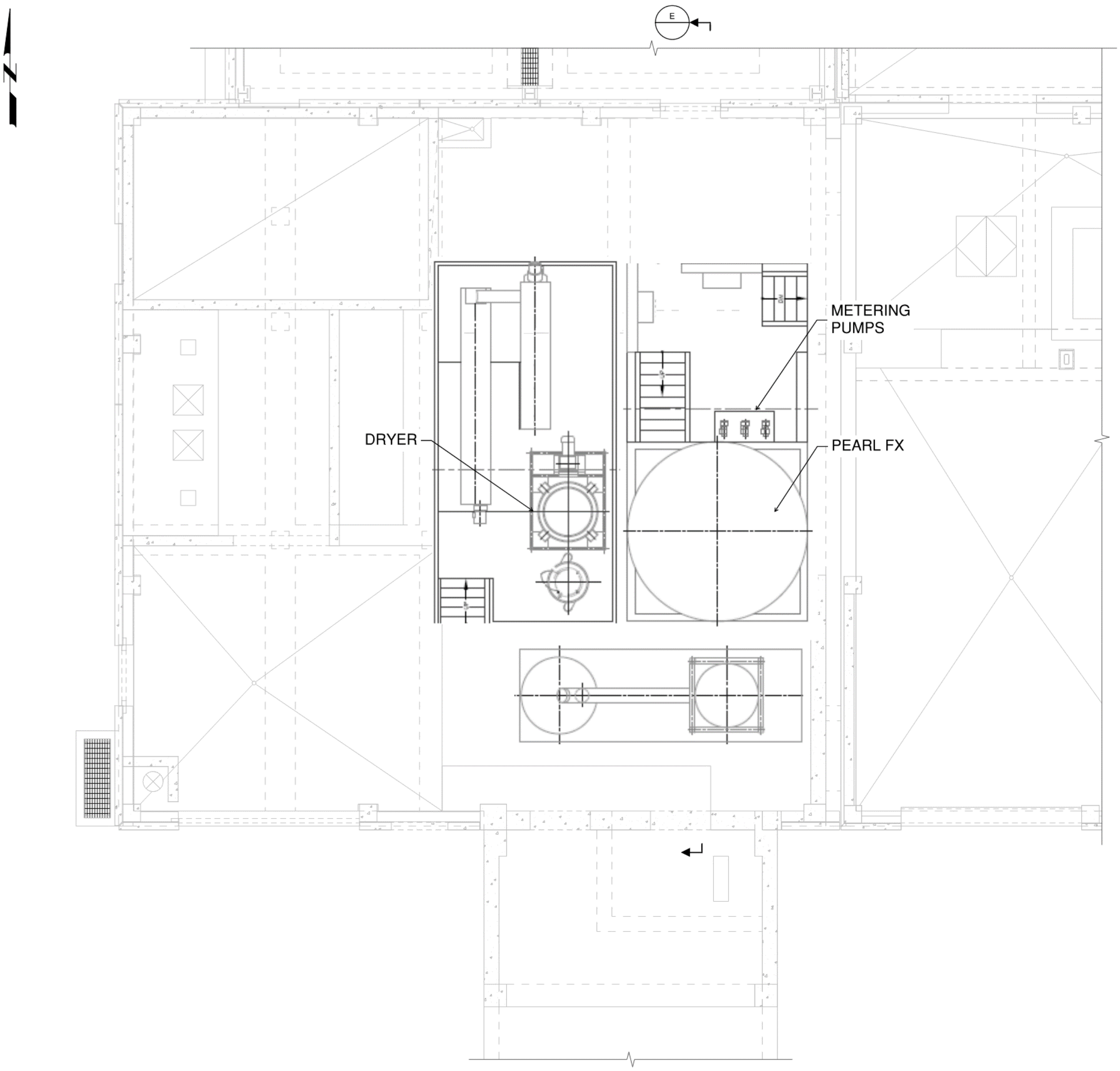
- Redundant raw solids pipelines from the solids handling building to the digesters.
- Redundant digested solids pipelines from the digesters to the dewatering equipment.
- Cleanouts and long-radius elbows on all new solids and return liquid piping.
- Glass-lined filtrate and centrate pipe.

Additionally, tanks will be included in the digester facility for chemical management options via iron salts, alum, or other chemicals. Other temperature-phased anaerobic digestion facilities in North America experience substantial nuisance struvite formation, thus a chemical management option will be provided.

After the biosolids upgrade project, nuisance struvite formation can be handled by a combination of chemical management and, if needed, reactive maintenance such as manual or chemical removal. After the costs and non-economic impacts those management methods have been accurately characterized, controlled precipitation could be considered.

A preliminary sizing analysis shows that both an Ostara Pearl FX system and a Centrisys MagPrex system will fit within the existing 520 Building. The MagPrex reactor can be provided as a single tank if the building is modified and access to the top of the MagPrex reactor tank is provided via the roof. Two MagPrex tanks would fit within the existing building, albeit at a higher cost and larger equipment footprint.

Appendix A: Ostara Pearl Preliminary Layout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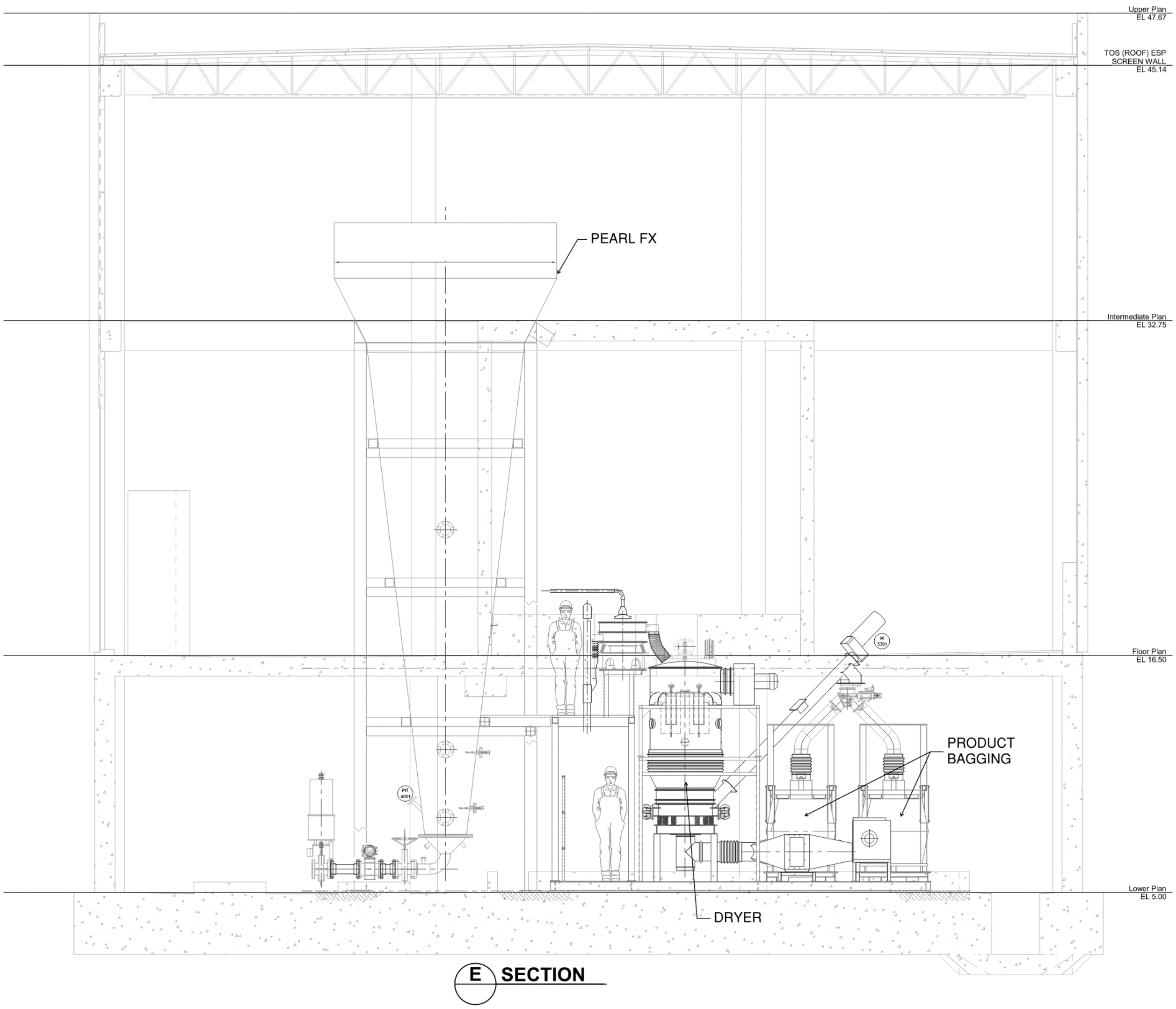
Upper Plan
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SCREEN WALL
EL 45.14
PEARL FX
Intermediate Plan
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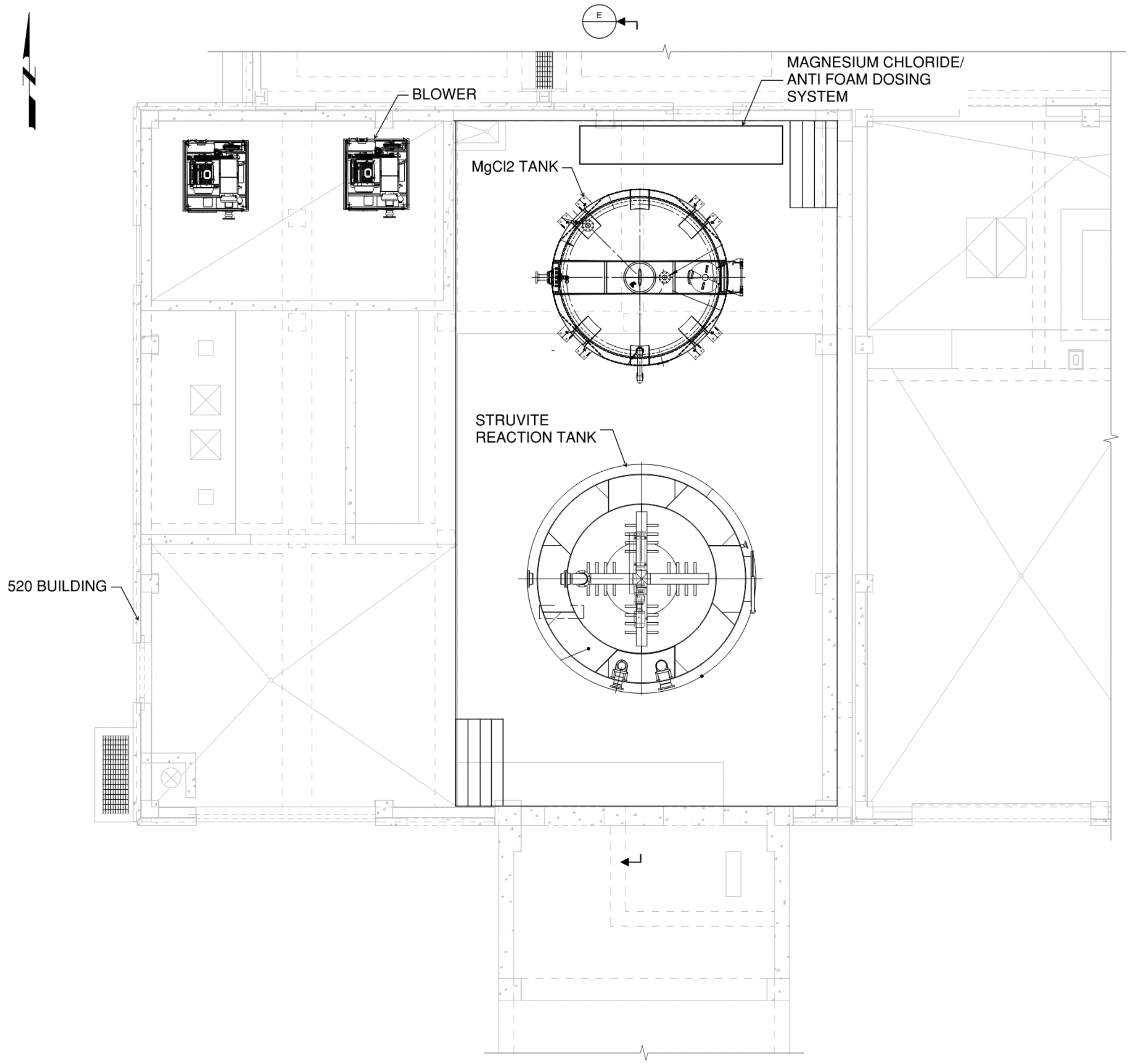
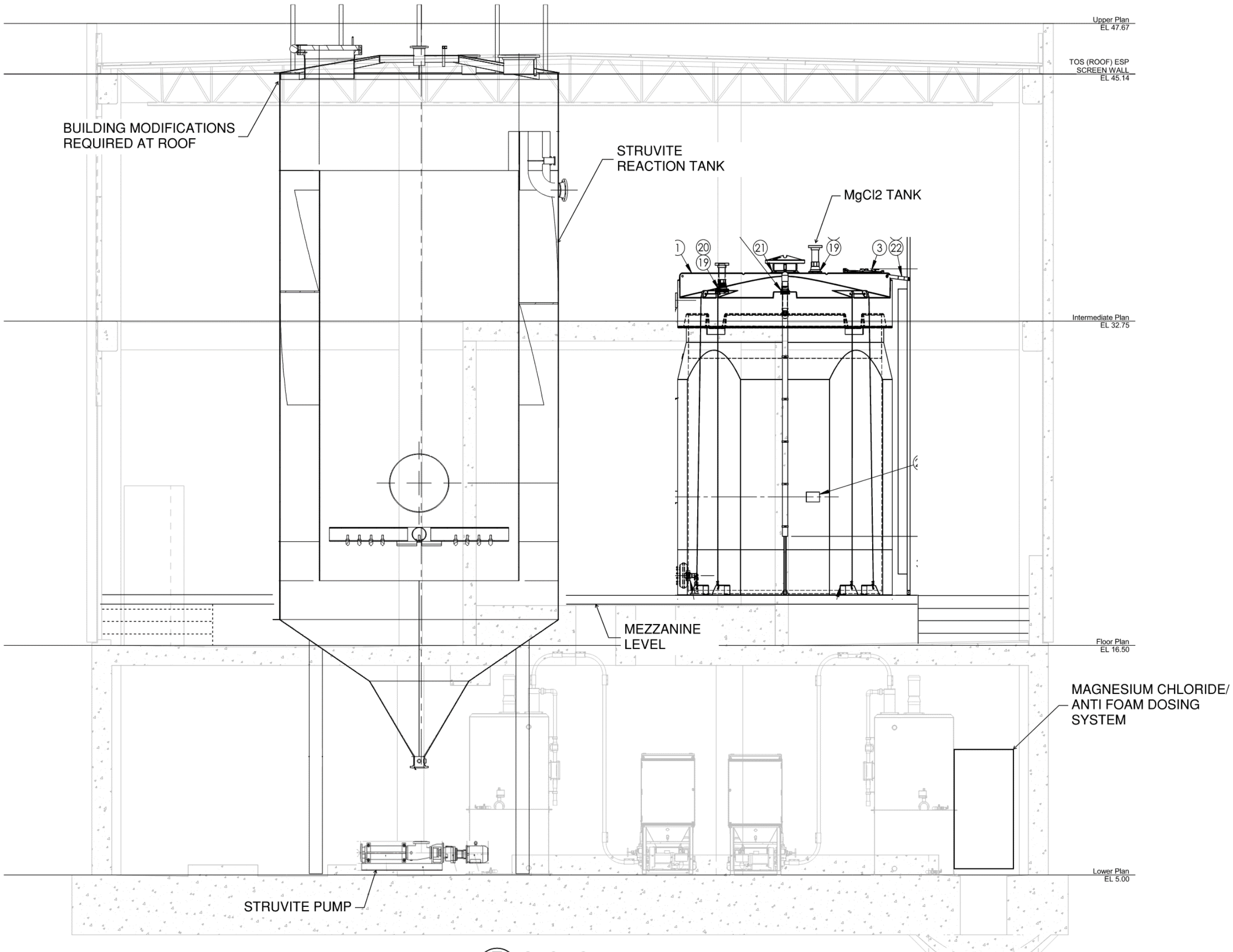
Floor Plan
EL 16.50
PRODUCT
BAGGING
Lower Plan
EL 5.00
DRYER
E SECTION

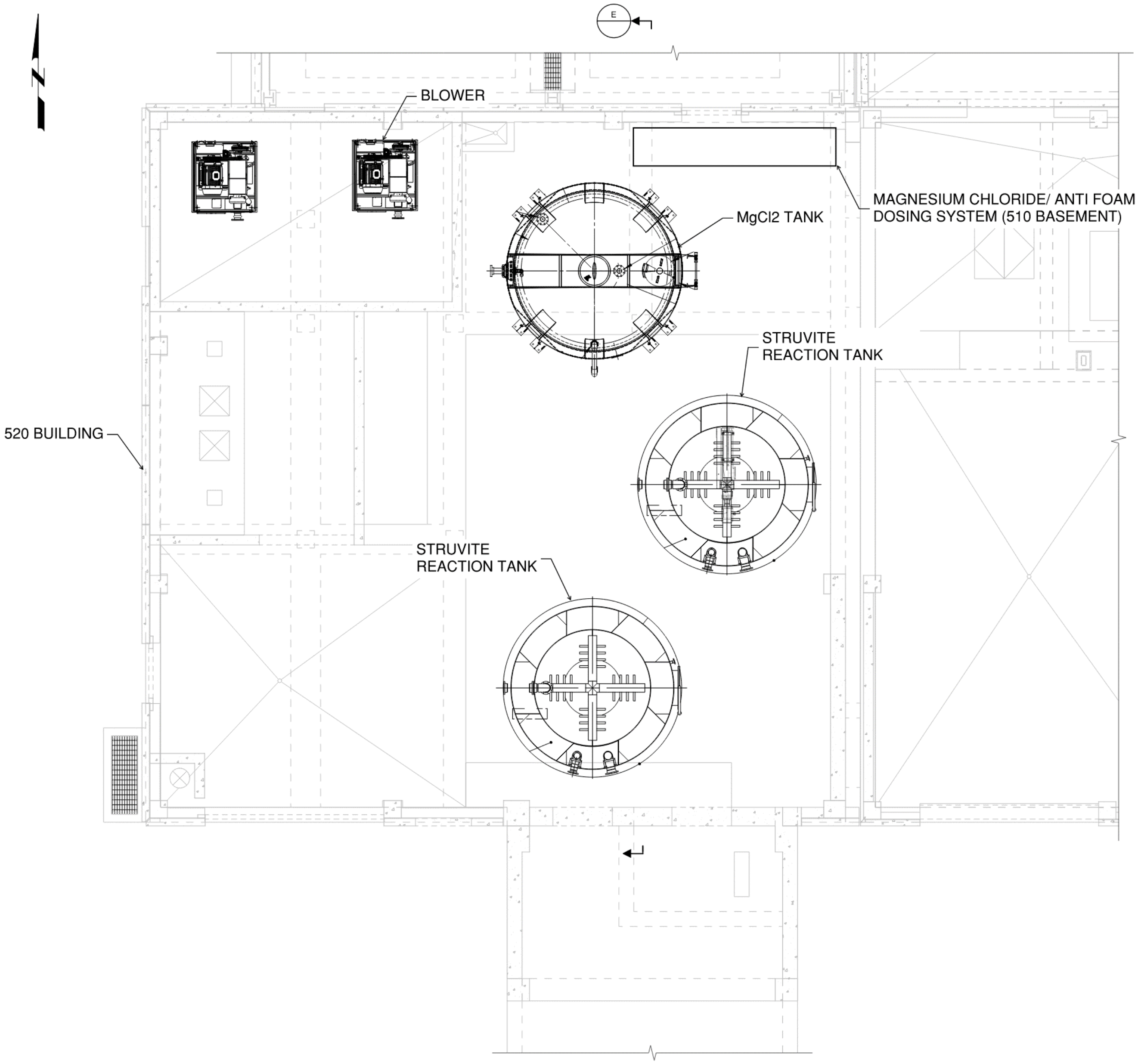
Appendix B: Centrisys MagPrex Preliminary Layout 1

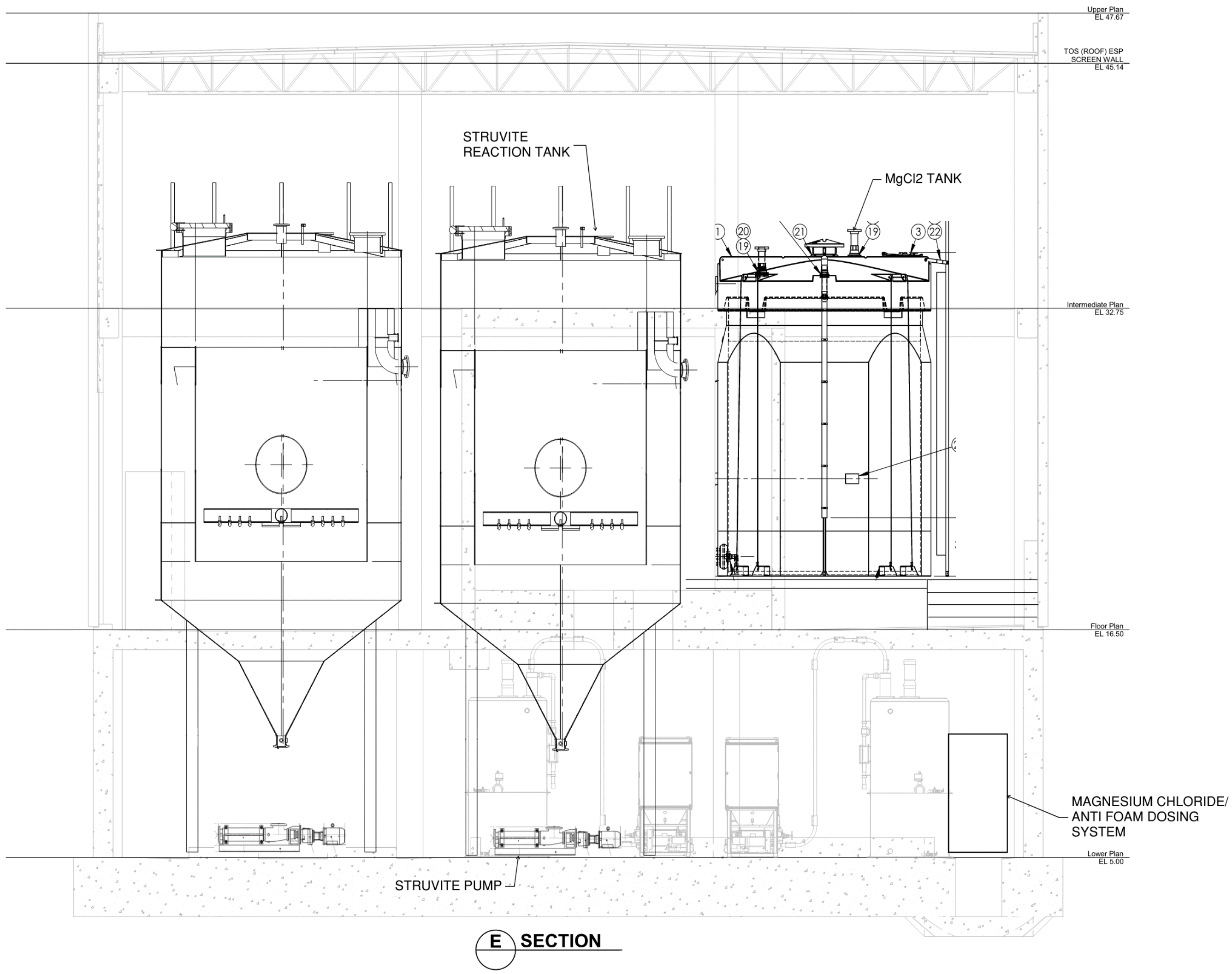

E
MAGNESIUM CHLORIDE/
ANTI FOAM DOSING
SYSTEM
BLOWER
MgCl2 TANK
STRUVITE
REACTION TANK
520 BUILDING


Upper Plan
EL 47.67
TOS (ROOF) ESP
SCREEN WALL
EL 45.14
BUILDING MODIFICATIONS
REQUIRED AT ROOF
STRUVITE
REACTION TANK
MgCl2 TANK
Intermediate Plan
EL 32.75
MEZZANINE
LEVEL
Floor Plan
EL 16.50
MAGNESIUM CHLORIDE/
ANTI FOAM DOSING
SYSTEM
Lower Plan
EL 5.00
STRUVITE PUMP

E SECTION

Appendix C: Centrisys MagPrex Preliminary Layout 2


E
BLOWER
MgCl2 TANK
MAGNESIUM CHLORIDE/ ANTI FOAM
DOSING SYSTEM (510 BASEMENT)
STRUVITE
REACTION TANK
520 BUILDING
STRUVITE
REACTION TANK


Upper Plan
EL 47.67
TOS (ROOF) ESP
SCREEN WALL
EL 45.14
STRUVITE
REACTION TANK
MgCl2 TANK
Intermediate Plan
EL 32.75
Floor Plan
EL 16.50
MAGNESIUM CHLORIDE/
ANTI FOAM DOSING
SYSTEM
Lower Plan
EL 5.00
STRUVITE PUMP
E SECTION