Advanced Nutrient Removal at the City of Montpelier Wastewater Treatment Facility

A Major Qualifying Project Submitted to the Faculty
of
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In Partial Fulfillment of the requirements for the Bachelor of Science Degree
By

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Abstract

This Major Qualifying Project was completed in conjunction with Stantec to evaluate and design tertiary treatment options for phosphorus removal at the Montpelier, VT Wastewater Treatment Facility. Discharge concentrations at the facility are under review by the EPA and this project developed design alternatives in anticipation of the new limits. This process included site investigations, preliminary design alternatives, construction phasing plans, and cost estimates. Based on design criteria this project proposes that CoMag© by Evoqua be implemented on site.

Executive Summary

Eutrophication is deteriorating water bodies across the United States. This damaging process has created the need for increased restrictions on nutrient loading from point and non-point sources, specifically in Vermont watersheds. Lake Champlain in VT is the primary source of livelihood and recreation for citizens in the surrounding area. Point and non-point discharge sources feeding into the lake are under increased scrutiny and subject to new regulations to preserve the quality of the lake.

The existing discharge permit for the Montpelier, VT Wastewater Treatment Facility (WWTF) included a limit of 0.8 mg/L as phosphorus (P). This limit is under review by the Environmental Protection Agency to reduce phosphorous loading into the lake. The new limit will be delivered in June 2015 and is expected to be 0.1 – 0.2 mg/L as P.

This Major Qualifying Project (MQP) was completed in conjunction with Stantec Consulting Services Ltd. to evaluate and conceptually design a tertiary treatment process for the Montpelier, VT Wastewater Treatment Facility (WWTF) to reach the anticipated discharge limit of 0.1 mg/L as P. The primary evaluation focused on existing plant structures and five available phosphorous removal technologies. The evaluation and conceptual design utilized site investigations, vendor representative discussions, site layout, construction phasing plans, sizing and loading calculations, and cost estimates.

Different components of the existing Montpelier WWTF were identified for upgrade by Stantec in May 2014. The most significant upgrade needed is to the UV Disinfection system. The current system is retrofitted where the previous chlorine contact tanks (2) were located. One of the chlorine contact tanks was retrofitted to include two UV disinfection channels with modulating weirs, while the other tank is not in use. Of the two channels in use, one is offline. The weirs are not fully functional and allow for leakage from the closed channel. The leakage, in conjunction with a poor building structure, leads to ice formation, which damages the UV disinfection bulbs. These shortcomings are addressed in the final design considerations.

The five phosphorous removal technologies were assessed by using several operational and implementation criteria and grading each technology accordingly. After the assessment, the technologies were narrowed down to, CoMag© by Evoqua and Ultra Filtration Membranes by GE/Zenon. These options were discussed with vendor representatives, the Montpelier WWTF site operator, and Stantec engineers to evaluate their applicability on site. The site visit to Montpelier identified primary concerns for choosing an option; footprint, energy costs, and ability to reach discharge concentrations lower than 0.1 mg/L as P. The visit also revealed a recently added FEMA pump station and corresponding piping in the vicinity of the current UV disinfection and potential area for a tertiary treatment process.

CoMag© was ultimately chosen for final conceptual design. CoMag© utilizes chemical precipitation and magnetite ballasted floc to rapidly settle out solids. This process has been piloted in other Vermont facilities and has easily achieved 0.1 mg/L as P discharge concentrations. The process has also achieved discharge concentrations of up to 0.05 mg/L as P in other pilot studies.

In the design phase, two layout options were considered based on a conceptual proposal given by Evoqua engineers. The proposal sized the process with four tanks for rapid mix, chemical precipitation, floc, ballast, and two clarifiers for settling. The final site design retrofits the sludge holding tanks currently not in use at the Montpelier WWTF with the tertiary clarifiers in the adjacent open space. The flow will then be rerouted through the unused channel in the UV disinfection building and back through for disinfection. In order to address the weir and ice issue, the MQP team recommends that the modulating weirs be replaced and a heated building be built encompassing the retrofitted sludge holding tanks and the UV disinfection system with a partition wall separating the two processes.

This project concluded that CoMag© should be chosen as the tertiary treatment process and a pilot study at the Montpelier WWTF should be conducted for two weeks to optimize the CoMag© process specifically for the facility. Following the pilot study, it is recommended that the final site design proposed in this MQP be pursued to reach new discharge concentrations.

Acknowledgments

The authors would like to sincerely thank all those involved in this project, their help and guidance allowed this project to be completed. The authors would like to personally thank their advisors, Professor Hart and Professor LePage, for their edits and time as they reviewed the report. This project could also have not been completed without the full support of Stantec Consulting Ltd. The MQP team would also like to thank Joe Uglevich, PE, Steve Calabro, PE, and the rest of the engineers at the Westford, MA office for sound technical advice and assistance. And a final thanks to the Montpelier, VT WWTF Staff, specifically Bob Fischer, for their support on site.

Capstone Design

The Accreditation Board for Engineering and Technology (ABET) requires that all accredited engineering programs include a capstone design experience. At Worcester Polytechnic Institute (WPI), this requirement is met through the Major Qualifying Project (MQP). The American Society of Civil Engineers (ASCE) specifies that this capstone experience must consider real-world constraints, such as: economic, environmental, sustainability, constructability, ethical, health and safety, social, and political. The following is a description of how this MQP incorporated these considerations.

Economic

To assist in the decision-making process for phosphorus reduction in an activated sludge wastewater treatment plant, a cost estimate of the chosen tertiary treatment process was assessed. The estimate took into account material, equipment, and labor costs associated with each technology. The cost estimate was ultimately a factor during the final design alternative decision process.

Environmental

The goal of the project was to reduce phosphorus discharge levels to comply with the Environmental Protection Agency's (EPA) revised Total Maximum Daily Load (TMDL), with the intent of making the effluent safer for the environment.

Sustainability

Through recommending state-of-the-art energy efficient design alternatives, the design goal for the WWTF was to increase the lifespan of the wastewater treatment plant while lifecycle costs of the treatment plant were reduced.

Constructability

An important aspect while the design alternatives were being developed was the constructability of each one, respectively. Site issues and space limitations were considered when design alternatives were evaluated.

Ethical

The project was sponsored by Stantec and regards wastewater treatment plants discharging into Lake Champlain. No aquatic animals were harmed or negatively affected by this project. There was no conflict of interest presented by the project. This project upheld the Fundamental Principles and Fundamental Canons set forth in the ASCE Code of Ethics.

Health & Safety

Chemical usage is a concern when choosing and constructing a new tertiary treatment technology. To reduce risks associated with reactive chemicals, storage spaces were allocated to provide extra safety in the case of a leak or explosion and any extra training required of the WWTF staff was recommended.

Social

Noise and odor are two common complaints from residents living in the vicinity of WWTFs. When considering design alternatives, noise and odor were evaluated to determine if they will have an impact on the surrounding community.

Political

The project was designed to meet the revised EPA TMDL for point and non-point phosphorus discharges and be compliant with all applicable federal laws.

Professional Licensure

Becoming a Professional Engineer (PE) in the civil & environmental engineering profession has become increasingly important, as ethics and law have become a prevalent element of society. Only after several years of qualifying engineering experience and passing the Principles and Practice of Engineering exam, is it possible to become a PE. PE's are considered to have attained the highest standard of knowledge in their respective field, and are expected to renew their licenses throughout their career to maintain that high standard. With a Professional Engineering license comes greater authority and responsibility. While non-licensed engineers may work in the same discipline, only PE's are allowed to approve engineering plans for public and private clients. Therefore, in order to advance in a civil & environmental engineering career, professional licensure is a necessary step towards becoming leaders and managers within the profession, whether public or private.

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1 Introduction

This Major Qualifying Project (MQP) is a redesign of a wastewater treatment facility (WWTF) to accommodate regulation changes made by the Environmental Protection Agency (EPA). The Total Maximum Daily Load (TMDL) for point and non-point discharge sources to Lake Champlain in Vermont is being revised. The EPA identified harmful phosphorous levels, which will lead to reduced discharge concentrations from point discharge sources. The new concentrations will affect all wastewater treatment plants (WWTPs) in the area with expired permits and will require substantial upgrades to meet new TMDL standards.

The work completed through this MQP focused on the advancement of upgrades to the Montpelier Wastewater Treatment Facility from the conceptual level to a preliminary design. While Stantec is examining the upgrades required for the entire treatment plant, a process that can take a team of engineers up to nine months to complete, this MQP focused specifically on the upgrades necessary to achieve new phosphorus discharge concentration limits. The advancement included a new tertiary treatment processes within the facility to meet a discharge concentration of 0.1 mg/L phosphorous in anticipation of new standards set forth by the EPA. The Montpelier WWTF currently provides secondary treatment prior to disinfection, which is sufficient for the existing discharge limit of 0.8 mg/L as P. Tertiary treatment is an additional treatment process beyond the secondary stage to remove additional phosphorus.

Project tasks included site investigations and discussions with operations staff; review and summarization of articles and papers on low-level nutrient removal technologies; discussions with equipment vendors; development of multiple options; followed by a schematic design; equipment and site layout; and a cost estimate for the recommended option.

2 Background

This chapter provides an overview of the Environmental Protection Agency (EPA) and the regulations placed onto the Lake Champlain region due to excess phosphorous loading. The Total Maximum Daily Limit (TMDL) was subject to change due to changing NPDES permitting. The Montpelier WWTF will be subject to a reduced TMDL and the City of Montpelier Wastewater Treatment Facility Modernization & Phosphorus Removal report completed by Stantec in collaboration with Aldrich + Elliott was done to assess its capability of handling increasingly more stringent regulations. The status of the plant components and a plant overview will be discussed in this chapter.

2.1 Montpelier Facility

The following section summarizes the *City of Montpelier Wastewater Treatment Facility Modernization & Phosphorus Removal* report completed by Stantec in collaboration with Aldrich + Elliott. This summarization will identify plant components in need of upgrade and a basic plant schematic. An aerial view of the Montpelier WWTF is shown in along with Dog River, where treated effluent is discharged.

The Montpelier WWTF is composed of eleven (11) components. The facility's supervisory control and data acquisition (SCADA) system as shown below in Figure 2 displays the processes the wastewater flows through before it becomes final effluent.

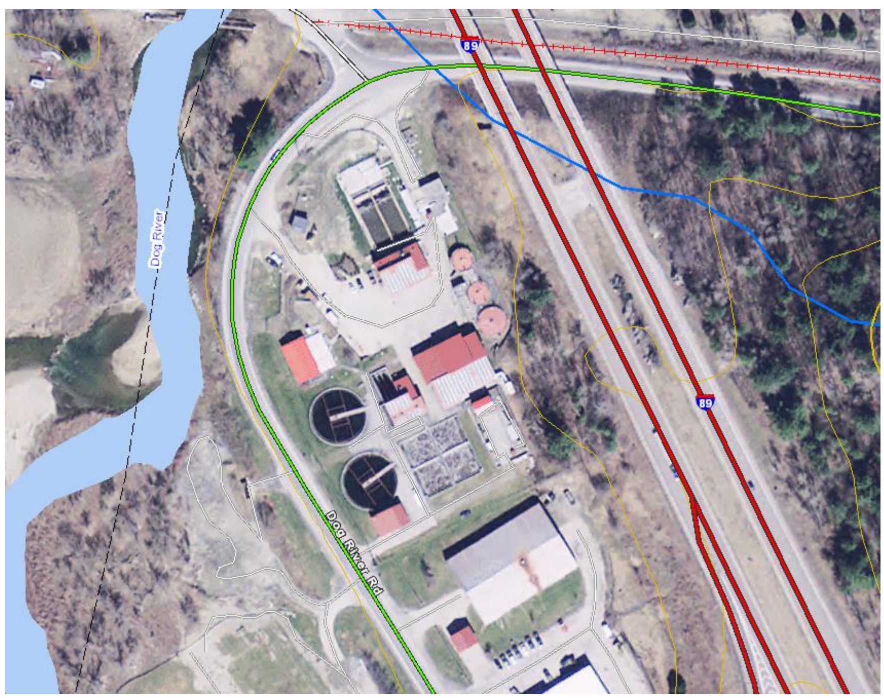


Figure 1: Aerial view of the Montpelier WWTF

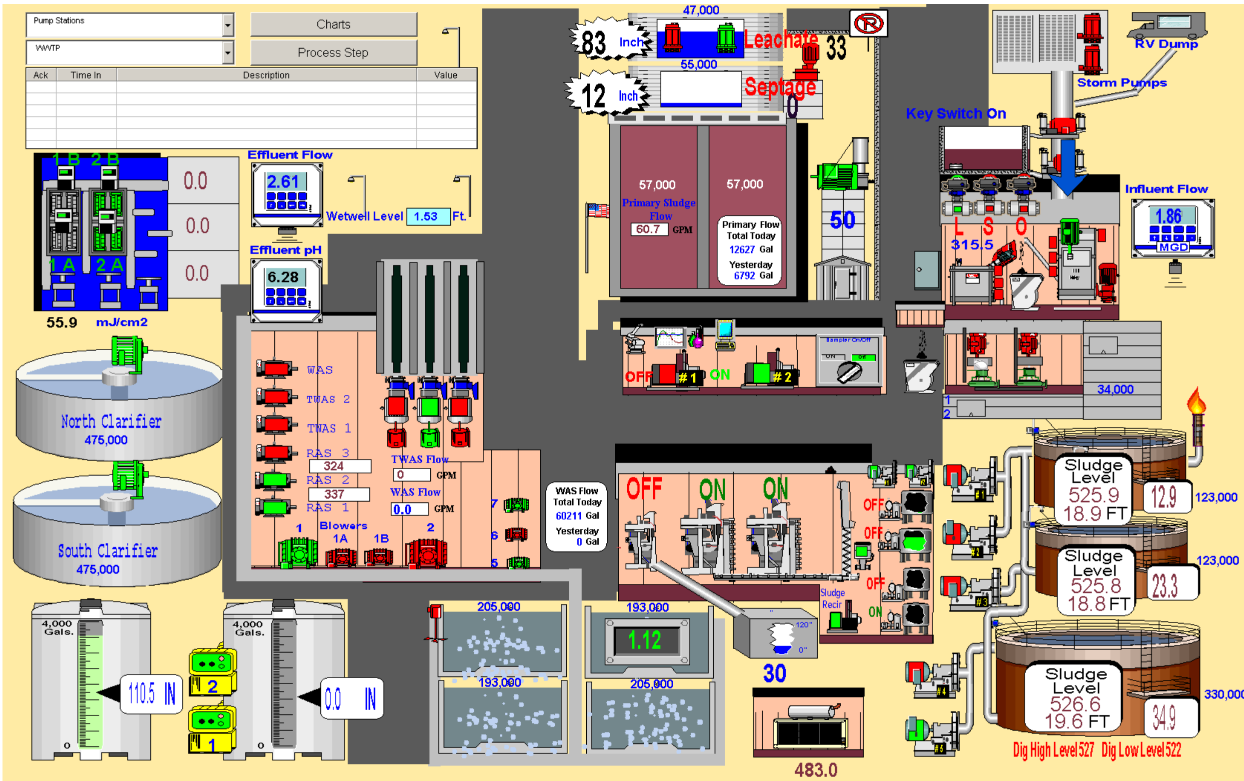


Figure 2: SCADA screenshot from the Montpelier WWTF

Additionally, Appendix B: Montpelier Treatment Facility Documents visually represents the treatment process at the existing Montpelier WWTF. The eleven (11) components are all of different ages and some are composed of their original construction and parts, having received no upgrades. Due to age and heavy use, certain sections have been identified for refurbishment or replacement as shown in Appendix C: Projected Upgrades & Costs[1] and discussed below.

2.1.1 Septage/Leachate Receiving

The septage and leachate facilities on site were designed for a daily flow of 16,000 gpd septage and 52,000 gpd leachate. The facility is responsible for handling the liquid sludge from other municipal facilities in its septage storage tank. Both tanks are covered and odor control is employed through a BioRem biofilter. The filter was designed for 15-ppm hydrogen sulfide. The septage and leachate tanks are provided with separate mixing and aerated with diffused air. A Diadisk leachate pump is located in the headworks building to pump from the holding tank into the headworks building.

The septage pump moves the septage from the holding tanks into the unheated primary anaerobic digester. The overall system is in fair condition.

2.1.2 Headworks

A gravity sewer brings flow into the facility with initial screening being done with a Huber Step Screen. The fluent flow is brought in with a parshall flume and this is where polyaluminum chloride (PAC) is added for phosphorous removal. An aerated grit chamber removes inorganics that reduce facility capabilities further in the treatment process. Bubble diffusers are provided air by three (3) 5 HP blowers in the blower building. Dewatering occurs in the Hydrogritter. The condition of the equipment ranges from fair to good and no immediate concerns were brought up regarding replacement.

2.1.3 Primary Clarifiers

The plant currently has two rectangular primary clarifiers that are supplied from the grit chamber flow. Primary sludge is pumped by two Penn Valley double disk pumps into one of the digesters. The equipment is generally in poor condition and is composed of the original components.

2.1.4 Lift Station

"Primary effluent flows to the facility lift station which consists of three (3) 54-inch diameter, 40 HP variable flow screw pumps each capable of pumping 4,200 gpm. The screw pumps lift the primary effluent 25 feet".[1] The station is in good repair with the exception of the control panel which could need replacement within the next 5 years.

2.1.5 Aeration Tanks

Four aeration tanks are fed from the lift station. PAC is fed into each tanks' influent for phosphorus precipitation. Each tank was designed for a maximum flow of 2.4 MGD. Air is provided by 3 positive displacement blowers and distributed by Sanitaire fine bubble aeration membrane diffusers. A fixed dissolved oxygen probe is in one tank with other monitored by a portable probe. Air flow is manually adjusted based on DO readings and equal balance is difficult to manage by operators. The effluent weir leads to the effluent channel into the secondary clarifiers. Based on the assessments, the condition of the tanks is poor/fair. The immediate concerns are with the aeration blowers.

2.1.6 Secondary Clarifiers

There are 2 secondary clarifiers with capacities of 476,328 gallons. Scum is collected in scum pits and pumped by the scum pump. Return activated sludge is pumped out of the clarifiers into the aeration tanks. The 3 pumps providing this are in the blower building and must be running whenever the aeration tanks are in operation. Waste activated sludge is pumped to the gravity belt thickener and a centrifugal pump was installed in 1978. Conditions are rated, as Fair/Poor and all original units in the process need replacement or refurbishment.

2.1.7 Chemical Feed

Currently, chemical feed is used for phosphorus removal. Poly-aluminum chloride (PAC) is injected at the headworks and lift station effluent channel. Two LMI metering pumps and two fiberglass storage tanks for the PAC are located in the Chemical building, while two HDPE tanks are located in the Headworks Building totaling 8,000 gallons of chemical storage available on site. Caustic is used for pH adjustment when necessary. The chemical feed system is currently in fair overall condition.

2.1.8 Disinfection

The facility currently uses ultraviolet disinfection. Ultraviolet disinfection utilizes electromagnetic energy to destroy a cell's ability to reproduce. This method is especially effective at inactivating most viruses, spores, and cysts. The facility utilizes four Calgon UV units in two parallel channels. During high flows, the effluent flapper gates need to be manually operated. The inlet gates also leak. Therefore disinfection is in poor to fair condition.

2.1.9 Sludge Thickening

Activated sludge is then pumped to a gravity belt thickener which is located in the Dewatering Building. The thickener operates 5 hours per day, 5 days per week. The thickened activated sludge then flows to a holding tank, where it is then pumped to a heated primary digester. Sludge thickening is required to reduce the volume of sludge removed from the system. Thickening optimizes the system by reducing the sizes of structures and operating costs. The sludge thickening process is overall in fair condition and is expected to have a lifespan of another 6 to 10 years.

2.1.10 Anaerobic Digestion

Sludge and scum from the primary clarifiers is then pumped to the 330,000 galloon primary digester for anaerobic digestion. Anaerobic digestion breaks down biodegradable material in the absence of oxygen. It is used to manage waste, produce fuels, and reduce landfill gas emissions. Cannon mixers are available in all three digesters, but only run in the primary digester. The other two digesters each have a volume of 120,000 gallons and are operated in series. Sludge recirculation pumps are used to recirculate the sludge between digesters. The decant from the secondary digesters flows to the primary clarifier influent by gravity. Most of the anaerobic facility is currently in fair condition. Digester decant valves, gas burners, and a heat exchanger for secondary clarifiers are in poor condition and require upgrading within the next two years.

2.1.11 Sludge Dewatering

Digested sludge is eventually pumped by two pumps to two belt filter presses. Sludge dewatering effectively increases particle size by breaking the cohesion of colloidal mud. This process occurs approximately 6.5 hours/day, 5 days per week. The sludge dewatering system is currently in fair condition.

2.1.12 Upgrades

The components that have been identified for upgrade within the next two years are the primary clarifiers, disinfection system, and anaerobic digester. The primary clarifier needs added heat trace cable to the rails to mitigate freezing risk. The disinfection system will need to have the inlet gates repaired and outlet gates replaced. Anaerobic Digesters require repaired decant valves and replacement of the waste gas burner. Based on Appendix C: Projected Upgrades & Costs, more than just the stated components are in need of refurbishment. The components that will last more than the next two years but still need replacement are discussed in the Methodology.

2.2 Lake Champlain Permitting

Lake Champlain in Vermont is a central component of life for many Vermont residents. The lake provides recreation and livelihood, making its health a primary concern from not only an EPA standpoint, but also from a holistic one. The State of Vermont is dedicated to improving the lake quality and has created the Vermont's Clean Water Initiative. This initiative is targeted at improving lake quality and has an individual component dedicated to phosphorous removal and reduction. The Clean Water Initiative is in response to both the Environmental Protection Agency's TMDL revision for Lake Champlain and growing concern from residents.

The existing discharge limit for the Montpelier WWTF is 0.8 mg/L P. The EPA and the State of Vermont are currently evaluating this limit to achieve a reduction of phosphorous loading for Lake Champlain. The evaluation has been ongoing since 2013 and is projected to be delivered on June 15, 2015. The June date is preceded by public comment on a drafted limit to be delivered in March of 2015. The discharge limit revision is expected to be either 0.2 mg/L or 0.1 mg/L as P. This revision is a drastic drop in allowable phosphorous that can be discharged and will require Montpelier WWTF facility upgrades.[1]

2.3 Phosphorous

Eutrophication of rivers, lakes, and streams is caused by excess nutrient loading, specifically nitrogen and phosphorous. Phosphorous is often the limiting nutrient creating conditions for algae blooms to form and toxic conditions to develop in water bodies. This increase in organisms results in less oxygen for the bodies of water and enhances both the growth and decay of plants, typically that of weeds and algae. Phytoplankton, a typical form of algal bloom, commonly develops under these conditions. Excess phytoplankton results in a lack of oxygen required by fish and other water-life. The lack of oxygen also impacts human life. Fishing and swimming are either hampered or non-existent and drinking water from an affected water body may be contaminated.

This damaging process has created the need for increased restrictions on nutrient loading from point sources, specifically in Vermont watersheds. The Montpelier WWTF discharges into the Winooski River which feeds into Lake Champlain[2].

Total phosphorus (TP), which is the nutrient that is under scrutiny, can be divided into 3 categories: orthophosphate, polyphosphate, and organically-bound phosphate.

Orthophosphate consists of dissolved inorganic phosphate. Polyphosphates consist of complex compounds, which are typically derived from detergents. Organically-bound phosphate consists of dissolved and suspended organic phosphates.[3]

TMDL is the 'Total Maximum Daily Load', or the amount of pollution that can be received by the lake and still meet water quality standards. The TMDL is important because pollution accumulates; by having a set limit, pollution input from multiple sources can be controlled. The process of setting a TMDL for a region includes a detailed study phase followed by a period for public comment, making it an outlet for public involvement and education. The components that create a TMDL are the Waste Load Allocation (WLA), Load Allocations (LA), and measure of safety (MOS). The waste load allocation is derived from origins such as industrial sources and municipal WWTP discharge. It is known as a 'point source'. The load allocation is considered a 'nonpoint source' and is typically generated from agricultural or urban runoff. The measure of safety is part of the equation to curtail any potential deficiencies or miscalculations of the WLA and LA components. These are all related in the equation for TMDL:

$$\mathrm{TMDL} = \mathrm{WLA} + \mathrm{LA} + \mathrm{MOS}$$ [4]

2.4 Low Level Phosphorous Removal Technologies

Five phosphorus removal technologies were identified and evaluated for tertiary treatment at the Montpelier WWTF. Each of the respective technologies had either already been implemented at a Vermont wastewater treatment plant or had been considered for a previous Stantec project. The technologies chosen for evaluation are as follows:

1. Chemical precipitation with disk filters by Aqua-Aerobics
2. Deep bed continuously backwashed sand filters by Blue Water Technologies
3. CoMag© process by Evoqua
4. ACTIFLO© process by Kruger
5. Membrane Filtration by GE/Zenon

Research was conducted regarding each technology. Through case studies and vendor information, a background for each of the respective technologies was developed.

2.4.1 Chemical precipitation with disk filters by Aqua-Aerobics

Cloth filters placed around a filter support are useful for removing phosphorus precipitate. As the wastewater flows through the filter, the phosphorous precipitate and other solids are either stopped by the filter or settle before reaching the filter. As solids build upstream of the filter, water levels rise due to the increased filtering resistance. Therefore, it is necessary to backwash these filters frequently.

AquaDisk® by Aqua-Aerobic features OptiFiber® Pile Cloth Media as the filtration cloth. The depth of the media allows for increased solids storage compared to microscreen media. Since filtered solids are stored for longer periods of time, backwashing is required less frequently when compared to microscreen media. Backing support provides durability to extend the media's lifetime.[5]

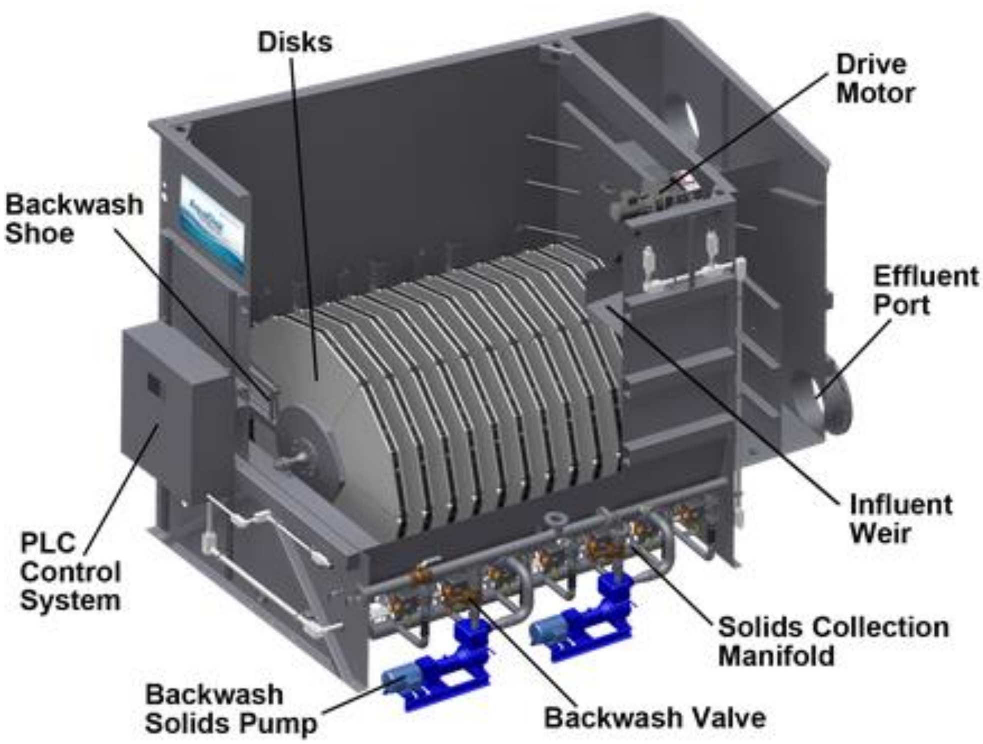


Figure 3: AquaDisk® Cloth Media Filter

The AquaDisk® system consists of vertically-oriented cloth media, with a fully automatic touchscreen control system. The AquaDisk® provides a versatile tertiary treatment option due to the ability to have the appropriate number of disks to meet the hydraulic loading rate and flow rate needs for the particular WWTF in which it is installed.[6] Each disk contains six removable segments, which simplifies maintenance.[7]

AquaDisk® requires three modes of operation: Filtration Mode, Backwash Mode, and the Solids Wasting Mode.

Filtration Mode

Filtration Mode is the primary mode and objective of the cloth media filters. Wastewater enters the filter and completely submerges the cloth filter. Simultaneously, solids either settle to the bottom of the tank or deposit on the cloth filter as the wastewater flows through the system.

Backwash Mode

To prevent head loss from becoming too great or inefficient filtration, solids are backwashed at a predetermined time or liquid level. Disks rotate slowly (two disks at a time) while the vacuum pressure from the backwash pump removes the solids and directs the remaining water to the headworks, all while filtration remains uninterrupted.

Solids Wasting Mode

The heavier solids that settle to the tank bottom are removed on an intermittent basis and are pumped to the digester, or other solids collection area of the WWTF.

Figure 4: AquaDisk® Cloth Media Filtration System at the Portland, Indiana WWTP

The Portland, Indiana WWTP is an example of a successful implementation of the AquaDisk® technology. Previous tertiary treatment at the facility employed six old granular-media filter units with a combined design average flow of

2.35 MGD. In the spring of 2013, two AquaDisk® Cloth Media Filters were installed with a combined capacity of 9.4 MGD to account for growth. Since AquaDisk® has been installed, backwash volume has been reduced 97% and energy consumption has also decreased.[8]

2.4.2 Deep bed continuously backwashed sand filters by Blue Water Technologies

Deep bed sand filters include fine grain sand, which traps suspended solids between the sand grains as wastewater flows through. Chemical additives are required to precipitate soluble phosphorous that is caught in the sand bed. Over time, head loss will increase due to the decreased number of voids in the sand bed requiring the sand bed to be backwashed.

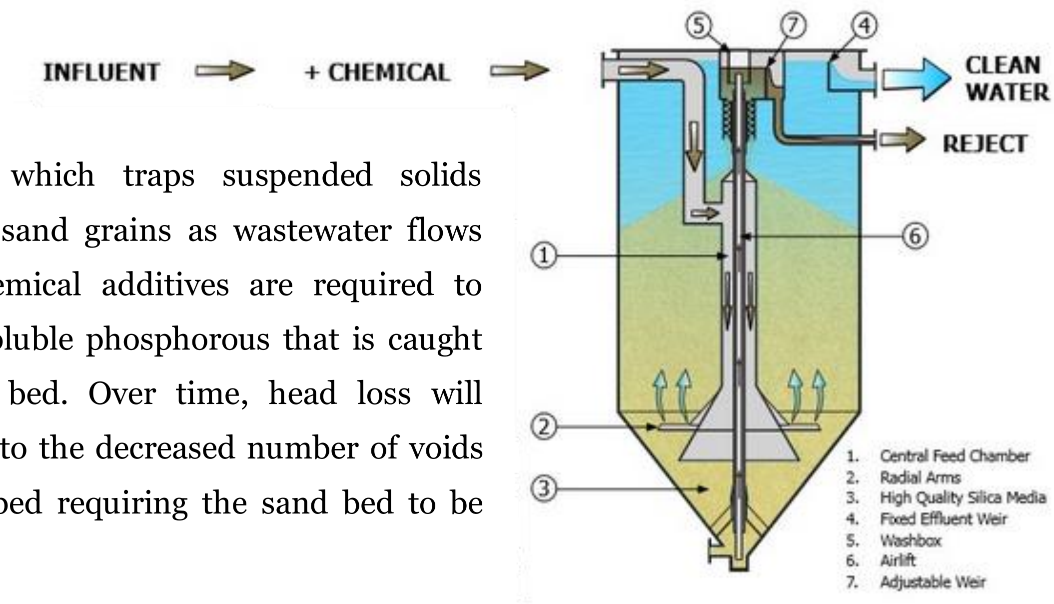


Figure 6: Blue PRO® Treatment Process

Blue PRO® by Blue Water Technologies is a reactive continuously backwashed gravity sand filtration system that optimizes adsorption. The chemical additive or, adsorptive surface, incorporated by Blue PRO® is a hydrous ferric oxide (HFO) coating that forms on the surface of the sand media. Solids, phosphorus, and waste HFO leave the filter through the backwash, which is later recycled upstream without interruption. Since the backwash is recycled and the phosphorous is chemically-bound, it leaves the treatment plant as part of the sludge removed from the treatment plant's clarification systems. Compared to other phosphorus removal technologies, Blue PRO® uses about 30% fewer chemicals, therefore resulting in less sludge.

Figure 5: Blue PRO® System at the Westerly, MA WWTF

Blue PRO® utilizes a modular-based filter system, which can be expandable as an in-ground or free-standing system. With slight modifications Blue PRO® can simultaneously denitrify as well as removal other contaminants such as mercury, arsenic, chromium, and uranium making Blue PRO® a versatile tertiary treatment system.[9]

Blue PRO® is currently installed at the Westerly WWTF in Marlborough, Massachusetts. The facility receives 4.15 MGD of average flow with an 11.62 MGD peak flow. The facility is required to meet permit requirements of 0.07 mg/L total phosphorous with the potential for needing to achieve lower levels in the future.[10]

2.4.3 CoMag© process by Evoqua

CoMag© achieves improved settling through chemical precipitation of secondary effluent and magnetite. As a ballast agent, the magnetite mixes with the phosphorous that has precipitated and settles in a small clarifier.[11] The magnetite is 95 to 99% recoverable and reused. This process enables removals of less than 0.05 mg/L of total phosphorus. CoMag© also provides flexibility to the plant with success in using alum, ferric, or polyaluminum chloride (PAC) in the process.[12]

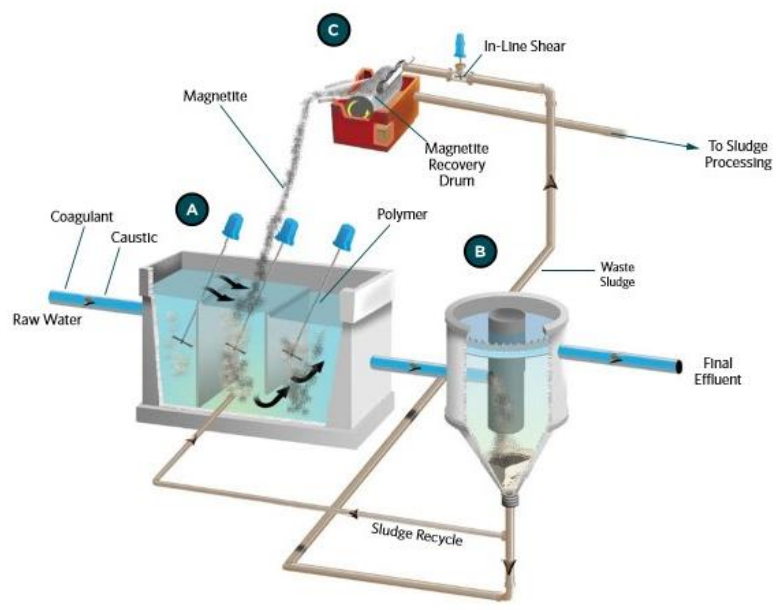


Figure 7: CoMag© Process Diagram

Magnetite, the key element to the success of CoMag© systems, is readily available, inexpensive, and has many advantages in advanced nutrient removal.[13] Magnetite is highly dense with a specific gravity of 5.2 and naturally hydrophobic, so when it bonds with floc settling rates are much faster and more efficient than in a conventional clarifier. Performance can be easily adjusted through chemical and magnetite dosing and the high transmissivity of effluent can lead to a reduction in costs associated with UV disinfection.[14]

Figure 8: CoMag© system at a 2.2 MGD WWTP

CoMag© has been fully operational at the Town of Concord, MA WWTP since 2011. The plant has a 1.25 MGD average daily flow and 4.4 MGD peak daily flow. The plant operated under a National Pollutant Discharge Elimination System (NPDES) permit which required an interim seasonal total phosphorus limit of 0.75 mg/L as P. The Massachusetts Department of Environmental Protection and the United States Environmental Protection Agency (USEPA) issued a new permit with a seasonal phosphorus limit of 0.2 mg/L as P. After evaluating the plant's existing phosphorus treatment, future permit limits were not expected to be met. An 18-month trial using CoMag© yielded consistent results and demonstrated the capability of achieving effluents of less than 0.05 mg/L of total phosphorus after which CoMag© was installed on a permanent basis. The system was also beneficial for the Concord WWTP in that it was able to be configured on the space-limited site and reduced the cost of UV disinfection.[15]

2.4.4 ACTIFLO© process by Kruger

ACTIFLO© utilizes chemical precipitation of secondary effluent and silica (sand), which can be recovered and recycled using hydrocyclones.[16] The silica is bonded with the phosphorous floc that then settles in a lamella clarifier. This process can achieve removals of 0.1 mg/L as P and when it is upgraded with a polishing filter can achieve even more removal. ACTIFLO© is also compatible with alum, ferric, and PAC.[17]

ACTIFLO© is a form of ballasted flocculation or high rate clarification. This process is physical-chemical and operates with recycled media to enhance floc formation; aiding in rapid settling of suspended solids. The footprint created from installing ACTIFLO© is much smaller than typical clarifiers and it is a suitable tertiary treatment option for phosphorous removal.[18]

For treatment, secondary effluent enters the system and coagulant is added. These inputs feed into the coagulation tank where the mixing helps move the mixture into the flocculation tank where the microsand and polymer are injected into the tank. Here a baffle moves the mixture into the settling tank and the clarified water is pushed out. The ballasted floc and microsand settle and are pumped into a hydrocyclone. The sludge is continuously discharged and the microsand is separated and recycled. An example of the ACTIFLO© system for tertiary treatment is shown below.[19]

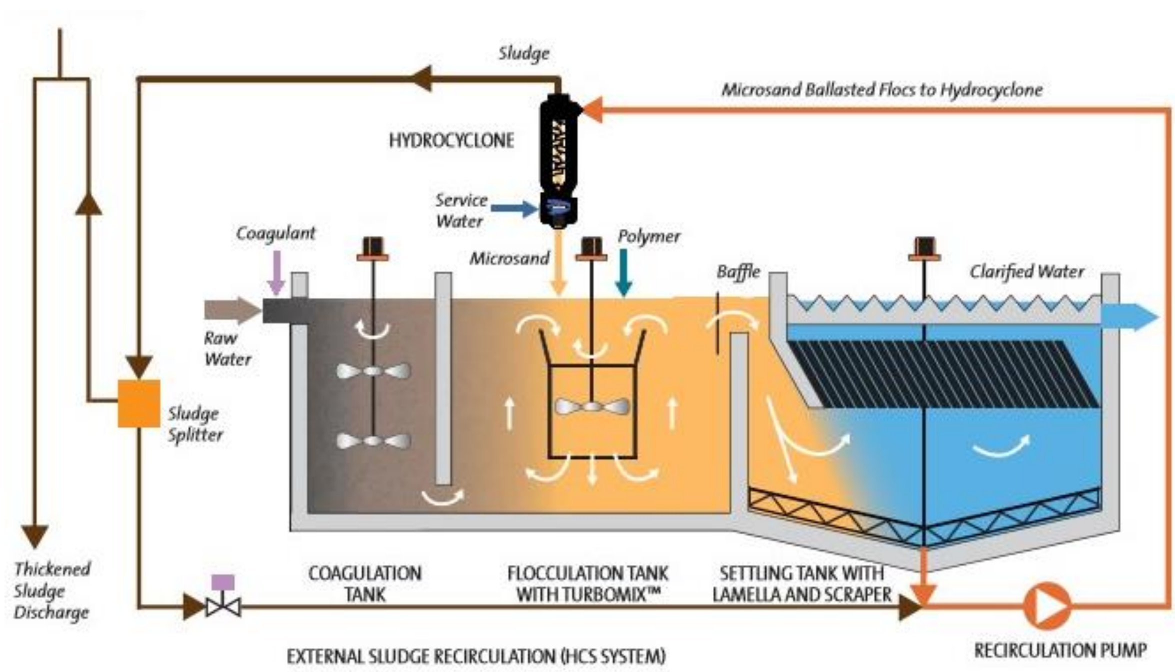


Figure 9: ACTIFLO© schematic for tertiary treatment

At the Syracuse, NY Onondaga County wastewater treatment plant, ACTIFLO© has been implemented and drastically improved the water quality of the receiving Onondaga

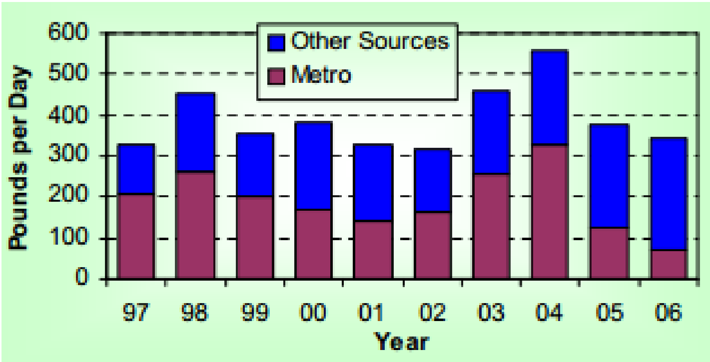


Figure 10: Annual Average Phosphorous Input from the Onondaga County Ambient Monitoring Program

Lake. The tertiary treatment system was constructed in 2005 to reduce phosphorous levels in the facility, which has a design capacity of 84.2 MGD. The phosphorous is treated through four parallel trains which reduced the phosphorous discharge concentration to 0.12 mg/L as P.[20] In 2010, new permitting lowered the permit level to 0.10 mg/L as P and optimization of the system was being evaluated; however all studies indicated that the system can achieve lower discharge concentrations. The system also consistently produced lower phosphorous concentrations compared to other sources discharging into the lake shown by the table created by the Onondaga County Ambient Monitoring Program.[21]

2.4.5 Membrane Filtration by GE/Zenon

Figure 11: ZeeWeed® 1500 module

Membrane filtration combines chemical precipitation and micro-filtration by using a vacuum pump to drive the filtration process. Therefore, the process generally has higher capital and operating costs compared to other filtration options. For this reason, membrane filtration is primarily considered when space is limited due to its compact size relative to other filtration technologies.[22]

The ZeeWeed® Membrane Bioreactor (MBR) by GE/Zenon incorporates a series of ZeeWeed® 1500 hollow fiber ultrafiltration membrane modules and cassettes incorporated with bioreactor tanks. The latest design is the LEAPmbr, which offers reductions in footprint and energy use compared to other MBR systems.[23]

The Archer Daniels Midland (ADM) Co. Inc. is the site of a conventional wastewater treatment facility and a large generator of organic nutrient discharge. The system recycles a portion of the wastewater to run the site cooling towers that required a high usage of chemicals for flocculation and additional treatment to remove phosphorous.

The site capacity is 5 MGD with a future capacity of 6 MGD and the system was installed in 2004.[24]

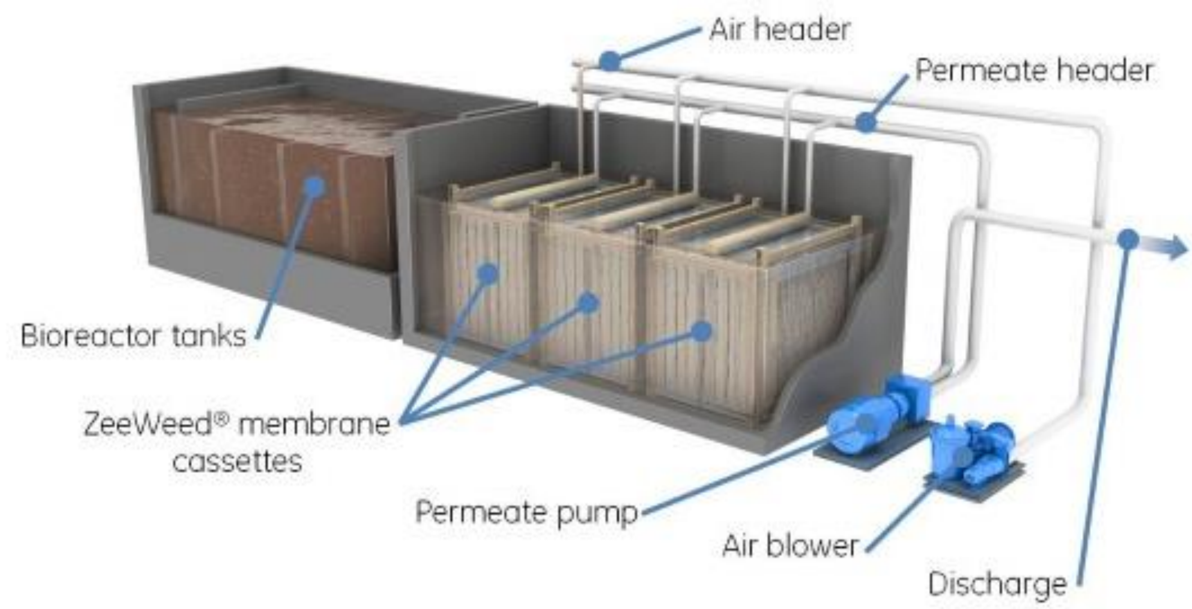


Figure 13: ZeeWeed® LEEPmbr

Figure 12: ZeeWeed® 1500 submersed membranes

Currently, the ZeeWeed® tertiary treatment system has 6 trains with room for expansion if increased capacity is needed. The ZeeWeed® is fed wastewater from the secondary clarifiers after it has been treated with alum in a pond. It is then pumped to the system tanks where a permeate pump creates a low pressure vacuum pulling the water into the membranes. The new process saved the company more $1 million in chemical costs.[25]

3 Methodology

This chapter documents the methods the MQP team underwent throughout the course of the project. During the preparatory term, a preliminary project schedule was created to ensure the successful completion of the project. The preliminary project schedule can be found in Appendix A: Proposal. The primary goal of our project included an evaluation of the tertiary phosphorous removal technologies considered for the Montpelier WWTF and the criteria used to evaluate them. The evaluation led to a selection of one technology to be used in a conceptual design for the Montpelier WWTF to reach a discharge concentration of 0.1 mg/L phosphorous. The conceptual design along with cost estimates were presented to Stantec and the City of Montpelier WWTF staff.

3.1 Site Visit

In order to gain a more in-depth understanding of the Montpelier WWTF, the MQP team visited the facility on February 4th, 2015 with Joe Uglevich, PE from Stantec. A tour of the facility was given by Chief Operator Bob Fischer. During the tour, Bob was able to answer our questions the MQP team had about the facility itself, his experiences with EPA regulations, and his thoughts and preferences on new tertiary treatment technologies.

Figure 14: Operator Bob Fischer giving the MQP team a tour of the facility

Bob was especially helpful taking us through the facility's process as the MQP team visited each stage of treatment. The facility has a well-documented SCADA system that monitors the treatment processes. Below, Bob is seen explaining the SCADA system. Additionally, a closer view of the system can be seen in Figure 2.

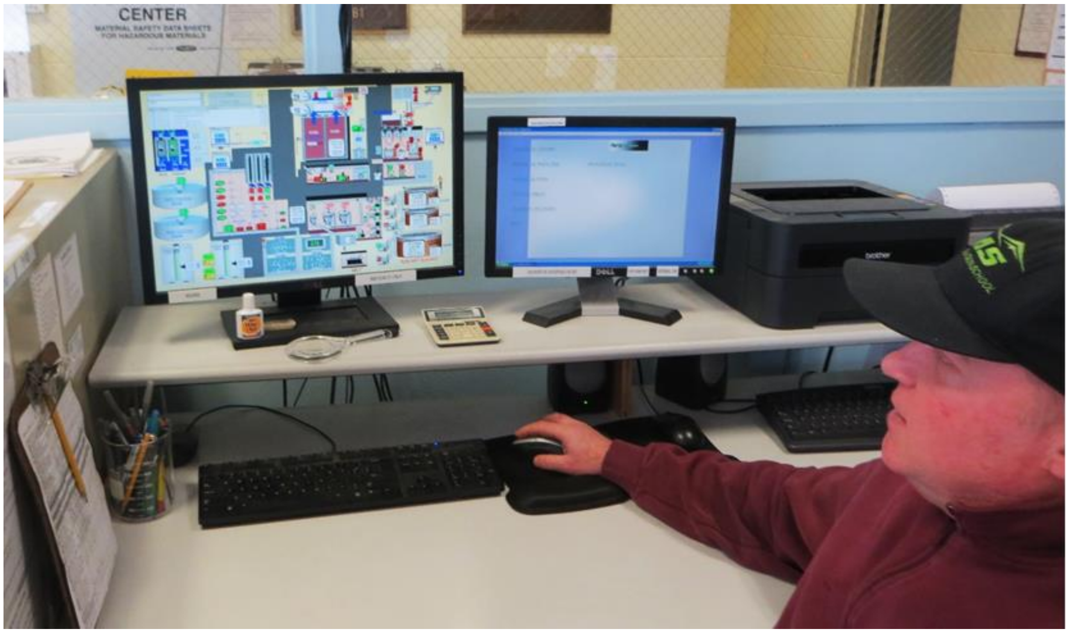


Figure 15: Operator Bob Fischer explaining the SCADA system

3.2 Evaluation of Phosphorous Removal Technologies

The criteria that were used to evaluate the five different treatment processes are shown in Table 1 and described below. Each category is also given a weighted value. The weighted values are higher for categories more important to the Montpelier facility. The lowest weight value is 2 and the highest is 4. Particularly important to the Montpelier facility was the footprint of the technology due to the space constraints, which also affects to construction phasing, rendering it difficult to implement a temporary treatment system during construction. Also of significance was the ability to reach future lower discharge limits, which is likely in the Lake Champlain outfall area in the near future during the lifespan of the selected technology. Operational costs, energy usage, and chemical costs were also deemed more important to the Montpelier facility after the site visit. The completed evaluation is shown in results – Section 4.4.[26]

Table 1: Phosphorous Removal Technology Evaluation Template

Criteria	*Weight*	Disk Filters	Deep Bed Sand Filter	CoMag©	ACTIFLO©	Membrane Filtration
Operational	*-*					
Staffing Requirements	*2*					
Overall Operational costs	*2.5*					
Energy Usage	*4*					
Chemical Costs	*3*					
Community Impacts	*2*					
Ability to Reach Future Lower Discharge Limits	*3.5*					
Employee Health & Safety	*2*					
Implementation	*-*					
Constructing Phasing	*4*					
Footprint	*4*					
Capital Costs	*2*					
Total	-			-		-
Weighted Total	-			-		-

3.2.1 Criteria Descriptions

Operational

The operational category corresponds to the facets of operating the technology.

- Staffing requirements
  - The scores were assigned relative to the amount of additional staffing necessary for typical operations. Processes that would require additional staff, additional training and skills, or daily operator adjustment received lower ratings
- Daily operating costs

- Daily operating costs encompass the wide range of fees that are required to keep the system running and functional. Two main subsets of this are chemical costs and energy costs.
  - Chemical Costs
    - These are the costs associated with buying the chemicals needed to make each system work and can encompass everything from PAC to caustic to polymers. Chemicals needed for cleaning the system are also included.
  - Energy Costs
    - Energy consumption is rated based on the amount of energy it takes to run the technology. System components such as pumps and mixers will add to the energy costs of the system.

- Community impacts
  - The impacts on the community are based on truck traffic in and out of the facility for deliveries, odors or noise from the new technology, and additional space requirements. The site is located across from a river and adjacent to a town barn, which limits the ability to expand; however, occupying the space where the DPW Barn is currently located will only be considered if there is no other alternative.
- Ability to Reach future lower discharge Limits
  - The ability to meet progressively more strict effluent requirements scored higher.
- Health & Safety
  - Processes where safety could be managed through familiar design and operations received higher scores. Low scores were given when workers with specialized training were required to operate the system safely

Implementation

- Construction phasing
  - Highest scores were assigned for processes that can be easily installed by contractors with wastewater treatment plant experience. The compact site

layout will require the new tertiary treatment to be implemented in phases. Technologies that made this process easier were ranked higher. Examples would be the ability to add chlorine contact while the UV system is offline or would fit into existing channels.

- Footprint
    - Scores were based on the space requirements for the technology and any pretreatment required after the secondary clarifiers such as mixing basins.
- Capital costs
    - The scores were determined by initial quotes given by each respective technology, which do not include costs associated with the operation of the process.

3.3 Review of Existing Conditions

The Montpelier site AutoCAD drawings describe the site layout and indicate where the tertiary treatment system would go. To better understand the land available, the group visited the facility to determine what options were available. On site, the plant operator, Bob Fischer, provided 100% drawings and updated previous drawings to better resemble what was currently on site. This process provided clarification as to the different plant components that were demolished and other aspects that have been added and were not available on the plans the group possessed.

3.4 Design Alternatives & Cost Estimates

To determine the design alternatives, information was taken from the meetings with equipment vendors and discussions with Stantec engineers. The Montpelier site layout was the largest determining factor in the decision process because geographic limits ruled out different process layouts. Each process was looked at holistically to determine all the necessary components. Once the components were identified, sizing the available space in comparison to the needed space for components was done.

For the ultrafiltration membranes, size was not an issue. The entire process can fit into the currently unused sludge holding tanks and the existing UV disinfection could be utilized. This was determined by the vendor representative of GE/Zenon. The representative supplied different layouts that would utilize space and build upward rather than outward.

The CoMag© layout design was more challenging. This required further discussions with the engineers and regard for the FEMA pump station. The clarifiers were larger than anticipated and needed to be placed outside of the initial space of the sludge holding tanks. To utilize the UV disinfection, reuse channels were explored. The greatest asset to the design alternative design was the use of AutoCAD and the scaling from original drawings. This allowed for more accurate scaling and feasibility analysis.

To determine costs, the preliminary conceptual proposal was used from Evoqua for CoMag© and the Membrane was not given a specific cost amount. In talks with the sales representative from GE/Zenon, it was explained that the ultrafiltration membrane process would be the most expensive option available on the market. This took into account the specifics of the Montpelier site flows, initial capital costs, and operating costs. The lifetime of each process was also accounted for during cost determination.

3.4.1 Calculations

Once a design alternative was chosen, calculations were done to explore the processes behind them. The chemical dosing calculations are theoretical and do not reflect what would be done at the plant due to the inability to perform jar testing for accurate wastewater characteristics. Jar testing was beyond the scope of this MQP. Dosing used equations 1 and 2 below.

$$FeCl_3 + PO_4^{3-} \xrightarrow{yields} FePO_4 \downarrow + 3Cl^-$$

(Equation 1: Ferric Chloride and Phosphorous Reaction)

$$FeCl_3 + 3HCO_3^- \xrightarrow{yields} Fe(OH)_3 + 3CO_2 + 3Cl^-$$

(Equation 2: Destruction of Alkalinity)

Calculations were also done for parts of the construction design. Chemical storage was sized out based on expected dosing.

Rapid mix tank design was also done. The rapid mix tank design included retention time calculations and power requirements. Equations 3 and 4 were used and are shown below. Full calculations are shown in Appendix D: Calculations.[27]

$$RT = \frac{basin\ volume}{influent\ flow\ rate}$$

(Equation 3: Retention Time)

$$P = \frac{\rho K_T n^3 {D_a}^5}{g}$$

(Equation 4: Power required to maintain turbulent conditions)

4 Results and Discussion

4.1 Site Visit

The key takeaway from our interview with Operator Bob Fischer was that there is a plan for the City of Montpelier to be carbon neutral by 2030. Bob went on to explain that while improvements have been made in recent years, the facility is still one of the city's highest energy consumers. This was an important piece of information that was taken into consideration during the evaluation of technologies and their energy efficiency.

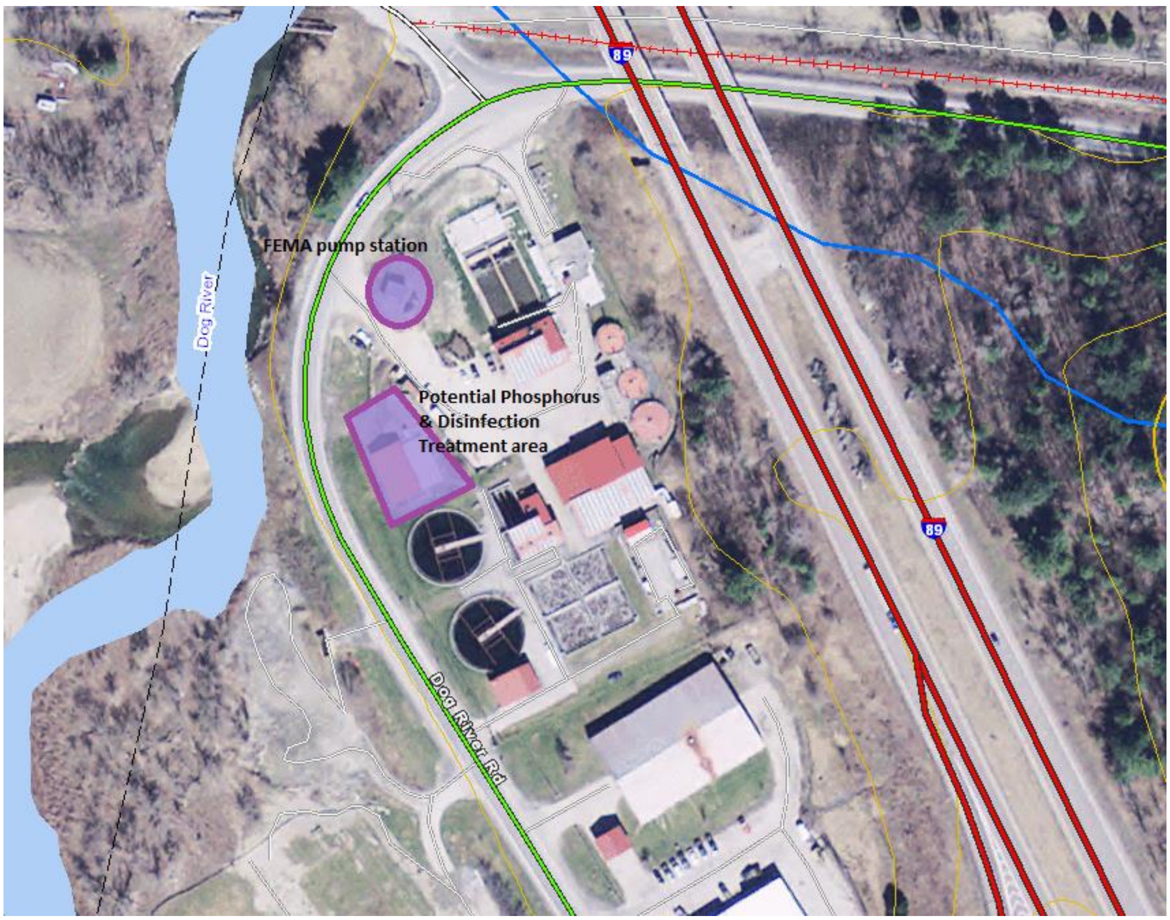


Figure 16: Aerial view of the Montpelier WWTF with potential phosphorus & disinfection area[1]

Our visit culminated in the potential location for a new phosphorus treatment technology. The potential location is shown in Figure 16. Currently, the UV disinfection system is located in the highlighted area shown. This will require either the construction of the tertiary treatment next to or in the current location of the UV disinfection system. Adjacent to the UV disinfection building are 3 unused 30,000-gallon tanks, which could potentially be the location of a phosphorus removal process. Additionally, across the entrance is a FEMA pump station installed four years ago. Unfortunately, there is a manhole and piping network to the pump station that is partially contained in the potential phosphorus and disinfection treatment area.

4.2 Design Basis

When designing the tertiary treatment options the original design criteria was consulted as well as operating data from 2013 and 2014. The original design criteria are from 1980 when the WWTF was built and the 2013 and 2014 data is from the plant operator's lab data. The primary information of note is the quantity and quality of effluent from the secondary clarifiers that will be flowing into the new tertiary treatment process. The current treatment flow is set up with the secondary clarifiers feeding into the UV disinfection.

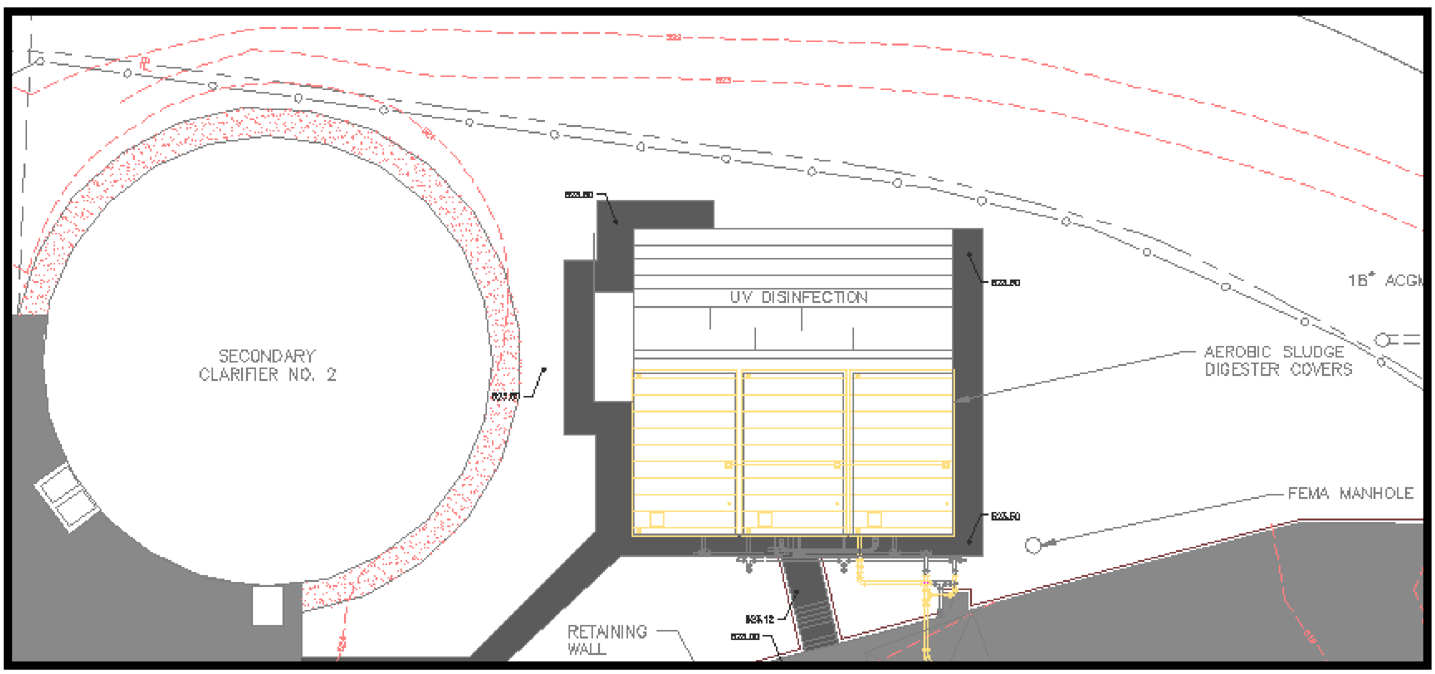


Figure 17: AutoCAD diagram of Secondary Clarifiers and UV Disinfection at the Montpelier WWTF

The quality of the secondary treatment effluent will be the basis for the design of the tertiary treatment. Table 2 characterizes the effluent quality and Table 3 examines the design parameters of the facility.

Table 2: Montpelier WWTF Effluent Characteristics

Characteristic	Effluent Quality
Total Phosphorus (mg/L)	0.40
TSS (mg/L)	7.00
BOD (mg/L)	10.00
Average pH	7.00
Average Turbidity (N.T.U)	1.99
Average E. Coli (C.F.U/100 mls.)	9.00

Table 3: Montpelier WWTF Operating Data

Characteristic	Montpelier Total
Current Average Daily Flow (MGD)	1.88
Average Daily Flow Design Capacity (MGD)	3.97
Current Peak Daily Flow (MGD)	5.00
Peak Daily Flow Design Capacity (MGD)	12.00
Max Design Flow (MGD)	9.58
Average PAC Usage (gals.)	83.00
Average Temperature (C)	13.90

4.3 Existing Site Investigations

Based on AutoCAD drawings and site visits, different construction and design choices must be explored. The site of the Montpelier facility is tight with limited expansion capabilities. The tertiary treatment process needs to be placed where the current UV disinfection process takes place without substantially increasing the footprint. The area surrounding the plant is state owned. The facility is surrounded by a fence limiting the potential expansion towards the state-owned road.

Figure 18: Secondary clarifier in the foreground with UV disinfection building and existing sludge holding tanks in background at the Montpelier WWTF

Based on discussions with Stantec engineers and from the site visit, different possibilities were explored. The first option would be to create a temporary chlorine contact point for disinfection from the secondary clarifiers and to completely demolish the existing structures highlighted above in Figure 16. The cleared site would then be repurposed for the tertiary treatment and a new disinfection process would be built as well. The second option would be to keep the UV disinfection online throughout the construction process of the tertiary treatment technology. This would reduce costs and allow the tertiary effluent to be redirected back to disinfection. This option would require significant upgrades to the facility housing the UV disinfection.

Other considerations were obtained through the site visit. These considerations align with the capstone statement and reiterate the need for real world applications because without the experience, students would not be exposed to typical problems faced in the field that are not encountered in a classroom setting. The visit to the UV disinfection building highlighted the need for assessing climate and the potential obstacles that can arise from extreme cold. At the Montpelier facility, the modulating weirs were installed to regulate the head of the UV channels. The weirs were functional in normal flows; however, during storms and wet weather, the weirs would create too much head which in turn damaged the bulbs in the UV system. To handle this, the plant operator must keep a rope attached to the weir to manually regulate during wet weather.

The building itself is ill-equipped to handle cold temperatures and the ceilings are poorly insulated creating condensation that drips and creates hazards. The slide gates have flow leakage when closed and this causes freezing of the low volume of water. The ice becomes dislodged and flows back into the channel, breaking the UV bulbs.

4.4 Technology Evaluations

The following summarizes the rankings given in Table 4. The ranking system employed was a standard 1 to 5 ranking which corresponded with an equivalent term. The lowest score a technology could receive was poor (1) and the highest was very good (5). The number ranking and corresponding term is shown in Table 5. These rankings were also given a weight related to their importance to the specific site we are designing for. After the site visit to Montpelier, the operator highlighted needs that were previously not noted. These additional considerations are expressed in categories given a higher weight. The weight scale ranged from 2 to 4, 2 was the lowest weight and 4 was the highest.

Table 4: Phosphorous Removal Technology Evaluation

Criteria	Weight	Disk Filters	Deep Bed Sand Filter	CoMag©	ACTIFLO©	Membrane Filtration
Operational						
Staffing Requirements	2	3	3	4	3	4
Overall Operational Costs	2.5	3	3	4	3	3
Energy Usage	4	4	3	3	3	2
Chemical Costs	3	3	3	3	3	3
Community Impacts	2	4	4	4	4	4
Long-term Effectiveness	3.5	2	3	4	4	4
Health & Safety	2	4	4	4	4	4
Implementation						
Constructing Phasing	4	4	3	4	4	4
Footprint	4	5	3	4	4	5
Capital costs	2	5	4	4	4	4
Total	-	37	33	38	36	37
Total	-	**103.5**	**93**	**109**	**104.5**	**106.5**

Table 5: Ranking Scale with Corresponding Term

Scale	1 to 5
1	**Poor**
2	**Below Average**
3	**Average**
4	**Good**
5	**Very Good**

All five of the technologies reviewed received the same score for Community Impacts and Health & Safety.

- A good (4) rating for Community Impacts represents the technologies' effect in causing undue burden on community members in terms of odor, traffic flow, and other concerns. All five technologies will not significantly increase this or become detrimental to the community they would be serving.

- Health & Safety received a good (4) rating for all options because all employ general chemical usage, which is a familiar task for operators and will not require additional training.

Construction phasing was ranked as good (4) for each technology except for deep bed sand filtration, which received a lower score of average (3). The other four will be easier to phase for construction due to smaller footprints that will fit more easily within the site and utilize temporary disinfection strategies.

4.4.1 Disk Filters

Based on the evaluation criteria, disk filters received a score of 103.5. Disk filters received the lowest score for ability to reach future lower discharge limits due to the aging technology and the inability to reach discharge concentrations for phosphorous if the TMDL is lowered again from 0.1 mg/L as P. The highest scores were for reduced footprint compared to other available technologies and the lowest capital cost based on preliminary price assessments. The other two categories were staffing and operational costs. In these categories disk filters were ranked as average (3). To staff the system, the filters require cleaning and backwashing, which is automated, but could cause problems if not properly maintained. The cost associated with backwashing is due to additional water needs and replacing the media.

4.4.2 Deep Bed Sand Filter

The Deep Bed Sand Filter received the lowest score at 93. This option received low scores due to the importance of a small footprint for the Montpelier site. The staffing ratings were average due to the need to backwash the system and replenish the sand concentration. The sand concentration is the amount of sand present in the system. Some sand is lost during operation and discharged with the sludge. These concerns also made the operational cost rating become lower because of chemical usage and sand replenishment. The initial capital cost is typical for a tertiary process, but the phasing would be more difficult than others due to its larger footprint.

4.4.3 ACTFLO©

ACTIFLO© received a score of 104.5 points. The system ranked good for staffing and average for operational costs. ACTIFLO© needs polymers and microsand to achieve the needed discharge concentration and also needs to be adjusted for pH which will add operation costs. In terms of ability to reach future lower discharge limits, the system ranked good. This was due to its ability to meet the 0.1 mg/L as P discharge limit, however if the secondary effluent is above 1.0 mg/L as P, the final effluent might not meet requirements. The footprint of ACTIFLO© is larger than some of the other options and would require more space. The upfront cost is typical of other tertiary treatment options.

4.4.4 CoMag© & Ultrafiltration Membrane

CoMag© and Membrane Filtration had the highest scores of 109 and 106.5 respectively. The two processes work very differently; however, both are suitable options to consider for tertiary treatment to reach low discharge limits. The processes consistently ranked as good in all categories except for membrane filtration, which lost points for operational costs but outclassed the other options in footprint. Membranes are harder to clean than the CoMag© system due to the need to chemically clean, but, the CoMag© system requires magnetite addition. CoMag© is automated and does not need constant observation. Operational costs are high for the membrane system. The membranes need a driver (either pressure or vacuum) for the water to be filtered through them, this requires constant pumping. The pumping greatly increases the energy costs and Montpelier is striving to lower their energy footprint.

4.5 Equipment Vendors

Based on the preliminary evaluation described above, and as discussed in Section 4.4, the two technologies to be considered for the Montpelier upgrade are CoMag© by Evoqua and the Zeeweed 1500 by GE/Zenon. In order to complete the evaluation and determine which treatment option will be selected, vendors were contacted for feasibility and layout designs. Meeting with Stantec engineers gave better insight into the correspondence process; therefore, different aspects of the plant design were highlighted and sent to the vendors for review. The correspondences with the vendors are included in Appendix G: Correspondence.

4.6 Process Diagrams

The two selected technologies are depicted in Figure 19 and Figure 20. Figure 19 shows the process for Ultra Membrane Filtration and Figure 20 shows the process for CoMag©.

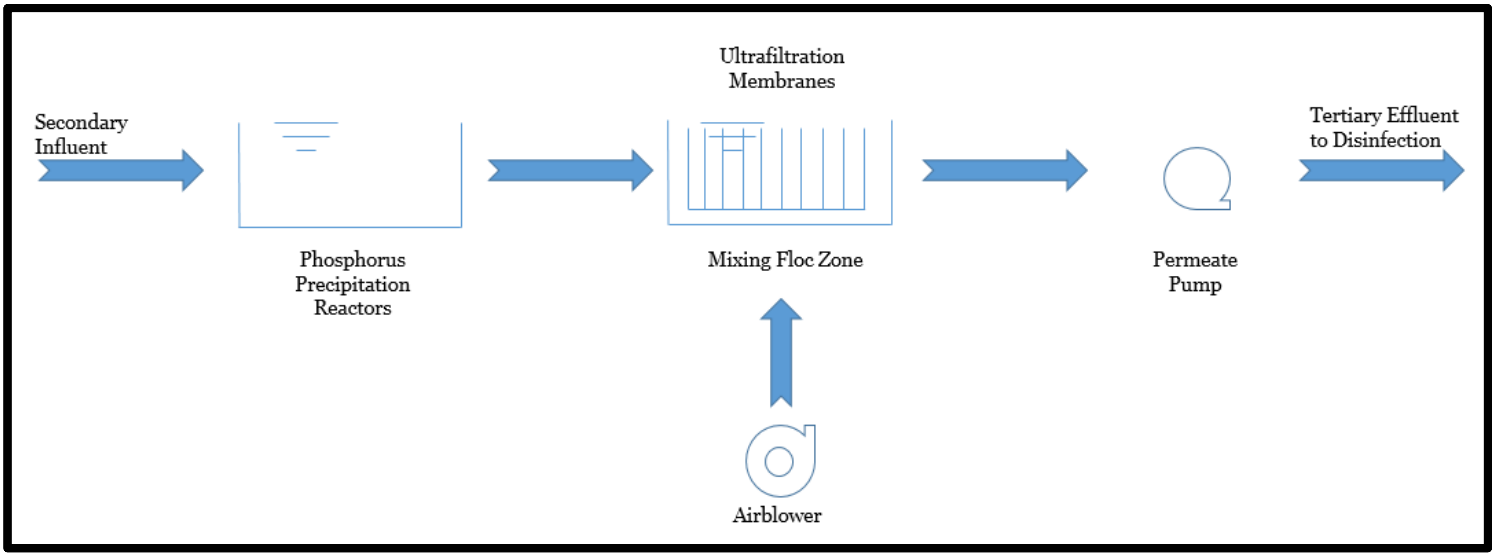


Figure 19: Ultrafiltration Membrane Process Diagram

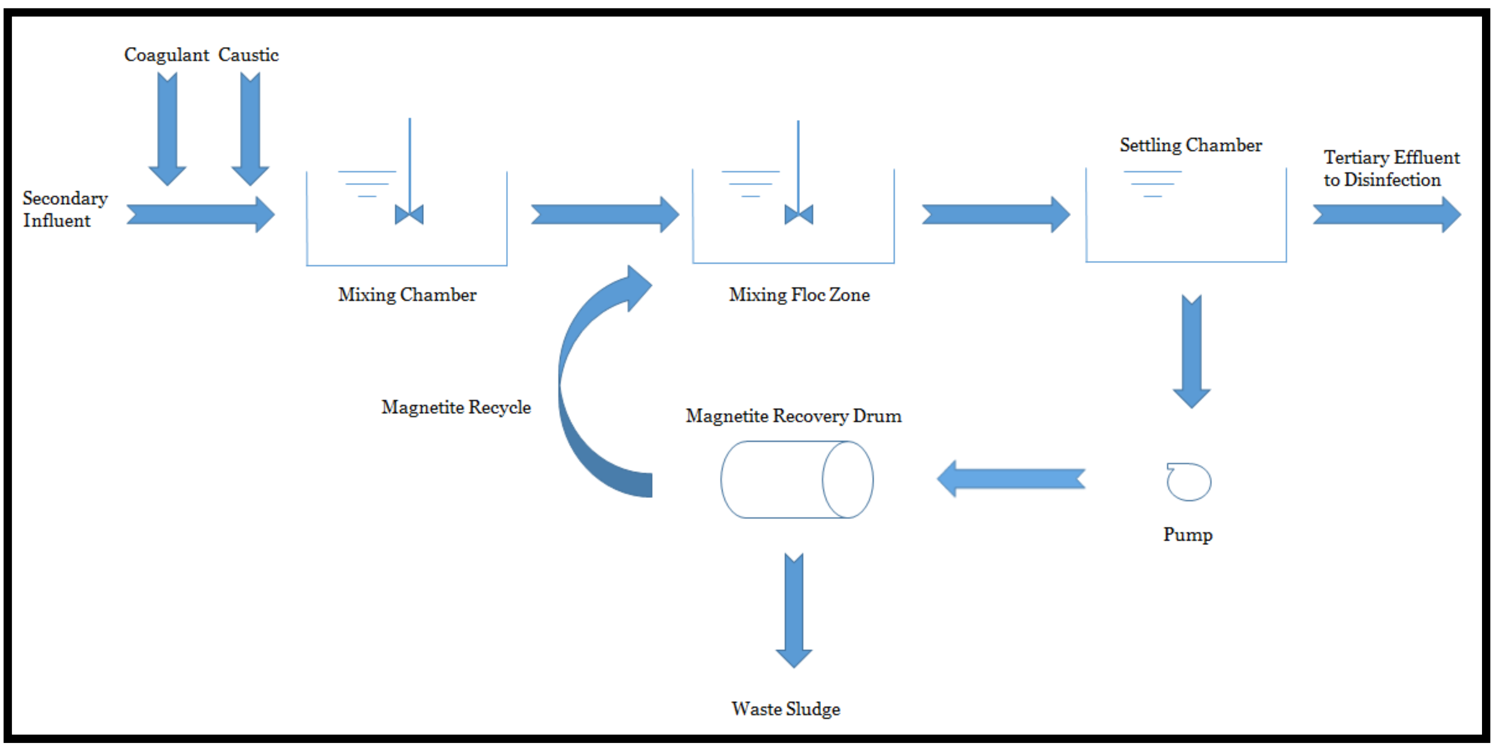


Figure 20: CoMag© Process Diagram

4.7 Level-Two Evaluation of CoMag© vs. Ultra Filtration Membranes

A secondary evaluation of CoMag© and Ultra Filtration Membranes was completed to determine which tertiary process would be selected for the final design. The secondary evaluation was done using information collected from sales representatives' presentations, the needs of the Montpelier WWTF, and engineering advice from the engineers at Stantec. The technologies were compared on preliminary site layouts and more in depth assessments of the categories discussed previously in Section 4.4.

4.7.1 Ultra Filtration Membranes by GE/Zenon

Ultra Filtration Membranes provide excellent water quality and can remove high levels of phosphorus. After speaking with the sales representative the ZeeWeed 1500 pressurized Ultrafiltration was identified as the selected membrane for the Montpelier application. The ZeeWeed 1500 holds the membranes in a capsule that can be discarded and replaced when it is no longer functional. The ZeeWeed 1500 was evaluated further because of its ability to remove high levels of phosphorous with an extremely small footprint.

The ZeeWeed 1500 will use the least amount of space on site. The system has two different layout options; however, both utilize the currently unused sludge holding tanks to retrofit the process. The benefits to the membranes are that they will not increase the current footprint on the site. The system has the ability to fit completely in the space of the current UV disinfection and sludge holding tanks area. Ultra Membrane Filtration is fully capable of reaching low discharge concentrations of up to 0.5 mg/L as P.

The primary applications thus far, however, have been in water treatment, typically on the west coast. This process has not been piloted in Vermont and may receive hesitation from regulators and plant operators as to the applicability and limitations imposed by the colder, more variable climate. Acceptance from these groups is imperative to the success of the process in the region.

A major concern for the implementation of ultra-filtration membranes at the Montpelier WWTF is its energy use. Since the membranes require pumping 24/7, electricity costs are much greater when compared to other tertiary treatment options that operate with gravity flow. Therefore, installing this technology at the Montpelier WWTF would directly conflict with the City of Montpelier's goal to be carbon neutral by 2030.

Other concerns with membranes are the need for increased operator attention. To ensure optimal filtration, chemical dosing must be carefully monitored. Membranes can be easily fouled if too many solids are being loaded and the cleaning system is not running. The membranes require cleaning daily and require a cleaning cycle every few months that completely shuts down the system for 2-6 hours. The cost to pilot an ultrafiltration membrane system would be approximately $6,500.

4.7.2 CoMag© by Evoqua

The CoMag© process will fulfill all the requirements necessary to be a successful tertiary treatment process at the Montpelier WWTF. The most important aspects in the Montpelier WWTF design considerations are the ability to reach a discharge concentration of 0.1 mg/L total Phosphorous and the total footprint the process will use. The CoMag© process can reach the low discharge concentrations consistently. The process is adaptable and will be able to reach discharge concentrations of 0.05 mg/L as P in the future if needed. This is important to plant operators because the EPA is expected to become more stringent with phosphorous discharge limits in the near future. By choosing a process that can sustain the changes over an extended lifespan, the economics of the process are expected to outweigh the initial capital costs. CoMag© has a proven performance record in wastewater for meeting low discharge concentrations in New England. It has been successfully piloted in Vermont WWTFs and is likely to be more readily accepted by operators and EPA regulators in the state.

The footprint of CoMag© is small and will fit on site. The entire process will require four tanks for the rapid mix, ballast addition, flocculation, and two clarifiers. The clarifiers will be substantially smaller than the secondary clarifiers on site and will be able to be arranged in the area available. Two clarifiers will allow for redundancy in the process, however it does increase the footprint.

CoMag© can run effectively using different coagulants including alum, ferric, and PAC. This variety gives the WWTF flexibility as to which coagulant it prefers. CoMag© does not require extensive operator attention. The magnetite needs to be refilled at intervals; however, the cleaning and daily system operation is fully automated. CoMag© can handle system upsets such as higher flows or higher loading rates without jeopardizing its ability to remove phosphorous and will not require immediate upstream treatment. Since CoMag© operates using gravity flow, operational and electrical costs are lower than competing technologies such as membranes that require constant pumping. The cost to pilot the CoMag© system is approximately $2,500.

4.7.3 Level- Two Evaluation Conclusions

Based on the parameters mentioned above, CoMag© is the selected choice for final design. CoMag© has a larger footprint than the membranes, but has more benefits for the Montpelier WWTF. The process will be able to handle larger loadings and flows, uses less energy, and has previously been implemented in the State of Vermont. The next section will discuss the advanced design options.

4.7.3.1 Ultra Filtration Membrane Advanced Design Options

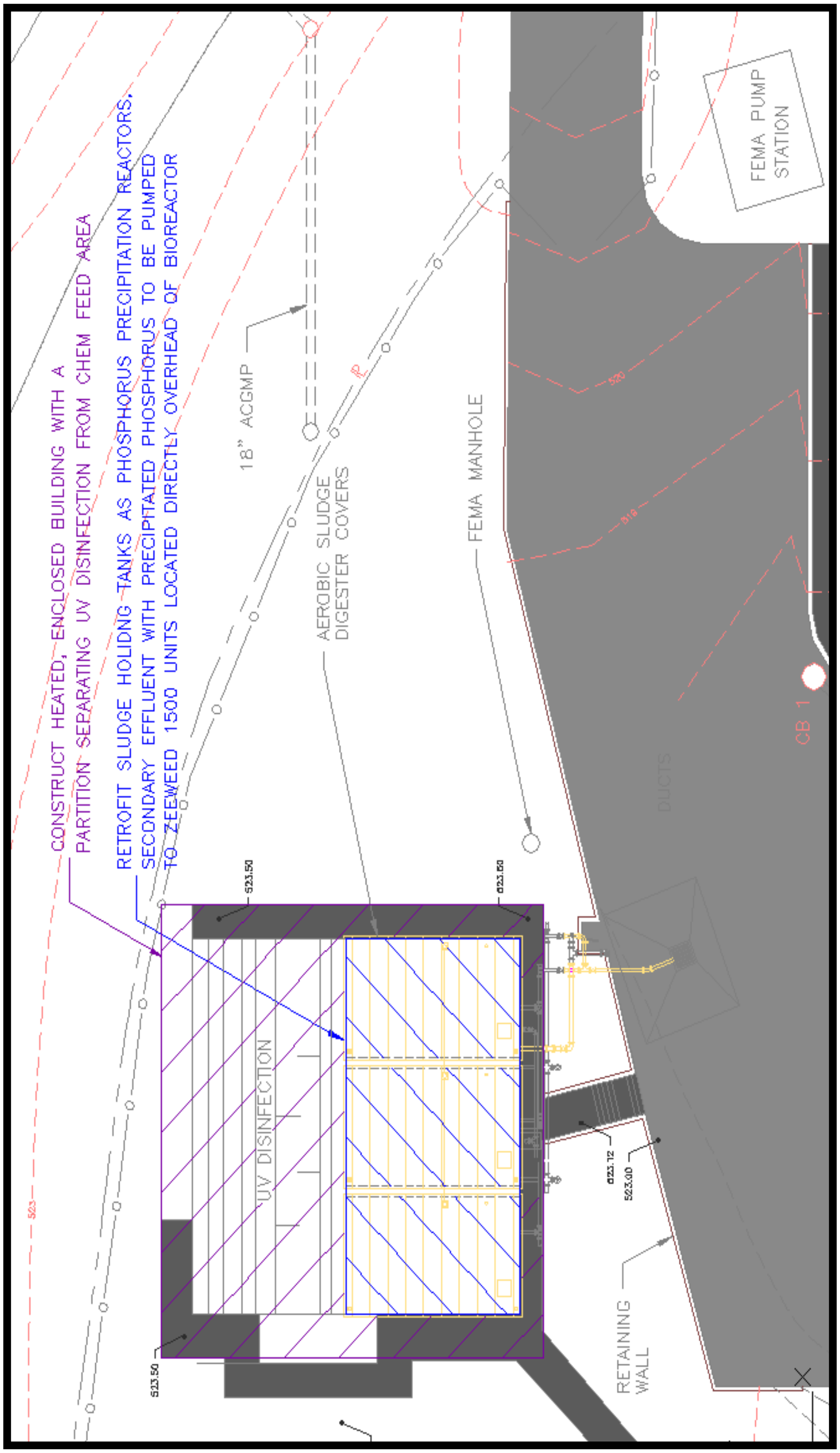


Figure 21: Ultra Filtration Membrane Design Option 1

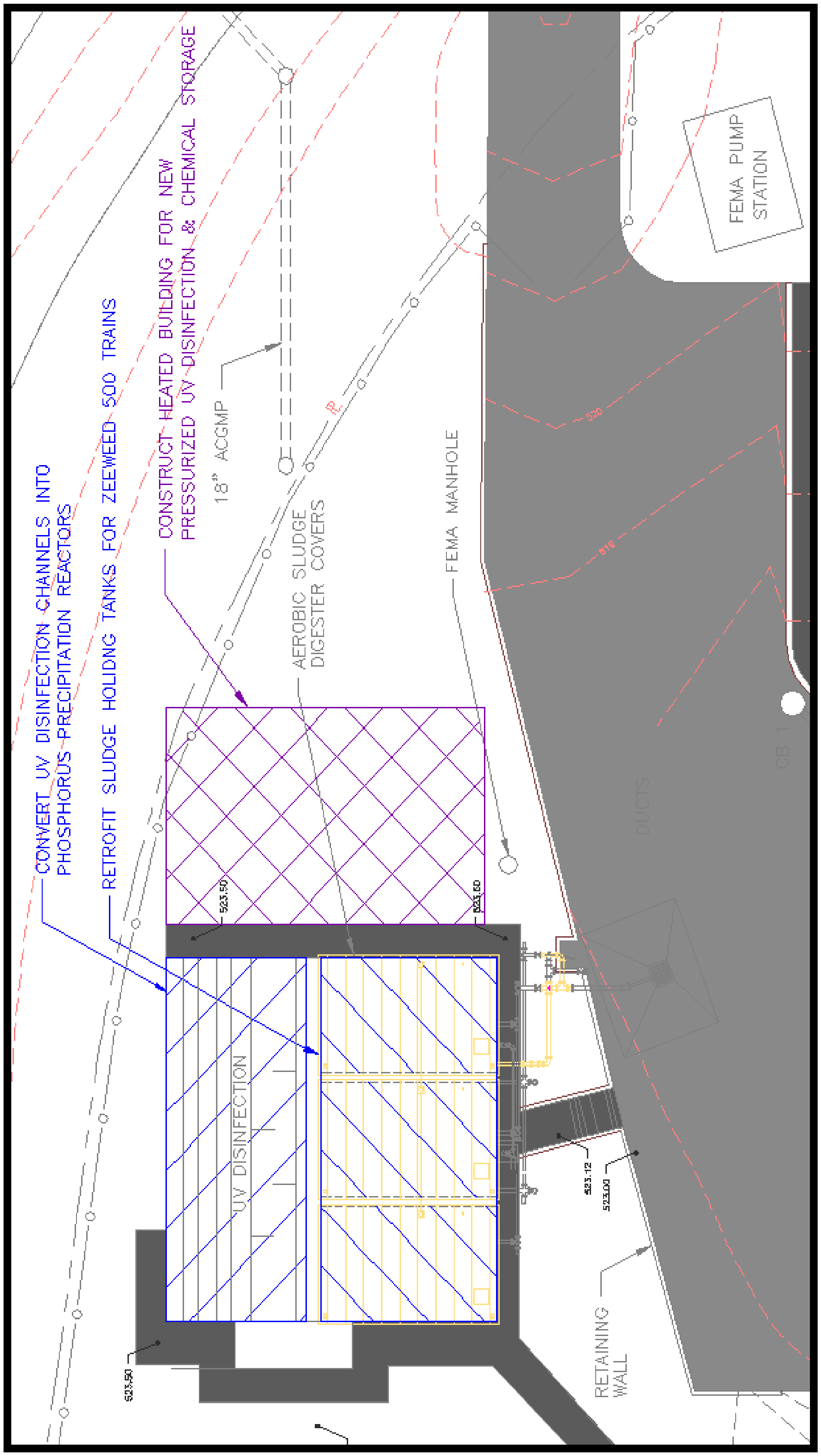


Figure 22: Ultra Filtration Membrane Design Option 2

4.7.3.2 CoMag© Advanced Design Options

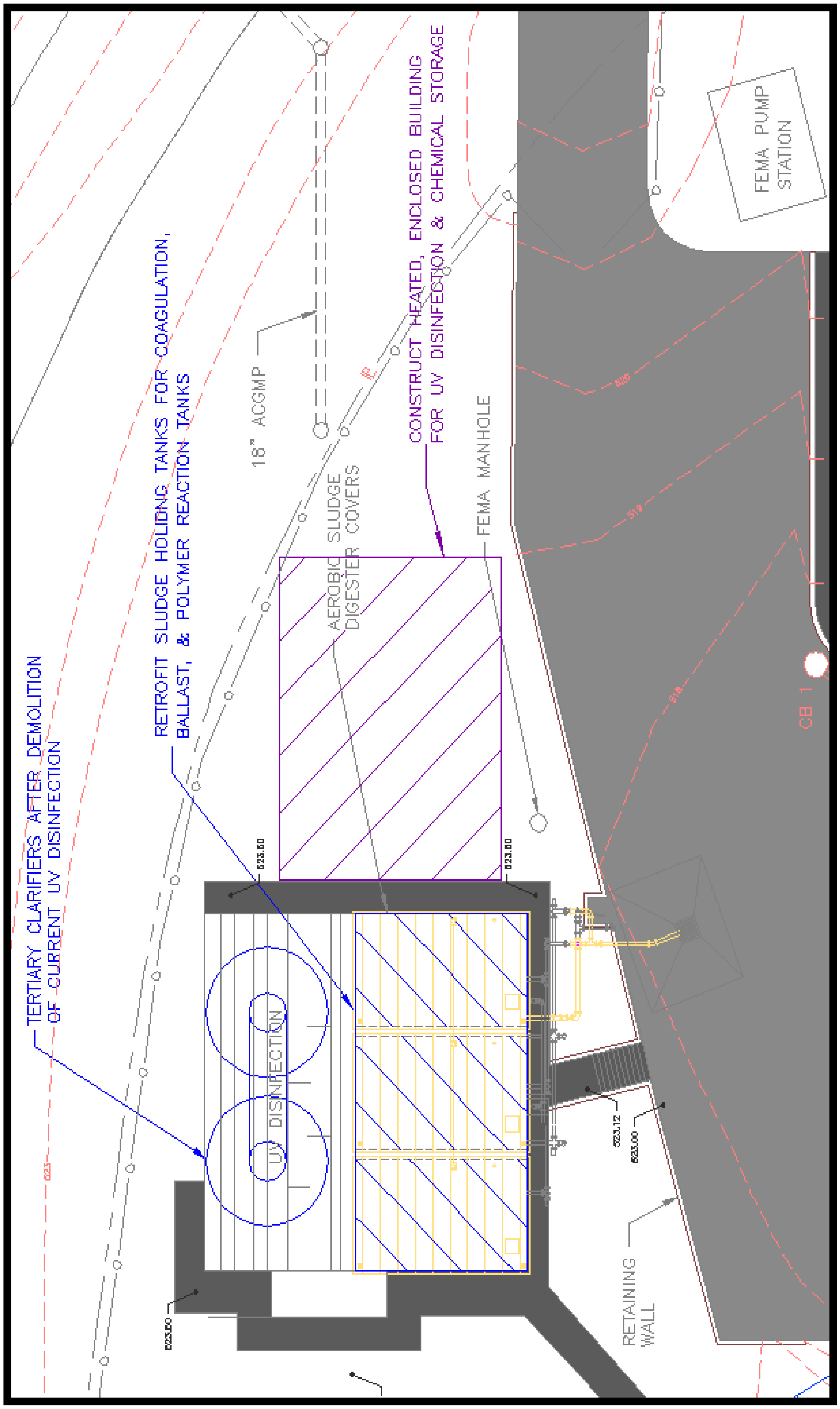


Figure 23: CoMag© Design Option 1

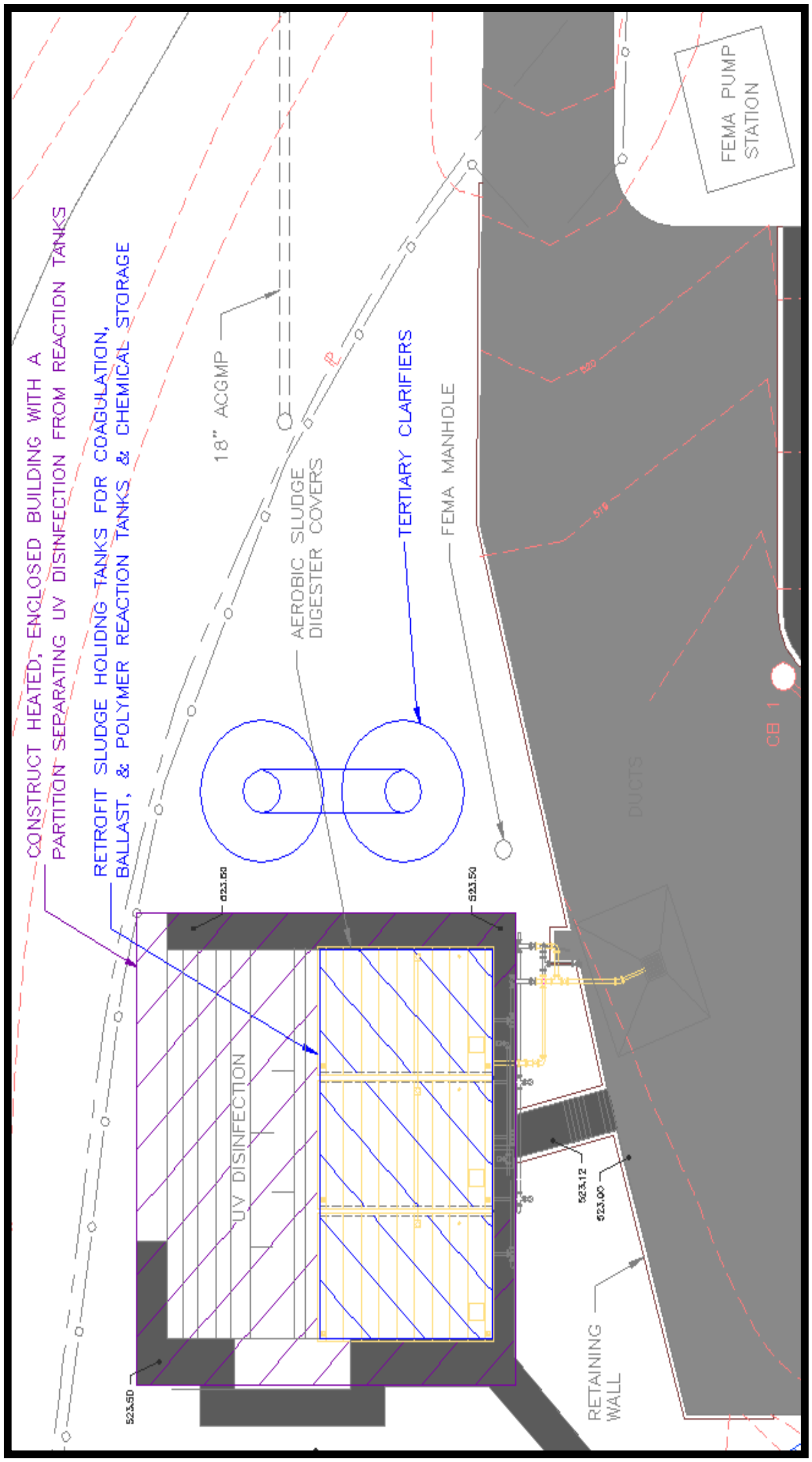


Figure 24: CoMag© Design Option 2

4.8 Final Recommendations

The final recommendation for the CoMag© design is based on Design Option 2 shown in Figure 24, with additional detail shown in Figure 26. The final design included all aspects proposed in the preliminary design proposal given by Evoqua shown in Appendix E: CoMag© Proposal by Evoqua. The design is based on the Montpelier WWTF parameters in Table 2 and Table 3. The basic process parameters are shown in Table 6.

Table 6: Preliminary Process Parameters

Parameter	Design
Number of Treatment Trains	1
Coagulation Reaction Tanks	2 Tanks 8' x 8' x 8' SWD
Ballast Reaction Tanks	1 Tank 8' x 8' x 8' SWD
Polymer Reaction Tank	1 Tank 8' x 8' x 8' SWD
Tertiary Clarifiers	2 Clarifiers 20' diameter x 10' SWD

Based on these design parameters a finalized AutoCAD process flow diagram was created. The process flow diagram showcases all aspects of the CoMag© process and individual points of chemical addition, mixing, and sludge pumping. The diagram also expresses the magnetite recycle process. The diagram is shown below in Figure 25.

For application at Montpelier there is one treatment train with different measures for redundancy within the process in case of a hardware or software malfunction. The treatment begins with secondary effluent from the secondary clarifiers feeding into the first coagulation tank with a static mixer. In the first tank, ferric chloride will be fed into the tank from day storage by a chemical feed pump. The tank will also have a system in place for the addition of caustic. Ferric Chloride depresses the alkalinity of the wastewater and caustic addition could be necessary for optimal pH range.

Following the coagulation tanks the effluent will flow by gravity into the ballast reaction tank. In this tank there is a static mixer where the magnetite is added. Magnetite is typically added once daily by the operator to replenish magnetite loss in the process.

Following the ballast tank is the polymer tank where polymer is added to increase adhesion of ballast to the floc. The ballasted floc feeds into the tertiary clarifiers where the solids settle and the sludge is pumped out. The two clarifiers are necessary because if one needs to be taken offline for cleaning the second clarifier can still be kept in operation. The sludge recycle goes through a magnetite separation drum where the magnetite is collected and placed back into the ballast tank and the sludge is then pumped out and sent back to the plant for processing. Clarified effluent flows out of the tertiary clarifiers to UV disinfection and discharged to the Winooski River.

CoMag© is equipped with various sensors throughout the process. As the secondary effluent is fed into the system is passes through a magnetic flow meter. The flow meter allows for accurate coagulant dosing and better management practices. A turbidity sensor is placed following the tertiary clarifiers. This sensor detects turbidity because the UV transmittance is determined by how turbid the water is. Other sensors in the process include; influent pH sensor, sludge blanket sensor, recycle sludge flow meter, waste sludge flow meter, and a magnetite concentration meter.

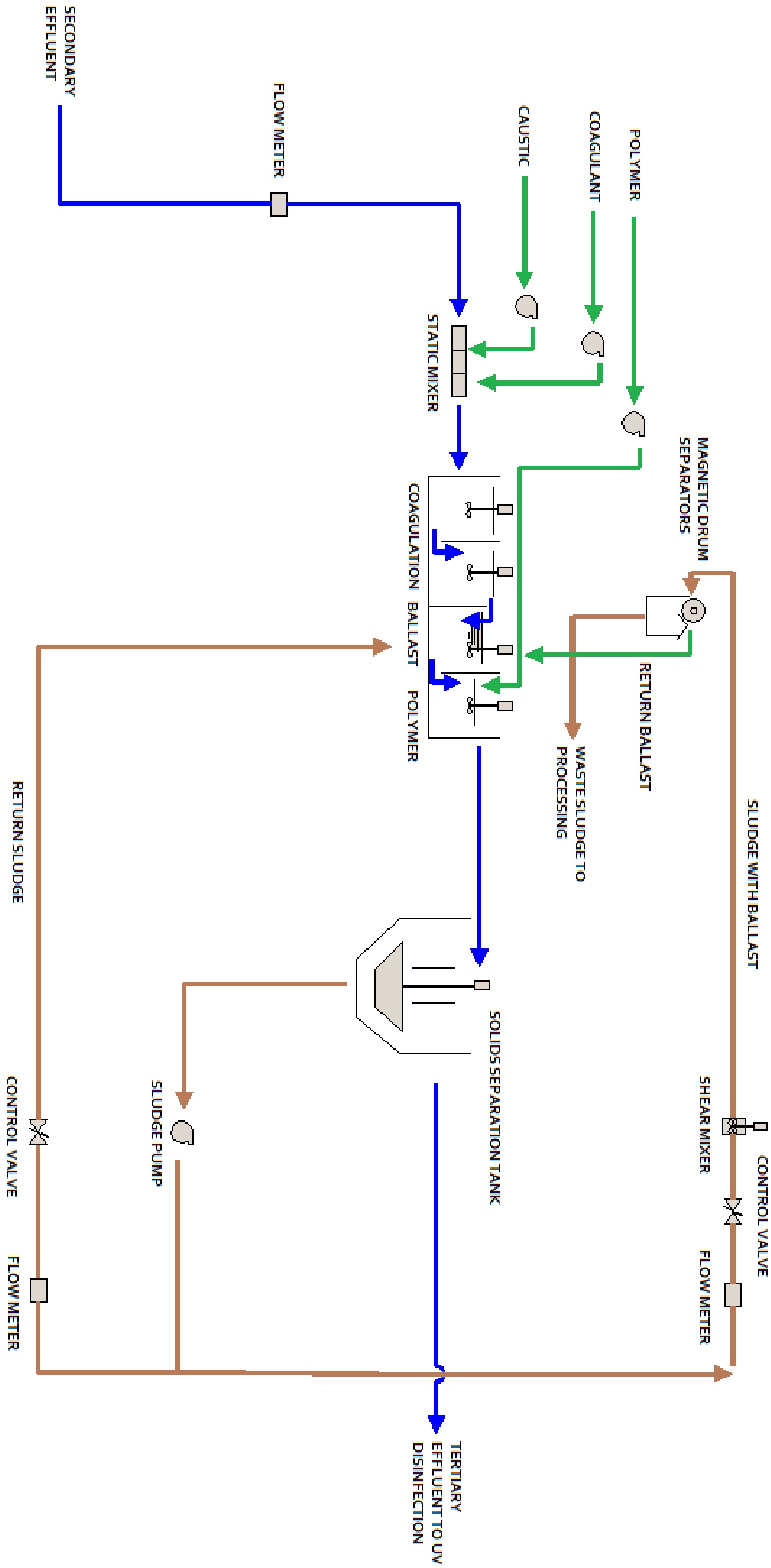


Figure 25: CoMag© Process Flow Diagram

4.8.1 Final Site Layout

The final site layout will optimize the available space and reduce construction costs. The designs shown in Figure 23: CoMag© Design Option 1 and Figure 24: CoMag© Design Option 2 were evaluated for efficacy and Option 2 was ultimately chosen.

Figure 24: CoMag© Design Option 2 was chosen because of its ability to utilize the sludge holding tanks for the four chambers needed in the process, and the capability to use the previous chlorine contact channel as a reverse flow channel from the tertiary clarifiers.

Figure 23: CoMag© Design Option 1 was not chosen for a variety of reasons. The construction of the option would have been much more labor intensive and likely would cost more. The option required the entire UV disinfection system to be decommissioned. The system is not imperative to keep; however, it is only 10 years old and has more years left in its life.

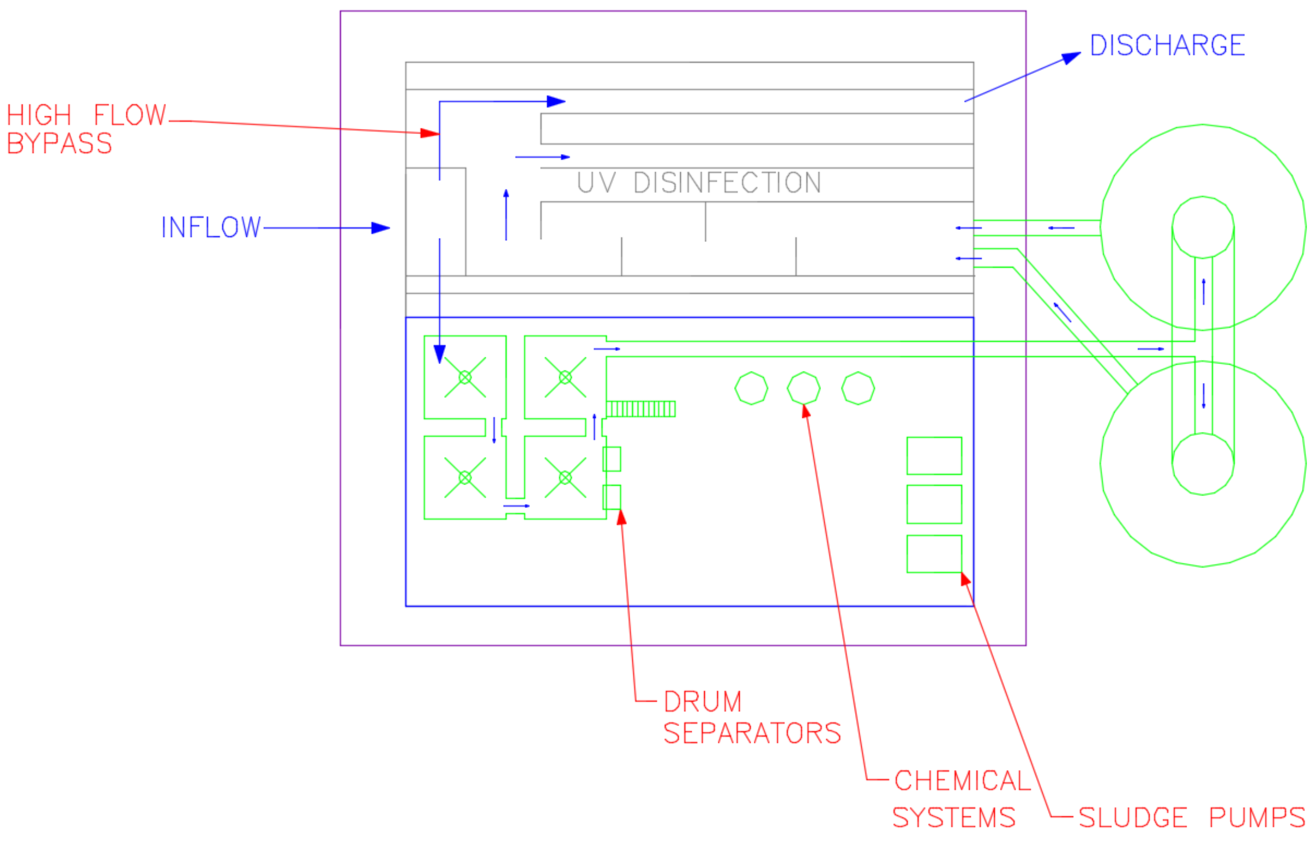


Figure 26: CoMag© & UV Disinfection Building Schematic

Figure 26 is a more in-depth look at what the CoMag© and UV disinfection building would be set up as. The inflow first flows through the two coagulation tanks, followed by the ballast and polymer tanks. At this point the flow will proceed to a tertiary clarifier, while the other remains on standby in case the other requires cleaning. From the clarifiers, the flow is diverted through the retrofitted chlorine contact tank before it reaches the existing UV disinfection.

4.8.2 Chemical Storage Design

In the CoMag© design proposal two different coagulants were offered as options for the process, ferric chloride and alum. These two coagulants, in addition to PAC, are typically used in the process with equal success. For the chemical dosing and design, ferric chloride was chosen as the coagulant for Montpelier, VT. Ferric was chosen because in previous pilot testing at the Waterbury, VT WWTF, ferric removed phosphorous the most effectively. All wastewater compositions are unique; however these results were the most appropriate lab testing available for reference given the scope of this MQP. With the 7 and half weeks available, jar testing was beyond the scope and time limitations.

To store ferric chloride, safety concerns determine the materials that can be used and basic design principles dictate the storage capacity. Liquid ferric chloride is shipped in 4,000-gallon truckloads. Utilizing full truckload deposits of chemicals, rather than individual amounts or half truckloads, reduces chemical costs because a premium will not be charged. Liquid chemical storage is sized for at least 50% greater storage capacity than needed and must be able to store enough chemicals to last 2 weeks. A better design option is to accommodate storage that will last 30 days. 30-day storage was used in this design as shown in Appendix D: Calculations. Bulk storage will be done in two tanks for process redundancy. The ferric dosing in CoMag© for Montpelier is limited, as such, the design parameters were for 4,000 gallons and sized for 6,000 gallons to accommodate the 50% excess storage needed. Therefore, storage will be two, 3,000 gallon storage tanks.[28]

Storage containers for ferric chloride must be made of compliant materials. Material options are fiberglass-reinforced plastic (FRP), rubber-lined steel, plastic-lined steel, or High Density Polyethylene (HPDE). The material options are due to the corrosive nature of the ferric. Ferric has a pH <2. Based on market prices, a single container would cost approximately $2,000.[29]

The bulk storage containers would be located further from the mixing tanks where the coagulant would need to be injected. This requires the installation of day tanks and a chemical feed system. There would need to be two chemical feed systems; one system to deliver ferric from the bulk container to the day storage and a second system to deliver from the day storage to the mixing tanks.

The chemical feed system is configured the same as the Waterbury, VT WWTF designed by Stantec. That plant's upgrade for phosphorous removal used ferric chloride as a coagulant and had the same considerations for pumping from bulk storage to day usage. The chemical feed pumps will be Peristaltic tube pumps. The benefits of these pumps are that they are low maintenance and self-priming. These pumps are a conventional choice and therefore easily accessible.

> "The pumps will be fabricated of powder coated aluminum, with a thermoplastic pump head and acrylic pump cover. Each pump will be provided with a tube failure detection system that will detect chemical in the pump head.
>
> Pumps for… [the] chemical feed system … will be provided in a duplex arrangement for 100% redundancy. One pump will be the duty pump with one dedicated standby pump for each system. Pumps will be controlled by an integral brushless DC motor capable of a 2500:1 turndown ratio. Adjustment of the pumps can be conducted manually via an integral control panel, or remotely. A 4-20 mA input for remote external speed control and a 0-30 VDC input for remote start/stop shall be provided to facilitate remove pump control.
>
> All pumps will be sized to accommodate the chemical flows necessary to achieve an effluent phosphorus concentration of 0.1 mg/l… (Stantec)[30]"

4.8.3 Construction Phasing

It is recommended that the construction of the new tertiary treatment and disinfection facility take place during the summer months. It is likely that a portion of the piping to the FEMA pump station will have to be relocated due to the construction of the tertiary clarifiers. Since the FEMA pump station only operates during the winter months for ice melting purposes, summer construction will not interrupt any operation of the pump station. Construction will also be easier during the summer months, because freezing will not be a concern for the UV disinfection system while the building is being built around it.

CoMag© Design Option 2 offers superior constructability compared to CoMag© Design Option 1 due to reusing the existing UV disinfection. Construction of Design Option 2 consists of 2 phases as outlined below.

Phase I

Phase I includes the demolition of the existing UV disinfection building. Temporary covers may be necessary to protect the Calgon UV disinfection systems from rain, wind, and other weather. After the existing UV disinfection building is demolished, the sludge holding tanks should be retrofitted to accommodate the 4 mixing tanks as shown above in Figure 26.

Phase II

Once the construction of the 4 mixing tanks is completed, construction of the building and installation of other smaller internal components such as the drum separators, chemical feed systems, and sludge pumps may commence. After the foundation of the building has been set, the construction of the tertiary clarifiers and grading of the surrounding area can commence. Once the tertiary clarifiers, building, and other internal components are constructed, the new tertiary treatment system is ready to be put online, with minimal disruption to the treatment process.

4.8.4 Capital Cost Estimates

The table below outlines approximate capital costs for the CoMag© upgrade. These costs do not include operational expenses such as coagulants, polymers, and electricity. These costs are estimates given by past feasibility studies, conceptual designs, and advice from Stantec engineers.[1]

Table 7: Capital Cost Estimate at Montpelier, VT WWTF

Item	Costs (USD)
Site Work	$1,500,000
Process Building	$1,039,500
Mechanical	$670,000
Chemical Storage (At Process Equipment)	$212,000
Chemical Feed	$1,500,000
CoMag© Treatment Process Equipment	$[redacted]
Solids Management, Process Equipment & Piping	$3,750,000
Sludge Disposal Equipment	$455,000
Miscellaneous Site Improvements, Existing	$1,000,000
Repiping FEMA pump station	$50,000
Subtotal- Construction Cost	**$[redacted]**
Bonds & Insurance (6% of Construction Cost)	$666,090
Electrical I/C (15%)	$1,665,225
Overhead & Profit (18%)	$1,998,270
Contingency (30%)	$3,330,450
Legal & Fiscal	$15,000
Administration	$15,000
Pilot Testing	$2,500
CoMag© Project Cost	**$7,692,535**
Total Project Cost	**$[redacted]**

The price of the CoMag© system is [redacted]. This cost estimate was given to the MQP team by Evoqua engineers. The pricing includes process and design engineering, field services, and equipment supply. The process building was estimated based off of an assumption of $350/ft^2 and a 2,970 ft^2 building. The chemical feed system estimate was pulled from the *City of Montpelier Wastewater Treatment Facility Modernization & Phosphorus Removal* document. To gauge costs to re-install piping to the FEMA pump station, $500.00 per foot of piping was used. The distance from the FEMA manhole to the pumping station was approximately 100 feet. This gives the $50,000 approximation. The price of a pilot study was discussed in meetings with the Evoqua sales representative and covers operating, testing, and employee costs. Other costs were scaled and estimated based on other Stantec reports and conversations with Stantec engineers.

4.8.5 Chemical Cost Estimate

The chemical cost estimate was found by scaling the Waterbury, VT upgrade values for chemical usage for use at Montpelier, VT. The scale was done by taking a ratio of the average day design flow at Montpelier, VT WWTF to the average day design flow at Waterbury, VT WWTF. The ratio was 7.8:1. These values were used because the Waterbury values were based off of pilot testing done onsite. The wastewater characteristics at the Waterbury, VT WWTF are the most geographically similar available to the MQP group. The values are shown in Table 8. The estimated total annual cost in chemical usage is $ 509,950.39.[31]

Table 8: Estimated Annual Chemical Costs at the Montpelier, VT WWTF

	Waterbury, VT WWTF	Montpelier, VT WWTF
Design Average Daily Flow (*MGD*)	0.51	3.97
Total Ferric Chloride Required at Design Year (*gallons/year*)	27,925	21,7376
Annual Ferric Chloride Cost	$62,825	$489,049
Total Polymer Required at Design Year (*lbs*)	1,300	10,119
Annual Polymer Cost	$2,685	$20,900
Total Cost	**$ 65,510**	**$ 509,950**

5 Conclusions

The following are conclusions and recommended next steps for the Montpelier, VT WWTF to advance the tertiary system upgrades.

1. Choose CoMag© as the new technology upgrade

In this MQP team's opinion, CoMag© is the most applicable phosphorus removal technology for the Montpelier, VT WWTF. This process, through various evaluations in this MQP, had consistently ranked the highest in performance and energy usage. Compared to other processes, CoMag© will fit in the allotted space onsite while still achieving a discharge concentration of 0.1 mg/L P with reduced energy costs.

2. Jar test secondary effluent and pilot test the CoMag© system

Theoretical dosing calculations were done based on Ferric Chloride for use in chemical precipitation. These calculations are useful; however, they do not give results based on secondary effluent characteristics. Jar testing was beyond the scope of this MQP so it is recommended that a 5-gallon sample of secondary effluent be sent to a lab for jar testing. It is also recommended that pilot testing of the system be done for at least 2 weeks. The pilot testing should include the use of Ferric Chloride and PAC. Alum should be tested for an additional week if time and money allow. The pilot testing will give accurate wastewater characteristics that can then be used to optimize coagulation chemistry for maximum phosphorous removal.

3. Fully develop the final recommendations from Section 4.8 Final Recommendations

The final recommendations section details the conceptual CoMag© design from Evoqua and the site layout, chemical dosing, and supplementary materials needed from implementation of CoMag© at the Montpelier, VT WWTF. The site layout will utilize the space of the sludge holding tanks not in use, the space adjacent to the UV disinfection building and the current UV disinfection. The system includes 2 Coagulation Reaction Tanks, 1 Ballast Reaction Tank, 1 Polymer Reaction Tank, and 2 Tertiary Clarifiers. The dosing will be 8-16 mg/L as Fe using ferric chloride based on theoretical dosing by Evoqua. The chemical feed will resemble the Waterbury, VT design by Stantec.

4. Assess the system upgrades identified in this MQP and previous feasibility studies and apply the upgrades during construction of the new technology

During the course of this MQP, different aspects of the Montpelier, VT WWTF existing facilities were identified as detrimental to optimal wastewater treatment. The most notable problems were in the UV disinfection building and the FEMA pump station located near the UV building. The UV disinfection system has ineffective modulating weirs and a poor building structure to house the unit. It is recommended that during construction, the existing building be demolished and new building be put in place to house both the CoMag© reaction tanks and the UV disinfection. The building is to be heated to eliminate freezing and increase ease of operation for the facility. The FEMA pump station has a manhole and piping that is located where the new tertiary clarifiers will be constructed. Additionally, the current pipes are not utilizing the full extent of the flow. It is recommended that the manhole and piping be replaced and rerouted to eliminate problems during construction and for more effective pumping.

6 References

[1] Stantec, Aldrich + Elliott. (2014). *City of Montpelier Wastewater Treatment Facility Modernization & Phosphorus Removal*. Montpelier, VT.

[2] "Lake Champlain Phosphorous TMDL: A Commitment to Clean Water." EPA. Environmental Protection Agency, 6 Feb. 2015. Web. 02 Mar. 2015.

[3] EPA. (2007). *Advanced Wastewater Treatment to Achieve Low Concentration of Phosphorus*. Office of Water and Watersheds.

[4] "Total Maximum Daily Load (TMDL)." EPA. Environmental Protection Agency, 6 November 2013. Web. 02 Mar. 2015.

[5] Aqua-Aerobic Systems, Inc. (n.d.). *Aqua-Aerobic Cloth Media Filters*.

[6] Aqua-Aerobic Systems, Inc. (n.d.). *Aqua-Aerobic Technologies Meet Small Footprint and Stringent Nitrogen and Phosphorus Requirements*.

[7] Rulseh, T. J. (2014). *Getting to Low P: Pilot Testing with Cloth Media Filtration Documents One Way to Achieve the Strict Effluent Total Phosphorus Limits Being Prescribed in Today's Permits*. Cole Publishing, Inc.

[8] Aqua-Aerobic Systems, Inc. (n.d.). *Two AquaDisk® Cloth Media Filters Replace Six Granular Media Units, Boosting Capacity 540% and Cutting Backwash Volume by 97%*.

[9] Blue Water Technologies. (n.d.). *Phosphorus Removal Blue PRO®*.

[10] Blue Water Technologies. (n.d.). *Phosphorus Removal Achieved with Capital Affordability: Westerly WWTP, Marlborough, Massachusetts*.

[11] Siemens. (n.d.). *BioMag® and CoMag® Systems Magnetite Ballasted Treatment*.

[12] Evoqua Water Technologies. (n.d.). *The CoMag® System for Enhanced Primary and Tertiary Treatment*.

[13] Evoqua Water Technologies. (n.d.). *The BioMag® and the CoMag® System: Sturbridge, Massachusetts POTW*.

[14] Siemens. (n.d.). *BioMag® and CoMag® Systems: Enhanced Treatment Solutions From One Reliable Source*.

[15] Cambridge Water Technology. (n.d.). *Town of Concord WWTP CoMag®*. Evoqua Water Technologies.

[16] Veolia Water Technologies. (n.d.). *ACTIFLO®*.

[17] Kruger, Inc. (n.d.). *Process For Wet Weather and Wastewater Treatment*. Veolia Water Technologies.

[18] EPA. (n.d.). *Wastewater Technology Fact Sheet: Ballasted Flocculation*.

[19] Kruger, Inc. (n.d.). *Warwick Wastewater Treatment Facility Warwick Sewer Authority Warwick, RI ACTIFLO® Pilot Study Preliminary Report*. Veolia Water Technologies

[20] CRA Infrastructure & Engineering, Inc. (n.d.). *Metro WWTP Optimization Analysis of Total Phosphorus Treatment*. Conestoga-Rovers & Associates.

[21] Pirro, N. J., & Ott, R. R. (2006). *Onondaga Lake: Progress Report 2006*. Onondaga County Department of Water Environment Protection.

[22] GE Water & Process Technologies. (2006). *ZeeWeed Membranes for Municipal Wastewater Treatment*.

[23] GE Water & Process Technologies. (2013). *ZeeWeed 1500 Pressurized Ultrafiltration*.

[24] GE Water & Process Technologies. (2008). *ADM Decatur*.

[25] GE Water & Process Technologies. (2011). *LEAPmbr: Taking ZeeWeed MBR Technology to the Next Level*.

[26] Tozer, P.E., H. G. (2008). *Study of Five Phosphorus Removal Processes Select CoMag to Meet Concord, Massachusetts' Stringent New Limits* (Volume 45, No.1). The Georgia Operator.

[27] Office of Research and Development, U.S. Environmental Protection Agency. "Chapter 4 Phosphorous Removal by Chemical Addition." Design Manual Phosphorous Removal. N.p.: U.S. Environmental Protection Agency, n.d. 55-77. Print.

[28] Cheremisinoff, Paul N. "Chapter 4." Handbook of Water and Wastewater Treatment Technology. New York: M. Dekker, 1995. 146-47. Print.

[29] "3000 Gallon Blue HD Vertical Plastic Storage Tank." 3000 Gallon Vertical Bulk Storage Tank. N.p., n.d. Web. 01 Mar. 2015.

[30]Stantec. 3.3.1 Chemical Feed Systems. VILLAGE OF WATERBURY, VT WASTEWATER TREATMENT PLANT PHOSPHORUS REMOVAL UPGRADE. N.p.: Stantec Consulting, n.d. 2. Print.

[31]Stantec. 3.1.4 Estimated Annual Chemical Costs. VILLAGE OF WATERBURY, VT WASTEWATER TREATMENT PLANT PHOSPHORUS REMOVAL UPGRADE. N.p.: Stantec Consulting, n.d. 3-4. Print.

Appendix A: Proposal

Improved Phosphorous Removal at the Montpelier, VT Wastewater Treatment Plant

A Major Qualifying Project Proposal Submitted to the Faculty
of
Worcester Polytechnic Institute
In Partial Fulfillment of the requirements for the Bachelor of Science Degree
By

Michael Enko
Alexis Simpson

December 21, 2014

Advisors:
Fred Hart
Suzanne LePage

Table of Contents

1.0 Introduction

This Major Qualifying Project (MQP) will be a redesign on a wastewater treatment plant (WWTP) to accommodate for regulation changes made by the Environmental Protection Agency (EPA) in regards to the Maximum Daily Limit (TMDL) for point and non-point discharge sources to Lake Champlain in Vermont. An EPA investigation found harmful phosphorous levels, which prompted reduced point source discharge concentrations of 0.2 mg/L and 0.1 mg/L. The new concentrations will affect all wastewater treatment plants (WWTPs) in the area with expired permits and will require substantial upgrades to meet new TMDL standards.

The work done on this MQP will focus on the advancement of the upgrades to one affected WWTP from the conceptual level to a preliminary design level. The advancement will include new treatment processes within the selected facility to meet the new standards set forth by the EPA. Project tasks will include investigating the existing site and WWTP; a field trip to the facility and discussions with operations staff; more detailed BioWin© treatment process modeling; review and summarization of articles and papers on low-level nutrient removal; discussions with equipment vendors; development of multiple options; followed by a schematic design; equipment and site layout; and a cost estimate for the recommended option.

2.0 Background

This chapter provides an overview of the Environmental Protection Agency (EPA) and the regulations placed onto the Lake Champlain region due to excess phosphorous loading. The Total Maximum Daily Limit (TMDL) was subject to change due to litigation and the changes are discussed. The Montpelier WWTP will be subject to the changed TMDL and the *City Of Montpelier Wastewater Treatment Facility Modernization & Phosphorus Removal* report completed by Stantec in collaboration with Aldrich + Elliott was done to assess its capability of handling increasingly more stringent regulations. The status of the plant components and a plant overview will be discussed in this chapter.

2.1 Lake Champlain TMDL

Lake Champlain, Vermont is a central component of life for many Vermont residents. The lake provides recreation and livelihood, making its health a primary concern from not only an EPA standpoint, but also from a holistic one. The State of Vermont is dedicated to improving the lake quality and has created the Vermont's Clean Water Initiative. This initiative is targeted at improving lake quality and has an individual component dedicated to phosphorous removal and reduction.

The Clean Water Initiative is in response to both the Environmental Protection Agency's TMDL revision for Lake Champlain and growing concern from residents. TMDL is the 'Total Maximum Daily Load', or the amount of pollution that can be received by the lake and still meet water quality standards. The TMDL is important because pollution accumulates; by having a set limit, pollution input from multiple sources can be controlled. The process of setting a TMDL for a region includes a period for public comment, making it an outlet for public involvement and education. The components that create a TMDL are the Waste Load Allocation (WLA), Load Allocations (LA), and measure of safety (MOS). The waste load allocation is derived from origins such as industrial sources and municipal WWTP discharge. It is known as a 'point source'. The load allocation is considered a 'nonpoint source' and is typically generated from agricultural or urban runoff. The measure of safety is part of the equation to curtail any potential deficiencies or miscalculations of the WLA and LA components. These are all related in the equation for TMDL:

$$\mathrm{TMDL} = \mathrm{WLA} + \mathrm{LA} + \mathrm{MOS}$$

The current discharge limit for the Montpelier WWTP is 0.8 mg/L. The EPA and the State of Vermont are currently evaluating this limit to create a reduction of phosphorous loading for Lake Champlain. The evaluation has been ongoing since 2013 and is projected to be delivered on June 15, 2015. The June date is preceded by public comment on a drafted limit to be delivered in March of 2015. The discharge limit revision is expected to be either 0.2 mg/L or 0.1 mg/L. This revision is a drastic drop in allowable phosphorous to be discharged and will require Montpelier WWTP facility upgrades.

2.2 BioWin

BioWin is the software used by Stantec to design, upgrade, and optimize wastewater treatment plants. BioWin is a software that models the biological, chemical, and physical processes of wastewater treatment plants by inputting plant data such as flow rates and phosphorous concentrations. Our project will primarily use BioWin to model the current wastewater treatment plant and our design alternatives. BioWin is expected to help in identifying the most efficient design alternative.

2.3 Plant Background

The following section summarizes the *City Of Montpelier Wastewater Treatment Facility Modernization & Phosphorus Removal* report completed by Stantec in collaboration with Aldrich + Elliott. This summarization will identify plant components in need of upgrade and a basic plant schematic.

The Montpelier WWTP is composed of eleven (11) components to treat and discharge the influent of the plant. Appendices A and B visually represent the treatment process.

The flow schematics both showcase the existing Montpelier WWTP. The eleven components shown are septage/leachate receiving, headworks, primary clarifiers, lift station, aeration tanks, secondary clarifiers, chemical feed, disinfection, sludge thickening, anaerobic digestion, and sludge dewatering. These components are all of different ages and some are composed of their original construction and parts, having received no upgrades. Due to age and heavy use, certain sections have been identified for refurbishment or replacement as shown in Appendix 4.3 Projected Upgrades taken from the Stantec report (29-30).

The components that have been identified for upgrade within the next two years are the primary clarifiers, disinfection system, and anaerobic digester. The primary clarifier needs added heat trace cable to the rails to mitigate freezing risk. The disinfection system will need to have the inlet gates repaired and outlet gates replaced. Anaerobic Digesters require repaired decant valves and replacement of the waste gas burner. Based on Appendix 4.3 Projected Upgrades, more than just the stated components are in need of refurbishment. The components that will last more than the next two years but still need replacement are discussed in the Methodology.

3.0 Methodology

3.1 Scope

The scope of the project is to provide design alternatives for the upgrading and modernization of the City of Montpelier Wastewater Treatment Facility. The design alternatives will include different technologies associated with phosphorus removal, so that the WWTP will meet new EPA phosphorus discharge limits.

3.2 Project Schedule

Figure 1 was prepared in order to organize our time that we are at Stantec and present our design alternatives at the completion of our project.

	Week							
	1	2	3	4	5	6	7	8
Task	Jan 15-17	Jan 20-24	Jan 27-31	Feb 3-7	Feb 10-14	Feb 17-21	Feb 24-28	Mar 3-6
Familiarize ourselves with Stantec Office	■							
Explain goals & expectations	■							
Begin Stantec's project tasks	■	■						
Site visit & land use investigations		■						
BioWin treatment process modeling			■					
Literature Review		■	■	■	■	■		
Meet with equipment vendors			▒	▒	■	▒		
Design alternatives & cost estimates					▒	■	■	
Final Report & presentation							▒	■
Meet with advisors	■	■	■	■	■	■	■	■

Figure 1: Project Schedule

The following tasks were created to systematically achieve the goals set forth in our scope. Weekly meetings or phone conferences will be held with our WPI advisors to give progress updates and receive feedback.

Task 1: Familiarize ourselves with Stantec Office
It will be necessary to acclimate ourselves with Stantec's resources and policies. Doing so will allow us to work efficiently in the office. Introducing ourselves to the employees in the wastewater department will provide the additional resource of junior and professional engineer's input. Once we are oriented with the office we can begin to integrate into the community and fully utilize the experience to improve our project goals.

Task 2: Explain goals & expectations
Explaining our goals and expectations immediately will be beneficial so that we know what Stantec expects of us. This will also help Stantec have a better understanding of what we need to accomplish academically. Further, we will establish what milestones need to be achieved by the end of our project to meet the goals of the project scope.

Task 3: Site & land use investigations

Researching the current WWTP site will give us an understanding of the land where the WWTP is located. Soil condition and wetlands are two factors that could affect or prevent the installation of design alternatives. Researching as-built drawings and available GIS maps will aid us in the design of upgrading alternatives. We will also look at other WWTP sites that have had phosphorous removal upgrades to gain more insight into the process.

Task 4: BioWin treatment process modelling

Using the BioWin treatment process software will allow us to determine the efficiency of the treatment plant in its current state. In addition, it will be important to evaluate the existing conditions and design options without the software to compare results and gain a more in depth understanding of the design and modelling process. By evaluating its existing conditions, areas of improvement can be identified. At this point, new technologies can be run on the software and compared to the current treatment levels. This information will be crucial when deciding the best design alternative.

Task 5: Literature Review

This time will be spent reviewing and summarizing reports on low-level nutrient removal. Using Stantec's resources we will be able to research previous phosphorus removal projects that Stantec has completed. In addition, using databases that Stantec subscribes to will allow us to access scientific journals and reports to further our understanding on phosphorus removal and related topics. At the culmination of this task, enough research and information will be gathered for the background section on phosphorus removal for the final report.

Task 6: Meet with equipment vendors

Once the research on nutrient removal is complete, we will contact equipment vendors to get quotes and information on their nutrient removal technologies. These vendors will be found through our research on previous phosphorus removal applications and contact with Stantec employees. It will be beneficial for the design process if the vendors are able to provide operating data from their respective technology. Once the land use & site constraints are known, and several different technologies are evaluated, the design process can move forward. It will be important to be flexible with this task depending on equipment vendor availability.

Task 7: Design alternatives & cost estimates

The culmination of the project will include designing alternatives for phosphorus removal. By working with Stantec engineers and using the information gathered from the previous tasks, we will be able to design alternatives for phosphorus removal including cost estimates and a recommendation. These recommendations will also consider the constraints placed from the site itself. The site is limited in size so the final plans will accommodate for new construction while keeping the existing site operational. This process will require further communication with engineers, construction, and facility staff.

Task 8: Prepare Final Report & Presentation

During our last week at Stantec, we will be preparing our final report and giving our presentation to the engineers we worked with.

3.3 Montpelier WWTP Design

As part of the process to redesign the Montpelier WWTP to meet new TMDL regulations, a basic design process must be followed. In order to achieve a basic design certain steps need to be taken and values found. Values that will need to be found are the loading rates, discharge, hydraulic loading, mass loading, design parameters, and the basic conditions around the physical site.

To find these, the group will review the *City Of Montpelier Wastewater Treatment Facility Modernization & Phosphorus Removal* Study report and use values gathered from the consulting team within the report. The report recommends further sampling of the facility to determine alkalinity and toxicity levels, which can be used in the design process to refine the BioWin model. These factors in conjunction with side stream and leachate/septage characterization can all be used for consideration of bioreactor capacity and upgrade options.

The Montpelier WWTP is in need of refurbishment and upgrades to achieve adequate treatment of its wastewater and to meet new TMDL requirements for phosphorous. The potential treatment processes for each possible TMDL will be discussed in this section, as will the refurbishments needed to the already existing components.

3.3.1 Existing Structure Upgrades

As stated in the background, components of the Montpelier WWTP will need to be upgraded or replaced within the next five years of operation to achieve improved treatment and to optimize current processes. Based on the report provided by Stantec, various components were recognized for this, which can be seen in the Appendix. To account for these upgrades when designing the facility, cost considerations will need to be made for the increased costs associated with upgrading the facility.

The projected upgrades and projected upgrade costs can be found in Appendix 4.3 Projected Upgrades and 4.4 Projected Upgrade Construction Costs. These estimated construction costs are based December 2013 construction costs. Both appendices are sourced from the *City of Montpelier Wastewater Treatment Facility Modernization & Phosphorus Removal Study* (32).

3.3.2 If proposed TMDL is > 0.2 mg/L

If a TMDL greater than 0.2 mg/L is issued, the discharge limit for the Montpelier WWTP will be affected, however tertiary treatment options will not be necessary. To achieve the new discharge limits expansion upon current technology will be needed. The options are listed below.

Options for TMDL of 0.2 or 0.3 or greater

1. Dual Point Chemical Addition using PAC (poly-aluminum chloride)
2. If at total permitted facility flows, the facility can make increases to:
    a. Bioreactor capacity
    b. Secondary clarifier capacity
    c. Anaerobic digester capacity

3.3.3 If proposed TMDL is 0.2 mg/L

If the TMDL is 0.2 mg/L the Montpelier WWTP will not be able to achieve adequate phosphorous removal with the current technology on site. To achieve new discharge limits tertiary treatment processes will need to be added. The technologies capable of achieving this are listed below.

Tertiary Treatment Options for 0.2 TMDL

1. Chemical Precipitation with Disk Filters
2. Deep Bed continuously backwashed sand filters
3. CoMag
4. ActiFlo
5. Membrane Filtration
6. AQUADAF Dissolved Air Flotation

3.3.4 If proposed TMDL is 0.1 mg/L

If a TMDL of 0.1 mg/L is determined, the Montpelier WWTP will continue to require a tertiary treatment process similar to the options proposed for a TMDL of 0.2 mg/L. These options are similar, however, AQUADAF will no longer be adequate. The options are listed below.

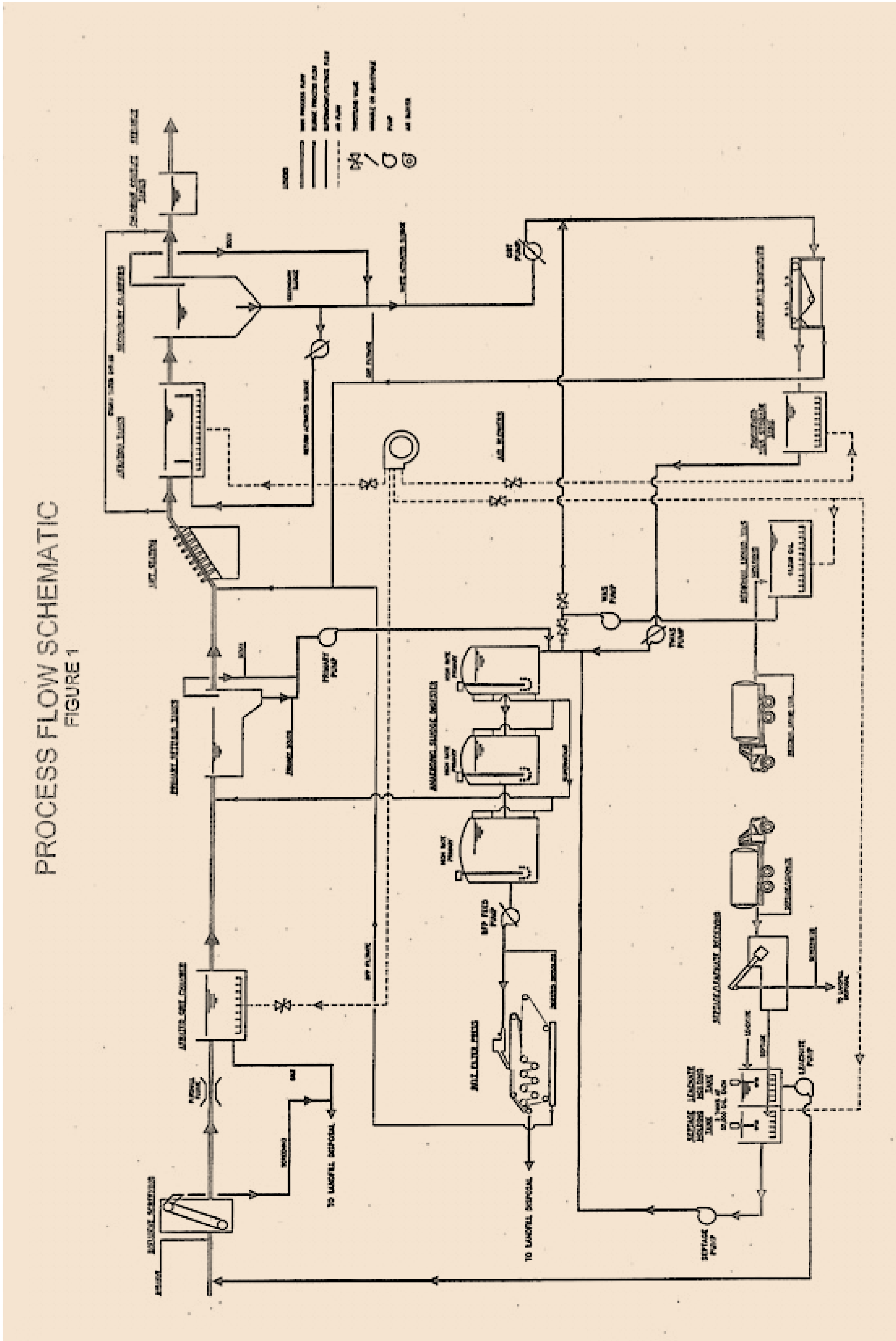
Tertiary Treatment Options for 0.1 TMDL

1. Chemical Precipitation with Disk Filters
2. Deep Bed continuously backwashed sand filters
3. CoMag
4. ActiFlo
5. Membrane Filtration

4.0 Appendices

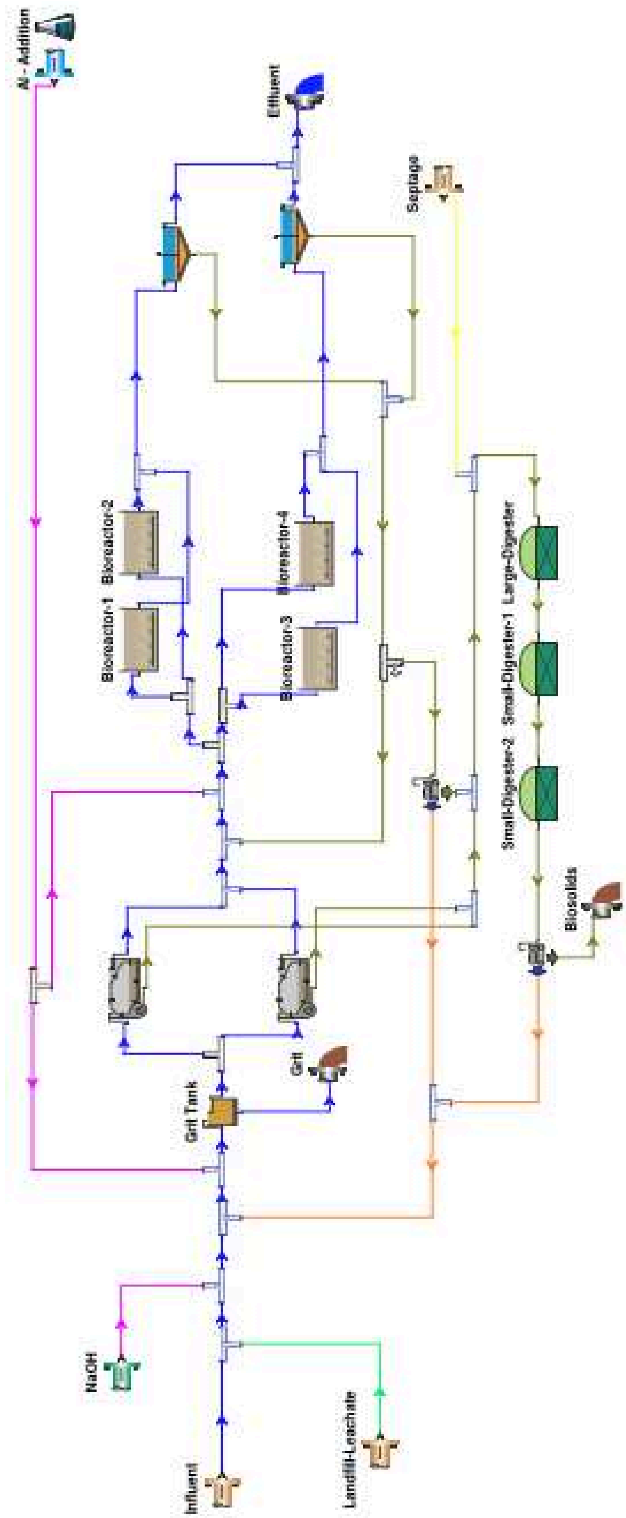
Appendix A

Process Flow Schematic



Appendix B

BioWin Flow Schematic



Appendix C
Projected Upgrades

Item Description	Projected Date of Required Upgrade		
	< 2 Years	2 to 5 Years	6 to 10 Years
Septage/Leachate Receiving			
Upgrade mixing			✓
Upgrade odor control system			✓
Replace automatic control valves		✓	
Headworks			
Replace grit pumps		✓	
Replace grit cyclone and conveyor		✓	
Heating/ventilation upgrades		✓	
Primary Clarifiers			
Concrete tank repairs		✓	
Replace gates		✓	
Add handrails		✓	
Add heat trace to rails	✓		
Replace weirs		✓	
Rehab travelling bridges		✓	
Replace interior components		✓	
Replace primary sludge pumps			✓
Lift Station			
Replace pump control panel		✓	
Aeration Tanks			
Replace gates		✓	
Improve air distribution to each tank		✓	
Upgrade air lines			✓
Replace aeration blowers		✓	
Secondary Clarifiers			
Replace gates		✓	
Replace drive assembly		✓	
Replace weirs		✓	
Refurbish interior superstructure		✓	
Replace RAS pumps and upgrade controls		✓	
Replace WAS pump		✓	
Disinfection System			
Repair inlet gates	✓		
Replace outlet gates	✓		

Appendix D

Projected Upgrade Construction Costs

Estimated Construction Costs

Item Description	**Estimated Cost (ENR 9700)**
Septage/Leachate Receiving	$135,000
Headworks	$450,000
Primary Clarifiers	$900,000
Lift Station	$260,000
Aeration Tanks	$550,000
Secondary Clarifiers	$510,000
Disinfection System	$0
Sludge Thickening/Dewatering	$525,000
Anaerobic Digestion	$400,000
Subtotal	$3,730,000
15% Contingency	$560,000
Total	$4,290,000
Use	$4,300,0000

Notes:

1. ENR 9700 = December 2013

Appendix E

Capstone Design

The Accreditation Board for Engineering and Technology (ABET) requires that all accredited engineering programs include a capstone design experience. At Worcester Polytechnic Institute (WPI), this requirement is met through the Major Qualifying Project (MQP). The American Society of Civil Engineers (ASCE) specifies that this capstone experience must include the following considerations: economic, environmental, sustainability, constructability, ethical, health and safety, social, and political. The following is a description of how our project intends to incorporate these considerations.

Economic

To assist in the decision making process for phosphorus reduction modifications in an activated sludge wastewater treatment plant, a cost estimate of each alternative will be prepared. The estimate will include material, equipment, and labor costs associated with each design. The cost estimate will ultimately be a factor during the design alternative decision process.

Environmental

The goal of the project is to reduce phosphorus discharge levels to comply with the Environmental Protection Agency's (EPA) revised Total Maximum Daily Limit (TMDL), with the intent of making the effluent safer for the environment.

Sustainability

Through recommending state-of-the-art energy efficient design alternatives, the design goal for the WWTP will be to increase the lifespan of the wastewater treatment plant while lifecycle costs of the treatment plant will be reduced.

Constructability

An important aspect while the design alternatives are being developed will be the constructability of each one, respectively. Site issues and limitations will be considered when design alternatives are considered.

Ethical

The project is sponsored by Stantec and regards wastewater treatment plants discharging into Lake Champlain. No aquatic animals intend to be harmed or negatively affected by this project. There will be no conflict of interest presented by the project. This project will uphold the Fundamental Principles and Fundamental Canons set forth in the ASCE Code of Ethics.

Health & Safety

While the contractor is responsible for much of the safety responsibility throughout the construction process, safety risks associated with the nature of the design of the alternatives can be abated before the project reaches construction.

Social

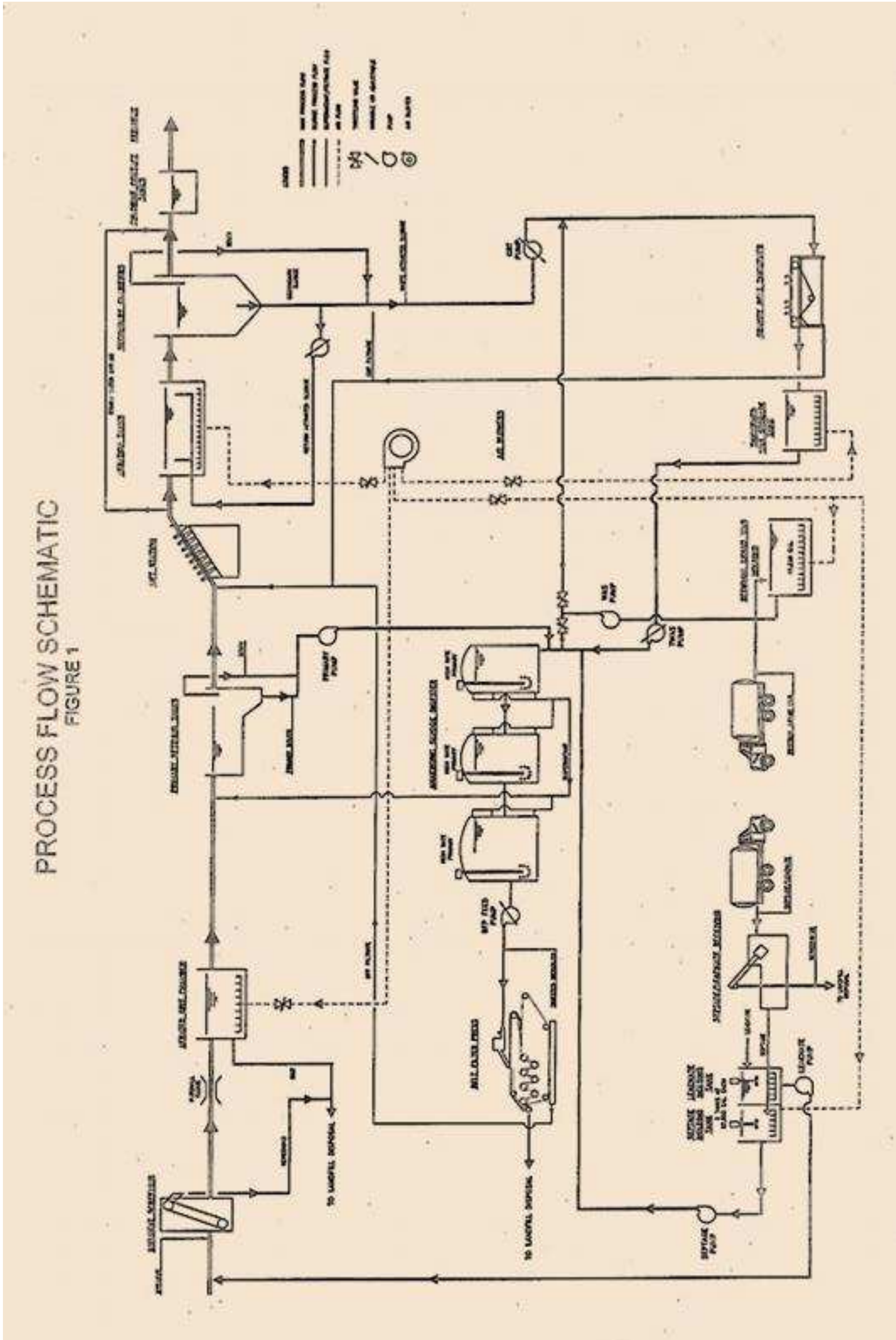
Noise and odor are two common complaints from residents living in the vicinity of WWTPs. When considering design alternatives, noise and odor should be evaluated to determine if they will have an impact on the surrounding community.

Political

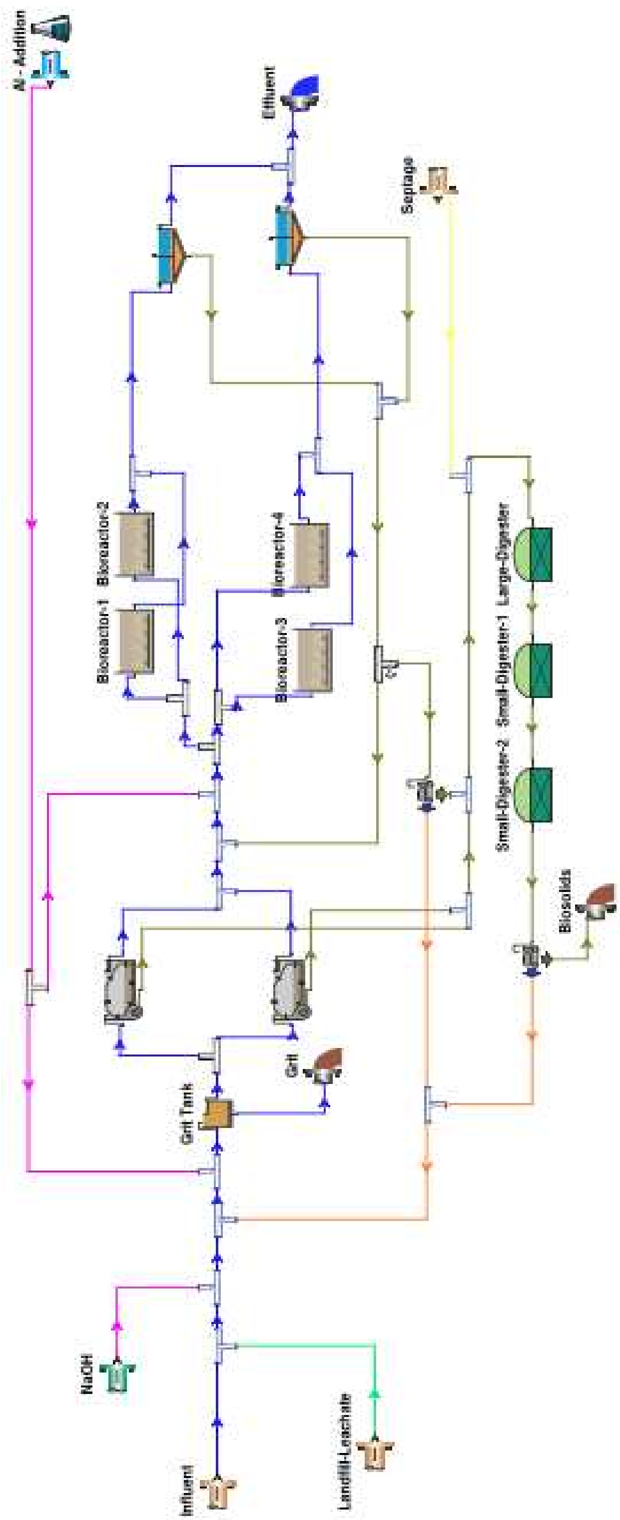
The project is designed to meet the revised EPA TMDL for point and non-point phosphorus discharges and be compliant with all applicable federal laws.

Appendix B: Montpelier Treatment Facility Documents

Process Flow Schematic



BioWin Flow Schematic



Appendix C: Projected Upgrades & Costs

Projected Treatment Facility Upgrades

Item Description	Projected Date of Required Upgrade		
	< 2 Years	2 to 5 Years	6 to 10 Years
Septage/Leachate Receiving			
Upgrade mixing			✓
Upgrade odor control system			✓
Replace automatic control valves		✓	
Headworks			
Replace grit pumps		✓	
Replace grit cyclone and conveyor		✓	
Heating/ventilation upgrades		✓	
Primary Clarifiers			
Concrete tank repairs		✓	
Replace gates		✓	
Add handrails		✓	
Add heat trace to rails	✓		
Replace weirs		✓	
Rehab travelling bridges		✓	
Replace interior components		✓	
Replace primary sludge pumps			✓
Lift Station			
Replace pump control panel		✓	
Aeration Tanks			
Replace gates		✓	
Improve air distribution to each tank		✓	
Upgrade air lines			✓
Replace aeration blowers		✓	
Secondary Clarifiers			
Replace gates		✓	
Replace drive assembly		✓	
Replace weirs		✓	
Refurbish interior superstructure		✓	
Replace RAS pumps and upgrade controls		✓	
Replace WAS pump		✓	
Disinfection System			
Repair inlet gates	✓		
Replace outlet gates	✓		

Projected Upgrade Construction Costs

Estimated Construction Costs

Item Description	Estimated Cost (ENR 9700)
Septage/Leachate Receiving	$135,000
Headworks	$450,000
Primary Clarifiers	$900,000
Lift Station	$260,000
Aeration Tanks	$550,000
Secondary Clarifiers	$510,000
Disinfection System	$0
Sludge Thickening/Dewatering	$525,000
Anaerobic Digestion	$400,000
Subtotal	$3,730,000
15% Contingency	$560,000
Total	$4,290,000
Use	$4,300,0000

Notes:

1. ENR 9700 = December 2013

Appendix D: Calculations

Ferric Chloride Dosing

Ferric Chloride and Phosphorous Reaction

$$FeCl_3 + PO_4^{3-} \xrightarrow{yields} FePO_4 \downarrow + 3Cl^- \quad \text{(Equation 1)}$$

$Mole\ ratio\ 1:1$

Destruction of Alkalinity

$$FeCl_3 + 3HCO_3^- \xrightarrow{yields} Fe(OH)_3 + 3CO_2 + 3Cl^- \quad \text{(Equation 2)}$$

Dosing

For effluent concentration of less than 0.5 mg/L, assume mole ratio of 6:1 $FeCl_3\ to\ PO_4^{3-}$.

Takes 5.2 grams ferric to remove 1 gram Phosphorous

$FeCl_3$

$Molecular\ Weight: 162.3\ g/mol$

$40\%\ by\ weight\ FeCl_3\ in\ solution$

$Weight\ per\ gallon: 11.2\ lb/gal$

$FeCl_3\ per\ gallon: 4.48\ lb/gal$

Theoretical Dosage → $1\ mol\ FeCl_3\ per\ mol\ P\ or\ 5.25\ lb\ FeCl_3\ per\ lb\ P$

$$\frac{1\ mol\ FeCl_3}{1\ mol\ P} * \frac{162.3\ g}{1\ mol\ FeCl_3} * \frac{1\ lb}{453.592\ g} * \frac{1\ mol\ P}{30.9\ g} * \frac{435.592\ g}{1\ lb} =$$

$$= \frac{162.3\ g\ FeCl_3}{30.9\ g\ P} = 5.25\ lb\ FeCl_3 / 1\ lb\ P$$

Assuming mole ration of 6:1, the dosage of 40% ferric chloride solution per lb P is:

$$\frac{5.25\ lb\ FeCl_3 / 1\ lb\ P}{1\ mol\ FeCl_3 / 1\ mol\ P} * \frac{1\ gal\ FeCl_3\ solution}{4.48\ lb\ FeCl_3} * \frac{6\ mol\ FeCl_3}{1\ mol\ P} = 7.03\ gal\ FeCl_3\ solution / lb\ P$$

If WWTF influent Total P concentration is:

$0.4\ mg/L\ then\ the\ dosage\ of\ FeCl_3\ per\ MG\ (million\ gallons)\ of\ flow\ is:$

$$\left(0.4\frac{mg}{L}\right)(8.34)(1\ MG)\left(\frac{7.03\ gal\ FeCl_3}{lb\ P}\right) = 23.45\ gal\ FeCl_3\ solution/_{MG}$$

$1.0 mg/L$ *then the dosage of* $FeCl_3$ *per* MG *(million gallons) of flow is*:

$$\left(0.1\frac{mg}{L}\right)(8.34)(1\ MG)\left(\frac{7.03\ gal\ FeCl_3}{lb\ P}\right) = 58.63\ gal\ FeCl_3\ solution/_{MG}$$

Ferric Chloride Storage Requirements

Assuming:

$Influent\ Total\ P = 0.4\ mg/L$

$Average\ day\ WWTF\ flow = 1.88$ MGD

$Peak\ day\ WWTF\ flow = 3.97$ MGD

Storage required for 30 day storage at average day usage:

$$\left(23.45\ gal\ FeCl_3\ solution/_{MG}\right)(1.88\ MGD)(30\ days) = 1{,}322.58\ gallons\ or\ {\sim}1{,}325\ gallons$$

Storage required for 3 day storage at peak day usage:

$$\left(23.45\ gal\ FeCl_3\ solution/_{MG}\right)(3.97\ MGD)(3\ days) = 279.28\ gallons\ or\ {\sim}280\ gallons$$

Theoretical Rapid Mix Design of CoMag©

$$RT = \frac{basin\ volume}{influent\ flow\ rate} \qquad \text{(Equation 3)}$$

$Basin\ Volume: 512\ ft^2 = 13.8\ m^3 = 3646\ gallons$

$Dimensions: 8'\ X\ 8'\ X\ 8' = 2.4\ X\ 2.4\ X\ 2.4\ m$

$Influent\ Flow\ rate =$

Power required to maintain turbulent conditions:

$$P = \frac{\rho K_T n^3 D_a{}^5}{g} \qquad \text{(Equation 4)}$$

$P = power\ requirement, {}^{ft-lb}/_{sec}$

$\rho = mass\ density\ of\ the\ fluid, {}^{lb}/_{ft^3}$

$n = impeller\ revolutions\ per\ second, rps$

$D_a = diamter\ of\ impeller, ft$

$g = acceleration\ due\ to\ gravity, 32.2\ {}^{ft}/_{sec^2}$

$K_T = constant$

*K_T values are from table 4-7 Phosphorous Removal Design Manual by the EPA.

$P =?\ {}^{ft-lb}/_{sec}$

$\rho = 62.4\ {}^{lb}/_{ft^3}$

$n = 600\ rpm\ (10\ rps)$

$D_a = 1\ ft$

$g = 32.2\ {}^{ft}/_{sec^2}$

$K_T = 1.00$

$$P = {}^{(62.4)(1)(10)^3(1)^5}/_{32.2} = 1940\ {}^{ft-lb}/_{sec} = {}^{1940}/_{550} = 3.5\ hp \sim 4.0\ hp$$

Appendix E: CoMag© Proposal from Evoqua

MONTPELIER, VT WWTP COMAG™ CONCEPTUAL PROPOSAL

STANTEC

February 2015

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EVOQUA COMAG™ SYSTEM SUMMARY

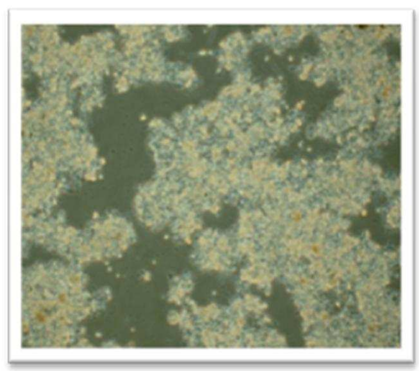
1 BASIS OF PROPOSAL

This budgetary proposal provided by Evoqua is based on the design information provided to date. Many factors, which may as yet be unknown, can affect the actual equipment and operating requirements of a fully installed and fully operational system. These factors include, but are not limited to, materials of construction, level of operational automation, degree of redundancy, spare parts, scope of equipment and services.

Reviewers of this proposal should clearly understand the CoMag system described in this proposal is preliminary and should not be deemed definitive or to obligate Evoqua. Instead this proposal should serve as a guideline for the decision makers in their evaluation of the relative value of CoMag compared to other solids removal treatment solutions.

2 COMAG PROCESS OVERVIEW

The CoMag Treatment System is an innovative and proven technology for the removal of solids, heavy metals and other particulate or precipitated contaminants. CoMag is capable of achieving solids removal levels that approach, and in many cases equal, the removal performance of ultra filtration membranes. The CoMag process, as shown in Figure 1 below, is based on conventional coagulation and flocculation, but uses an innovative ballast material which differentiates the process from other technologies. The ballast material is magnetite (Fe_3O_4), which is a fully inert, high specific gravity (5.2), finely ground, non-abrasive, iron ore.


Flocs with no ballast settle slowly


Ballasted flocs settle rapidly and reliably

Through simple mixing, the magnetite is infused into the metal hydroxide floc, thereby significantly increasing the specific gravity of the floc. When the magnetite infused flocs are introduced to the CoMag clarifier, the flocs settle 20 to 60 times faster than conventional flocs or those infused with micro-sand. Rapid settling enables CoMag systems to employ much smaller and less expensive clarifiers.

Unlike other ballasted clarification systems, CoMag recycles settled solids from the clarifier back to the reaction tanks to increase nucleation sites, enhance precipitation kinetics and promote sweep floc. The result is superior solids removal and more efficient chemical use.

The magnetite ballast is recovered from the waste sludge magnetically with almost no energy consumption and returned to the treatment system with very little magnetite loss, thereby keeping operating costs low.

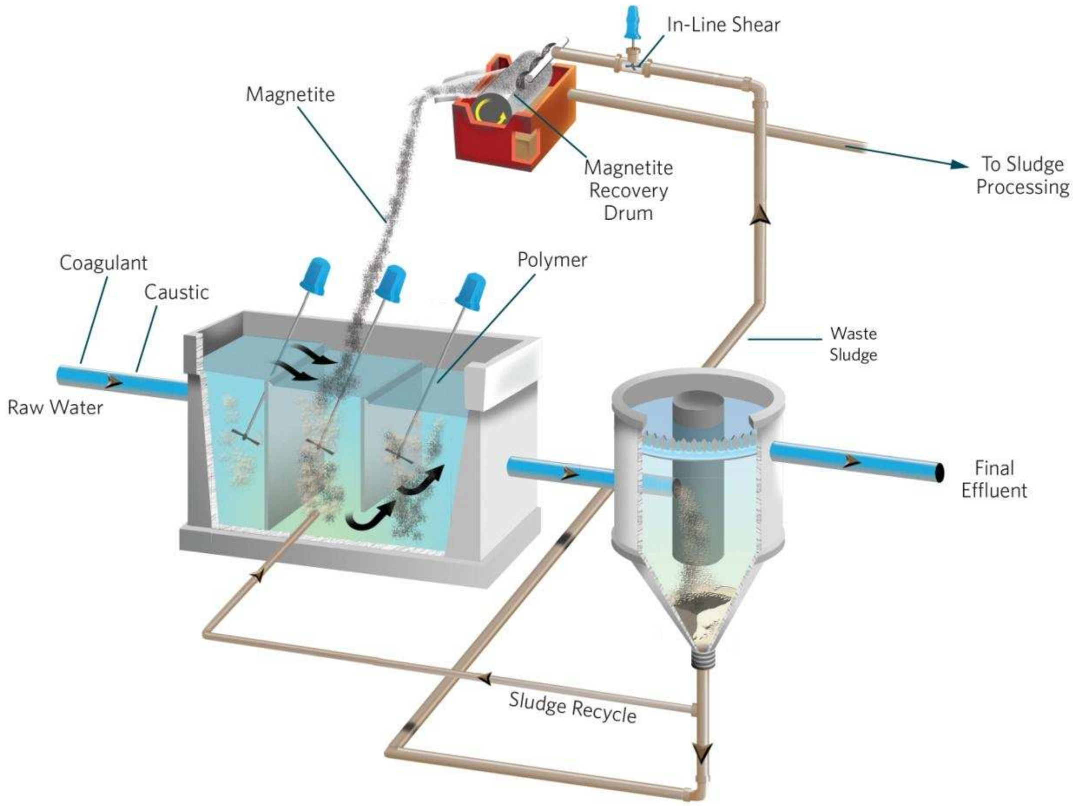


Figure 1: CoMag Treatment Process

2.1 Detailed Description

Depending on the plant's hydraulic profile, influent to the CoMag system can either be pumped or flowed by gravity. An influent flow meter is used upstream of the CoMag system to monitor incoming flow and to control the dose of coagulant being metered into the system. The CoMag system is capable of operating with commonly used coagulants including aluminum sulfate, ferric chloride, or PAC. The proposed method for coagulant addition is an in-line static mixer.

Coagulation and flocculation occur in the CoMag system reaction tanks. Unlike conventional coagulation and flocculation with other ballasted systems the use of magnetite in the CoMag™ process allows for relatively short reaction times (HRT) because the process does not require development of large flocs for settling. Each CoMag reaction tank is equipped with a VFD controlled mixer to allow for optimal mixing conditions.

Magnetite serves two major functions:

1. With its high specific gravity (SG) of 5.2 (in contrast micro-sands have SG of 2.7), magnetite increases the weight of the metal hydroxide floc (unballasted chemical floc has SG of just over 1.0) and significantly increases its settling velocity;

2. Magnetite is attracted to a magnet which enables it to be recovered using a simple magnetic drum and recycled back to the reaction tanks.

After coagulation and the infusion of magnetite, polymer is added to consolidate the floc just prior to settling in the clarifier. CoMag works well in multiple clarifier configurations including cone, circular and rectangular designs.

Settled sludge from the clarifier flows to the recycle and waste sludge pump systems. A large and variable portion of the solids underflow is conveyed back to the reaction tanks by a recycle sludge pump. These recycled solids greatly improve the flocculation process by increasing the mass of solids in contact with the precipitate.

The remainder of the settled sludge is pumped through a sludge shear system which breaks up the floc particles and creates a mixture in which the ballast particles are no longer physically attached to the floc. This slurry flows over a magnetic drum separator that magnetically captures the ballast and returns it to the process. The metal hydroxide and precipitated sludge flows to the sludge system for further processing and disposal.

The CoMag™ system is designed for automated operation. A PLC, located inside the control panel, manages the CoMag™ treatment system under normal operations. Various field instruments provide the raw data needed for process control. The PLC continuously monitors the instrument signals and, based on the programmed control logic and set points, adjusts the chemical feed rates, turns the pumps on and off, and makes other process changes.

3 COMAG™ COMPARATIVE BENEFITS AND ADVANTAGES

The benefits and advantages of CoMag over competitive technologies are multiple:

- ✓ **Low capital/installation costs**: CoMag's high-rate, ballasted clarification technology enables the use of small foot print, solids reaction and clarification tanks that have relatively low fabrication and construction costs. Also as stated above, the advantage of CoMag in terms of capital costs comes from the elimination of post media filtration.

- ✓ **Low operating costs:** CoMag employs the same coagulation and flocculation processes as most other chemical treatment systems: chemical and power consumption are also about the same. CoMag's advantage comes from ease of operation, no lamellas to clean, no media to plug or foul, and no abrasion to increase maintenance costs.

- ✓ **Non-abrasive ballast:** CoMag's ballast is less abrasive than micro-sand and hence, reduces wear and tear on mixers, pumps, and other treatment components. In 4+ years of operation at our seminal plant in Concord, Mass., operators have seen no wear on the equipment including the impellers of the plant's sludge pumps.

- ✓ **Reliable components:** CoMag components and fundamental processes have been proven in over 40 years of industrial operation; they can readily be purchased on the open market. CoMag advantage is its simplicity; it is not a "Black Box" technology.

- ✓ **Flexible and robust operation:** With its internal solids recycle increasing nucleation sites, enhancing precipitation kinetics and promoting sweep floc, CoMag's treatment efficiency actually improves when an upset in the up-stream systems discharges excess solids. Hence, the system can process wide ranges of flows and loads with almost no effect on contaminant removal performance or operational stability.

- ✓ **Flexibility of coagulant type:** CoMag produces high quality effluent with alum, ferric chloride, ferric sulfate or polyaluminum chloride (PAC). A facility is thereby free to determine which coagulant makes the most sense for its needs without concern for performance loss.

In summary, CoMag offers a simple, reliable, and highly effective process that easily handles highly variable flows and solids loads.

4 DESIGN SUMMARY

Table 1 summarizes the design basis for the proposed CoMag system.

Table 1: Design Basis

Parameter	Units	Design
Design Average Daily Flow	MGD	1.88
Design Peak Hourly Flow	MGD	3.97
Design Average Daily Influent Total Phosphorus	mg/L	0.4
Average Monthly Effluent Total Phosphorus	mg/L	0.1

Table 2 summarizes the preliminary process parameters for the proposed CoMag system.

Table 2: Preliminary Process Parameters

Parameter	Design
Number of Treatment Trains	1
Coagulation Reaction Tanks	2 Tanks 8′ × 8′ × 8′ SWD
Ballast Reaction Tank	8′ × 8′ × 8′ SWD
Polymer Reaction Tank	8′ × 8′ × 8′ SWD
Tertiary Clarifiers	2 Clarifiers 20′ diameter × 10′ SWD

5 SCOPE OF SUPPLY

5.1 Evoqua Scope of Supply

In evaluating the relative value of CoMag to other systems we encourage the decision-makers to assess the fully installed and fully operational economics of CoMag and its competitors. We often find at this stage of the evaluation, costs can vary greatly depending upon the scope of supply proposed by competing vendors; and price advantages at this stage can often be reversed when required components of a competitive solution are placed outside an equipment vendors' scope of supply.

Item	Quantity
Influent pH sensor and controller	1
Reaction tank mixers – *top mount*	4
Reaction tank level switch	1
Tertiary clarifier internals	2
Sludge blanket level sensor	2
Effluent turbidimeter	1
Sludge pump (Return sludge / waste sludge)	1 Duty, 1 Standby

Item	Quantity
Recycle sludge flow meter	1
RAS flow control valve	1
Waste sludge flow meter	1
WAS flow control valve	1
Sludge shear mixer	1
Magnetic recovery drum separator	1
Magnetic recovery drum level switch	1
Magnetic recovery drum proximity switch	1
Magnetite concentration meter	1
PLC control panel	1

5.2 Items Provided by Others

Item
Influent feed flow meter
Inline Static Mixer
Coagulation reaction tanks
Ballast reaction tank
Polymer reaction tank
Tertiary clarifier tanks
Power Panel including Motor Starters and VFDs.
Coagulant feed system
Caustic feed system
Polymer feed system
Compliance permitting and approval (Federal, State and/or local)

Item
Detail shop fabrication drawings
Electrical, hydraulic, or pneumatic controls unless specifically noted
Engineering and supervision of all equipment and labor for civil works
Laboratory, shop, or field testing other than supervision of start-up testing
Taxes, bonds, fees, permits, lien waivers, licenses, etc.
Tools or spare parts
Unloading of equipment and protected storage of equipment at jobsite
Utilities connections
Adhesives, adhesive dispensers, grout, mastic & anti-seize compounds
Anchor bolts and/or expansion anchors unless otherwise noted
Base slabs, equipment mounting pads, or shims
Concrete work of any sort, grout, mastic, sealing compounds, shims
Demolition, removal, or transfer of anything that is existing
Engineering, permitting, and surveying
Equipment lifting hoists, cranes, or other lifting devices
Field surface preparation and/or painting
Floor grating, stairways, ladders, platforms, handrailing unless noted
Installation of equipment
Interconnecting materials external to enclosures such as cable, pressure taps, tubing, etc.
Labor for field testing
Lubricants, grease piping, grease guns
Modifications to existing equipment or structures
Pipe supports and hangers for piping
Piping, pumps, valves, wall sleeves, gates, drains, weirs, baffles not mentioned
Plumbing associated with waste disposal, floor drains, and/or emergency and safety wash stations
PVC solvent weld materials

Item
Conduit or wiring in the field
Cable trays, fittings, and supports
Power to Evoqua supplied equipment
Supply and installation of building power, lighting, main service disconnects and control panels
Supply, installation and control of a remote telemetry system (SCADA) to monitor and control the operation of the system and overall plant operation other than CoMag Control System
Underwriters Laboratory inspection of electrical controls

6 OPERATION AND MAINTENANCE REQUIREMENTS

The estimated operation and maintenance requirements listed below are based on past experience at other CoMag installations. Project specific O&M requirements will be defined after completion of jar testing and/or a comprehensive pilot testing program. The quantities listed herein are estimates and do not represent a warranty or guarantee. The actual requirements might differ due to differences in the influent wastewater characteristics and the manner by which the system is operated.

6.1 Electrical Loads

Table 3 lists the motor horsepower for equipment supplied by Evoqua. The pump motors are based on typical hydraulics and are subject to approval of the layout. Motors greater than 0.5 HP are 460-volt, 3-phase, 60 Hz, high efficiency and inverter duty unless noted otherwise. Motors less than or equal to 0.5 HP are 120-volt, 1-phase, 60 Hz, unless noted otherwise.

The total connected power equals the number of motors multiplied by the nameplate motor power. The estimated operating power (which is less than the nameplate) in kilowatt-hours is calculated for average design flows (ADF), the number of motors in use at ADF, and the design operating period. It does not include small electrical loads associated with electrically actuated valves and similar demands.

Table 3: CoMag Electrical Loads

Load	Qty	Motor HP	Connected HP	Qty at ADF	Operating HP at ADF
Mixer – Coagulation reaction tank	2	2.0	4.0	2	3.0
Mixer – Ballast reaction tank	1	2.0	2.0	1	1.5
Mixer – Polymer reaction tank	1	2.0	2.0	1	1.5
Clarifier drive[1]	2	1.0	1.0	1	0.75
Sludge shear mixer	1	1.0	1.0	1	0.75
Magnetic drum separator	1	1.0	1.0	1	0.75
Sludge pump	2	5	10	1	3.75
Total Loads					12.0

6.2 Chemical Use

Table 4 lists the estimated chemical doses to achieve the treatment goals listed in the design basis. The concentrations of coagulant are based on typical performance seen at other facilities. Different coagulants are listed; only one would be used.

The ballast use assumes operation of the ballast recovery equipment. A small amount of ballast is lost in the waste sludge. The make-up ballast can be manually added once daily. The table lists the typical amount.

Table 4: Chemical Doses and Consumption

Chemical	Dose
Coagulant	
Ferric Chloride (40%)	8 - 16 mg/L as Fe
Alum (48.5%)	4 - 8 mg/L as Al

[1] Clarifier drive HP may change based on clarifier design chosen.

Ballast	Make-up 10 lbs per MG
Polymer dry	0.5 - 1.0 mg/L
Caustic (pH adjustment)[2]	Varies

6.3 Sludge

The amount of sludge produced by the CoMag system will depend on the influent solids, coagulant type and dose, the flow, and operating conditions. Table 5 lists the estimated sludge production for each of the coagulant doses listed in Table 4. Metal hydroxide solids typically have some water of hydration attached. The total sludge production will be the sum of the metal hydroxide solids and the influent suspended solids (TSS).

Under normal operating conditions, the total solids concentration of the waste sludge will range from 0.2% to 1.0%, with 0.5% being typical.

Table 5: Sludge Production

Coagulant	Sludge Production
Ferric chloride (40%)	2.3 lb/lb $FeCl_3$
Alum (48.5%)	3.2 lb/lb Alum

[2] Caustic dose depends on the alkalinity in the influent wastewater, the treatment goals, and the operating pH. It varies significantly, with some plants needing little or none and other plants needing more.

7 SUPPORT SERVICES

Evoqua will provide the following services:

Installation and Pre-Commissioning: Services of a representative to visit the site for up to 4 days to assist the contractor during installation. Additionally, Evoqua will provide the services of a representative for up to 5 days verify the installation of CoMag™ system and ancillary systems prior to startup and to check that the installation complies with design requirements; adjust and test equipment.

Pre-Commissioning: **Checkout, Startup and Testing**: Evoqua will provide the services of a representative for up to 10 days for startup of the CoMag™ system following successful completion of the pre-commissioning inspection. During startup and testing Evoqua shall tune the treatment process so that it operates in accordance with the design requirements.

Training: Evoqua will provide a qualified trainer to conduct a training course for operating staff. The training period, of up to a total of 16 hours of normal working time, shall start after the system is functionally and installation is completed. The field instructions shall cover all of the items contained in the operating and maintenance instructions, as well as demonstrations of routine maintenance operations.

Technical and Operational Support: Evoqua shall provide for 5 days of supports services to review and evaluate the performance of the CoMag System.

8 BUDGETARY PRICING

Appendices

A. Frequently Asked CoMag Questions

B. Typical Drawings

APPENDIX A – FREQUENTLY ASKED QUESTIONS

1. GENERAL QUESTIONS ABOUT MAGNETITE, THE FUNDAMENTAL ELEMENT USED IN COMAG TO INCREASE SETTLING RATES AND RELIABILITY.

Q. What is magnetite?

A. Magnetite is fully oxidized iron ore (Fe_3O_4). It is completely inert; it cannot rust; it doesn't degrade with time or usage; it has no effect on biological floc; and it is not magnetic itself; i.e., it doesn't stick to metal. If you have ever played with an "Etch-a-Sketch," the material inside the toy is magnetite.

Q. How does magnetite improve the performance of clarifiers and biological treatment systems?

A. Magnetite is a very dense material with a specific gravity of 5.2. By comparison the specific gravity of water is 1.0; a chemical hydroxide floc is fractionally over 1.0; and a biological floc is ≈1.25. By infusing magnetite into either a chemical or biological floc, the specific gravity is increased by 50 to 100%; thereby significantly increasing the settling rate of the floc and gaining consistent control of the sludge blanket in the clarifier and greater stability for the whole system.

Q. Is magnetite readily available?

A. Yes, magnetite is mined and processed at multiple sites around the world. In the USA, Evoqua has identified multiple vendors that will provide magnetite to our specifications.

Q. What is the cost of magnetite?

A. Magnetite is very inexpensive, ranging from $0.20 to $0.50 per pound delivered, depending on the location of the distributor and the facility. Moreover, since the recovery rates of magnetite in CoMag systems are so high, daily consumption is very low; so much so that in assessing the operating cost of a CoMag system, the ongoing cost of magnetite is of no consequence.

Q. Is the magnetite abrasive? Does magnetite cause excessive wear to pumps?

A. Unlike micro-sand, a ballast used by our competitors, Evoqua specified magnetite is so fine that it has the consistency of talcum powder. Hence, it is not abrasive and doesn't cause abnormal wear and tear on a treatment systems pumps, mixers, valves and other components. At the seminal CoMag plant in Concord, MA there has been no discernable wear on the plants sludge pumps or mixers after 5.0 years of operation.

Q. Does magnetite degrade at high temperatures (or low temperatures) or with changes in pH?

A. *Magnetite does not undergo any physical or chemical change in the temperature and pH ranges associated with almost all municipal and industrial wastewater treatment.*

Q. Does magnetite affect pH or the chemical characteristics of the effluent?

A. *No, magnetite is completely inert; has no effect on pH or the chemical characteristics of a system's effluent.*

Q. Does magnetite affect the oxygen content of wastewater?

A. *Since magnetite (Fe_3O_4) is fully oxidized, it does not consume dissolved oxygen in the wastewater.*

Q. How much magnetite is recovered on the magnetic drum and where does the remainder go?

A. *Evoqua has modified the design of conventional magnetic drums to optimize the capture and reuse of magnetite. In CoMag systems, the drums recover in excess of 99.8% of the magnetite in the sludge. Any magnetite not captured by the drum is carried away in the sludge where we have found no effect on downstream sludge management systems or processing.*

Q. What is the impact of magnetite on the effluent; TSS, turbidity, etc.

A. *Less than a half a percent of the magnetite used in CoMag escapes the system; hence, the direct effect on the effluent quality of either system is negligible. It is however, the use of magnetite in Evoqua's CoMag systems that enables both systems to achieve such high levels of contaminant removal. For example, the effluent turbidity from the Concord CoMag system can be easily reduced to levels less than that of bottled drinking water.*

Q. How does magnetite in the effluent effect the performance of a downstream UV disinfection system?

A. *Since very little of the magnetite escapes the system, the direct effect is not discernable. In fact, CoMag as a tertiary polishing system is a UV enabler. The fact that CoMag can perform well with alum coagulants and achieve very high levels of transmissivity, makes it possible to employ less UV treatment (and power)to achieve required levels of pathogen removal. Concord uses only 50% of one of its three banks of UV to meet its permit levels.*

2. QUESTIONS OFTEN ASKED ABOUT THE COMAG PROCESS AND PERFORMANCE:

Q. How does CoMag handle high flows and surges?

A. *CoMag uses automated controls to rapidly respond to flow variations. CoMag is also particularly effective in maintaining high removal levels during surges in solids loading. Unlike other ballasted sedimentation systems, the CoMag process recycles a significant fraction of settled solids from its clarifier back to its reaction tanks. The high mass and density of solids in the* *reaction tanks is many times greater than that of any surge in influent loading. The system is fully capable of managing surges in load with little degradation of performance. The result is superior solids removal, especially compared to those processes that don't incorporate an internal solids recycle.*

Q. Can CoMag equipment be serviced over the 20-year design period?

A. All the components of the CoMag process are readily available in the marketplace. The system employs standard pumps, mixers, piping, valves, clarifier systems, and instruments. The magnetic components have been used in the mining industry since the early 1970s. Spare parts are readily available from multiple sources.

Q. What is the cost to install CoMag including the cost of structures, equipment, connecting piping, peripheral support systems, associated power and instrumentation, etc?

A. The installation costs are low for a CoMag system because of its simplicity, small footprint, and readily available parts. In addition and unlike alternative solutions, CoMag may not need expensive post treatment filters to achieve the required treatment levels of current and expected future permits.

Q. What are the costs of chemicals, additives, power, equipment, and labor associated with the CoMag process.

A. Generally, the operational costs of CoMag are quite low.

Chemical consumption is likely to be less than competitive systems due to the ability of CoMag to achieve required treatment levels with less coagulant and flocculent.

The process provides for a nearly complete recovery and reuse of the magnetic ballast hence the cost is low.

Energy consumption is very low given the gravity flow of the system and the minimum required head. The ballast recovery drum employs permanent magnets and hence consumes no energy other than that required to turn the drum.

The system is fully automated; the need for operator attention is minimal.

The system does not use tube settlers, which require regular cleaning.

Q. Are there major parts that will require replacement?

A. There are no major parts that will require replacement other than the perhaps the pumps and sludge shear mixer, which are expected to have a useful life of 10 years or more. Their replacement is a simple process as they are easily accessible and readily available. None of the parts are hazardous or would require special disposal.

Q. Does CoMag enable the use of alternative chemicals with the same performance?

A. Yes. CoMag will produce nearly the same contaminant removal levels with alum, ferric chloride, or poly-aluminum chloride (PAC), and other conventional coagulants. The size of the CoMag system is the same for any coagulant, unlike other competitive systems. This gives the flexibility to meet limits with a coagulant chemical that best suits it's a plants needs.

Q. Are CoMag and its operation easily understood and operated?

A. Yes, CoMag is very operator friendly. The system readily responds to changing influent flows and loads, easily handling excess solids from the secondary clarifiers. It has few parts needing replacement and no inclined tubes that require regular cleaning to keep them from clogging. CoMag requires no sand filters, which can clog and must be backwashed.

Q. Can the process operate 24 hours with only being manned 8 hours a day?

A. Yes. The CoMag system has fully automated PLC controls.

Q. Are the process and its operation safe for operations and/or maintenance personnel?

A. Yes. CoMag equipment complies with industry standards for safety. It uses chemicals that can be safely handled without additional or specialized training.

Q. Does the process have operational flexibility such as taking some units out of service on a seasonal basis to save on operational costs?

A. Yes. CoMag provides a high level of redundancy and the ability to modify operations to meet effluent requirements

The process design provided by Evoqua is redundant. The design of the CoMag system will hydraulically pass peak flows and meet the treatment requirements.

Inherent in the operation of CoMag is the ability to manage dosage levels to meet effluent contaminant requirements.

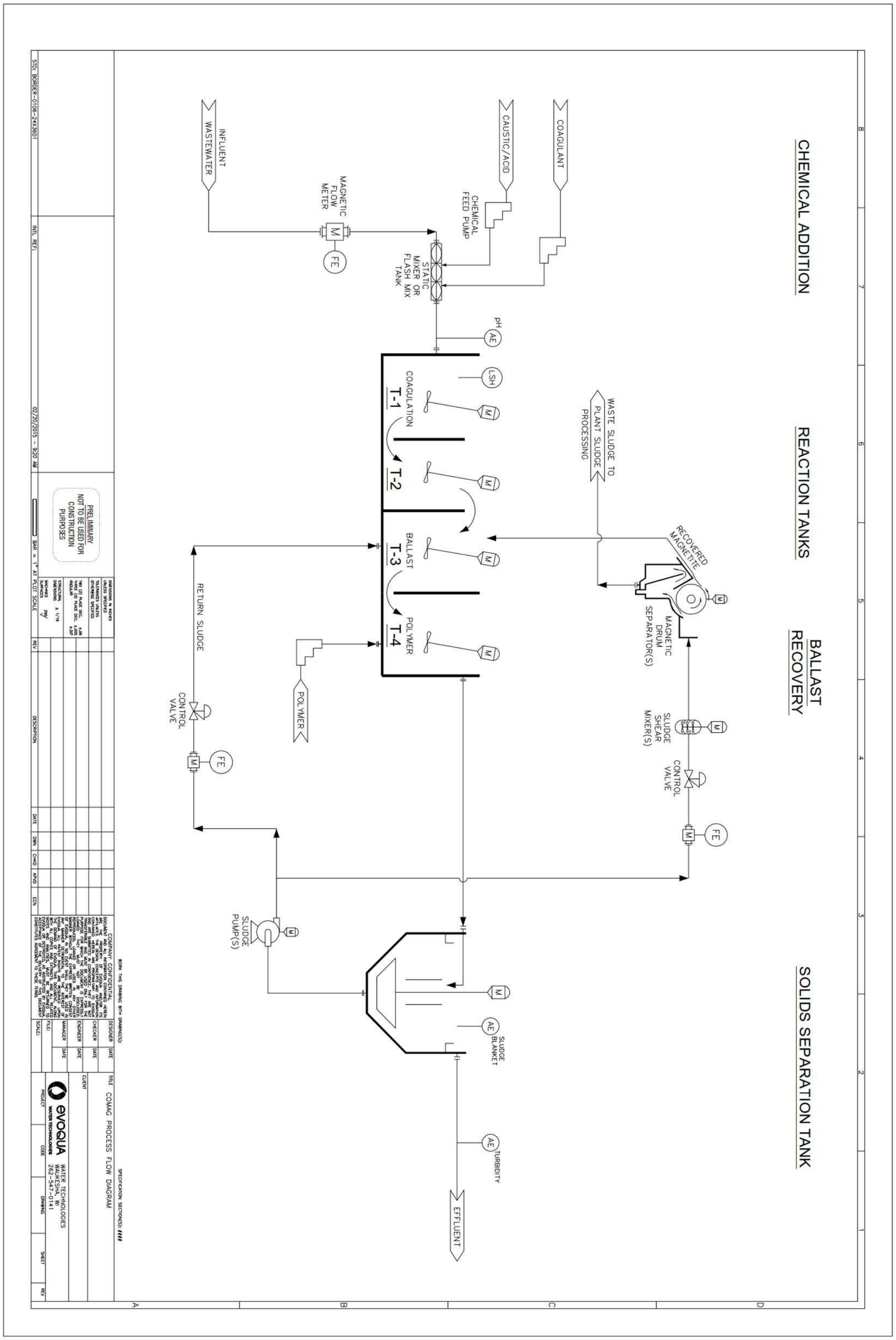
Q. Could the process have a negative effect on downstream unit operations, if needed for higher effluent quality in the future?

A. Implementation of CoMag will eliminate the need for downstream filters, thus eliminating the associated capital and O&M costs.

Q. Does the ballast rust or stick to steel pipe?

A. No, the ballast is a type of iron ore that is fully oxidized and does not rust. It is attracted to magnets, but it does not attach itself to steel pipe.

APPENDIX B – TYPICAL DRAWINGS



Appendix F: Montpelier WWTF Documents

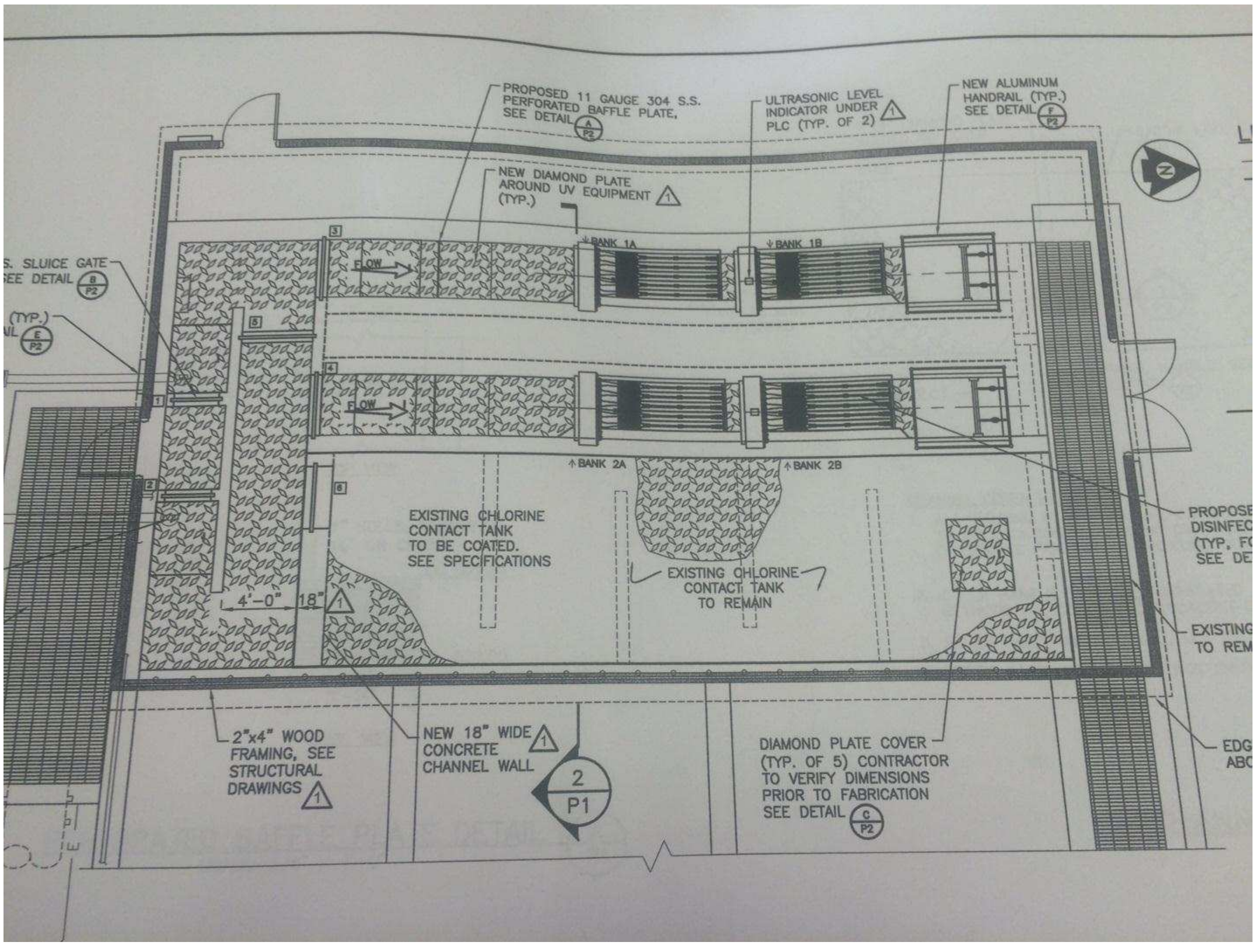
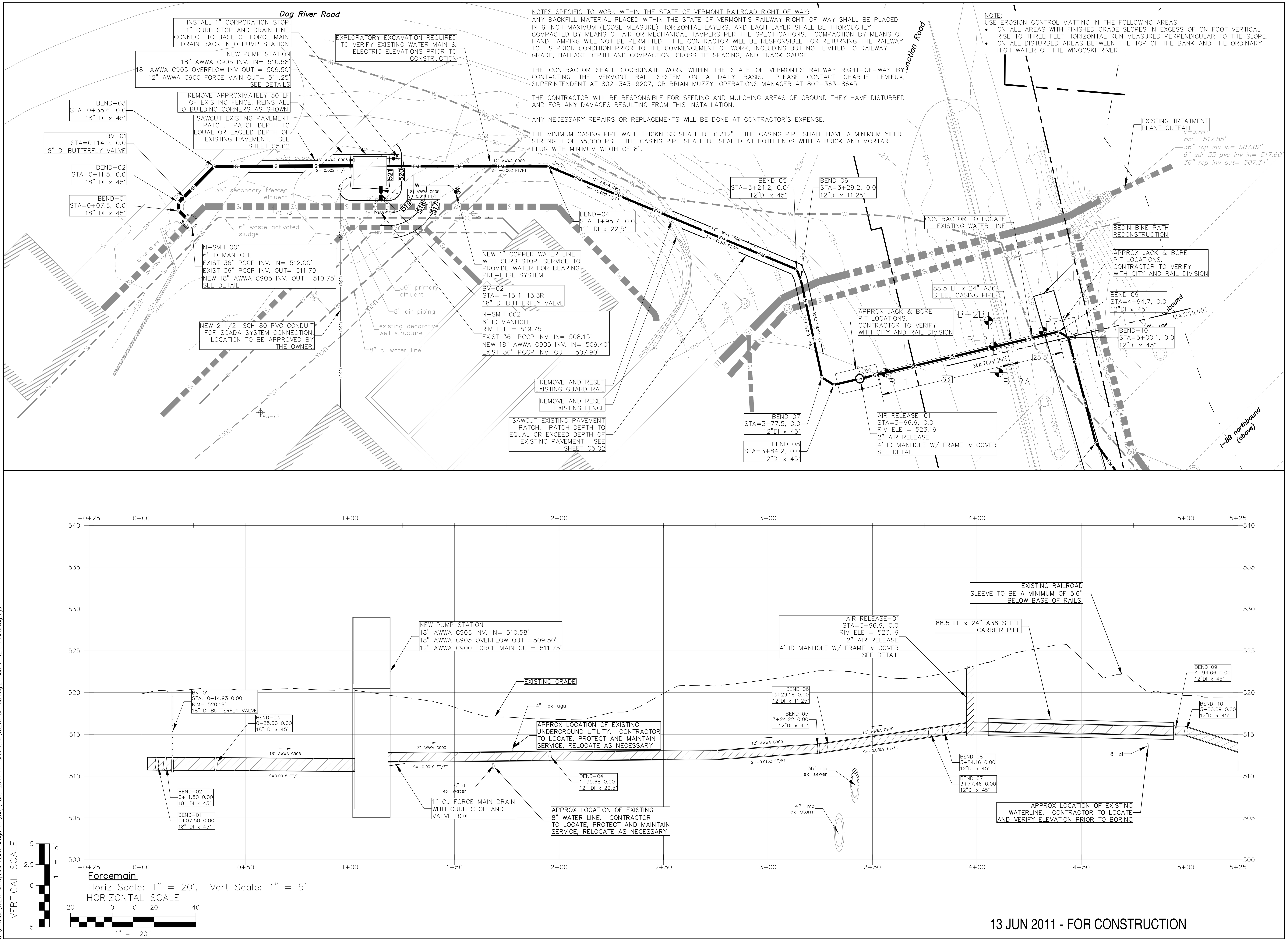


Figure 1: UV Disinfection Schematic



13 JUN 2011 - FOR CONSTRUCTION

G:\Jobfiles\10210 Montpelier FEMA Mitigation\dwg\ACAD 2009 For Submittal\10210-SP-06.dwg 21 Jun 11 12:55 PMJsvgzdys

REVISION | DATE | NO.

Civil & Structural Engineers
DeWolfe ENGINEERING ASSOCIATES
81 River St., P.O. Box 1576, Montpelier, VT 05601-1576
t. 802-223-4727 f. 802-223-4740 www.dewolfe.com

FEMA FLOOD MITIGATION
MONTPELIER BIKE PATH
MONTPELIER, VERMONT
CITY OF MONTPELIER

SHEET DESCRIPTION
PUMP STATION PLAN & PROFILE

PROJECT NO. 10210	DATE 13 JUN 2011
SCALE AS NOTED	C2.01
DRAWN AAM	
CHECKED JJS	SHEET 3 OF 15

Montpelier Water Resource Recovery Facility

Laboratory Results: *2013*

Average Flow (MGD)	1.86

Average Turbidity (N.T.U)	2.08

Average Influent Temperature (C)	Average Effluent Temperature (C)
13.5	13.9

Average Influent BOD (mg/L)	Average Effluent BOD (mg/L)	BOD Percent Removal
284	9	96.7

Average Influent TSS (mg/L)	Average Effluent TSS (mg/L)	TSS Percent Removal
431	6	98.6

Average Influent Total P (mg/L)	Average Effluent Total P (mg/L)	Average Total P Percent Removal
6.5	0.4	93.8

Average E.Coli (C.F.U./100 mls.)	9

Average PAC Usage (gals.)	80

Montpelier Water Resource Recovery Facility

Laboratory Results: 2014

Average Flow (MGD)	**1.88**

Average Turbidity (N.T.U)	**1.99**

Average Influent pH	**Average Effluent pH**
7.4	**7.0**

Average Influent BOD (mg/L)	**Average Effluent BOD (mg/L)**	**BOD Percent Removal**
276	**10**	**96.2**

Average Influent TSS (mg/L)	**Average Effluent TSS (mg/L)**	**TSS Percent Removal**
318	**7**	**97.9**

Average Influent Total P (mg/L)	**Average Effluent Total P (mg/L)**	**Average Total P Percent Removal**
4.4	**0.4**	**90.6**

Average E.Coli (C.F.U./100 mls.)	**9**

Average PAC Usage (gals.)	**83**

Process Notes:

Sodium Hydroxide was added to the facilities effluent starting June 5th and ending December 9th; this is a total of **187 days**. The total amount of chemical used was 5,086 gallons; approximately **27.2 gallons per day**. Total cost of Sodium Hydroxide addition for 2014: **$10,426**. Last year, chemical addition started August 1st and ended October 2nd; this is a total of **63 days**. The total amount of chemical used was 772 gallons; approximately **12.3 gallons per day**. Total cost of Sodium Hydroxide addition for 2013: **$1,582**.

Appendix G: Correspondence

From:	Michael D. Sullivan
To:	Simpson, Alexis
Cc:	Enko, Michael; Calabro, Stephen
Subject:	RE: CoMag Application
Date:	Thursday, February 12, 2015 4:03:40 PM

I will book it Alex. See you then. Can you guarantee no snow that day? :O(

Michael D Sullivan
David F Sullivan & Assoc.
19 Batchelder Rd., Suite 2B
Seabrook, NH 03874
www.davidfsullivan.com
ph: 508-878-1016

From: Simpson, Alexis [mailto:Alexis.Simpson@stantec.com]
Sent: Thursday, February 12, 2015 3:54 PM
To: Michael D. Sullivan
Cc: Enko, Michael; Calabro, Stephen
Subject: RE: CoMag Application

Mike,

That sounds great. Would 1 PM work for you?

From: Michael D. Sullivan [mailto:mikesullivan@davidfsullivan.com]
Sent: Thursday, February 12, 2015 3:48 PM
To: Simpson, Alexis
Cc: Enko, Michael; Calabro, Stephen
Subject: RE: CoMag Application

Alex,

Tuesday will work for me. I actually live in Lowell so I can be in to your Westford office as early as would be convenient for all. Hopefully we will have our proposal pulled together by then but if not I can present the CoMag system to you and we can look at the specific requirements for Montpelier as well. Let me know what time works for you all and we will plan accordingly.

Michael D Sullivan
David F Sullivan & Assoc.
19 Batchelder Rd., Suite 2B
Seabrook, NH 03874
www.davidfsullivan.com
ph: 508-878-1016

From: Simpson, Alexis [mailto:Alexis.Simpson@stantec.com]
Sent: Thursday, February 12, 2015 3:41 PM
To: Michael D. Sullivan
Cc: Enko, Michael; Calabro, Stephen
Subject: RE: CoMag Application

Mike,

Thanks for the quick turnaround. Unfortunately we do need to meet sooner and were wondering if you could come in Tuesday.

If Tuesday won't work please let us know and we can pick another day. We look forward to your visit and assistance.

Best,

Alex Simpson
Mike Enko

From: Michael D. Sullivan [mailto:mikesullivan@davidfsullivan.com]
Sent: Thursday, February 12, 2015 2:20 PM
To: Simpson, Alexis
Cc: Enko, Michael; Calabro, Stephen
Subject: RE: CoMag Application

Hi Alex,

Thank you for this inquiry. I have forwarded it to our engineers and a proposal that will address your questions is in process. Our regional manager for the Evoqua CoMag systems, Tom Miles, will be in this area within the next few weeks and we will make an appointment to see you and the others working on this project to present the CoMag system in general and address the questions specific to Montpelier as well. If we need to meet sooner than that I can make it by your offices when it is convenient for you. I am away next Wed-Fri but other than that I would be available. I look forward to assisting you with this opportunity.

Regards,

Michael D Sullivan
David F Sullivan & Assoc.
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Seabrook, NH 03874
www.davidfsullivan.com
ph: 508-878-1016

From: Simpson, Alexis [mailto:Alexis.Simpson@stantec.com]
Sent: Thursday, February 12, 2015 11:37 AM
To: Michael D. Sullivan
Cc: Enko, Michael; Calabro, Stephen
Subject: CoMag Application

Hi Mike,

We are doing a study for the upgrade to the Montpelier VT WWTP for phosphorous removal to advance the project with Steve Calabro and Joe Uglevich. We are currently expecting the phosphorous limit to be 0.1 mg/L The facility uses multiple point chemical addition of PAC and clarification to achieve 0.4 mg/L We would like to consider adding CoMag to achieve 0.1 mg/L or lower.

Design Basis:

- 1.88 MGD current Average Daily Flow
- 3.97 MGD design capacity Average Daily Flow
- Max Design flow: 9.58 MGD
- Peak Daily flow: 5.0 MGD in wet weather
- Peak Design flow: 12 MGD
- Influent to the CoMag Process at: 7 mg/l TSS, 10 mg/l BOD, 0.4 mg/l Total P
- Effluent: < 0.1 mg/l Total P

The plant has no bypass for wet weather flows, so what comes in will need to go through the CoMag unit up to a flow of 3.97 MGD. All flow beyond this will be bypassed to disinfection. We are open to layout suggestions, however, the site has limited space.

At this point, we need the following:

1. Confirmation that this is a good application for CoMag
2. A suggested equipment layout/footprint (overall size would be helpful)
3. Budget price for the equipment- or the entire system if you have it.
4. For you to come to the Westford, MA office and meet with us to discuss the design options and capabilities.

We appreciate your time and look forward to hearing back from you soon.

Best,
Alex Simpson
Mike Enko

From:	Calabro, Stephen
To:	Michael Caso
Cc:	Simpson, Alexis; Enko, Michael
Subject:	RE: GE/Zenon ultrafiltration membranes
Date:	Wednesday, February 18, 2015 10:58:13 AM

Mike .... The meeting to discuss GE/Zenon membranes for low-level Phosphorus removal has been re-scheduled for this Friday, 2/20 at 9:00 AM at our office in Westford.

Thanks for agreeing to meet with us ..... Steve

Steve Calabro
Stantec
5 LAN Drive Westford MA 01886-3538
Phone: (978) 577-1418
Cell: (781) 789-5389
steve.calabro@stantec.com

From: Michael Caso [mailto:mcaso@techsalesne.com]
Sent: Tuesday, February 17, 2015 9:26 AM
To: Simpson, Alexis
Cc: Enko, Michael; Calabro, Stephen; 'Best, Graham (GE Power & Water)'
Subject: RE: GE/Zenon ultrafiltration membranes

Alex,
Will 9am Wednesday work?
Thanks

Thank you for the opportunity to be of service.
Learn more at www.TechSalesNE.com

Michael J. Caso
Technology Sales Associates Inc.
Cell: 508-878-7641
O: 978-838-9998 x13
Email: MCaso@TechSalesNE.com

From: Simpson, Alexis [mailto:Alexis.Simpson@stantec.com]
Sent: Tuesday, February 17, 2015 8:44 AM
To: Michael Caso
Cc: Enko, Michael; Calabro, Stephen; Best, Graham (GE Power & Water)
Subject: RE: GE/Zenon ultrafiltration membranes

Mike,

Sorry for not getting back to you earlier. We would like to have you come in into the office sometime this week if you are still available, would tomorrow work?

There are existing tanks, there are 3, 30,000 gallon tanks and they are approximately 28 x 18 x 8 each.

But we would also like to look at the option for a package system.

Best,
Alex Simpson
Mike Enko

From: Michael Caso [mailto:mcaso@techsalesne.com]
Sent: Friday, February 13, 2015 11:22 AM
To: Simpson, Alexis
Cc: Enko, Michael; Calabro, Stephen; Best, Graham (GE Power & Water)
Subject: RE: GE/Zenon ultrafiltration membranes

Alex,
Thank you for the opportunity.
This is a very good membrane application and I welcome the opportunity to meet with you.
I will have GE look at a 4mgd tertiary membrane system for Montpelier.
Are their existing tanks to put the membranes in or are you thinking a package membrane system in a new building?
Are you available Tuesday morning?
Thanks

Thank you for the opportunity to be of service.
Learn more at www.TechSalesNE.com

Michael J. Caso
Technology Sales Associates Inc.
Cell: 508-878-7641
O: 978-838-9998 x13
Email: MCaso@TechSalesNE.com

From: Simpson, Alexis [mailto:Alexis.Simpson@stantec.com]
Sent: Thursday, February 12, 2015 11:38 AM
To: mcaso@techsalesne.com
Cc: Enko, Michael; Calabro, Stephen
Subject: GE/Zenon ultrafiltration membranes

Hi Mike,

We are doing a study for the upgrade to the Montpelier VT WWTP for phosphorous removal to advance the project with Steve Calabro and Joe Uglevich. We are currently expecting the phosphorous limit to be 0.1 mg/L The facility uses multiple point chemical addition of PAC and clarification to achieve 0.4 mg/L We would like to consider adding GE/Zenon ultrafiltration membranes to achieve 0.1 mg/L or lower.

Design Basis:

- 1.88 MGD current Average Daily Flow
- 3.97 MGD design capacity Average Daily Flow
- Max Design flow: 9.58 MGD
- Peak Daily flow: 5.0 MGD in wet weather
- Peak Design flow: 12 MGD
- Influent to membranes at: 7 mg/l TSS, 10 mg/l BOD, 0.4 mg/l Total P
- Effluent: < 0.1 mg/l Total P

The plant has no bypass for wet weather flows, so what comes in will need to go through the membranes up to a flow of 3.97 MGD. All flow beyond this will be bypassed to disinfection. We are open to layout suggestions, however, the site has limited space.

At this point, we need the following:

1. Confirmation that this is a good application for the membranes
2. A suggested equipment layout/footprint (overall size would be helpful)
3. Budget price for the equipment- or the entire system if you have it.
4. For you to come to the Westford, MA office and meet with us to discuss the design options and capabilities.

We appreciate your time and look forward to hearing back from you soon.

Best,
Alex Simpson
Mike Enko

From:	Michael D. Sullivan
To:	Simpson, Alexis; Enko, Michael
Cc:	Calabro, Stephen; "thomas.miles@evoqua.com"
Subject:	FW: Montpelier, VT WWTP CoMag proposal
Date:	Monday, February 23, 2015 10:45:03 AM
Attachments:	Montpelier, VT CoMag Proposal 022015.pdf

Alex and Mike,

Per your request of Feb 12 and our meeting to discuss the Evoqua CoMag system I am pleased to provide their preliminary proposal for the new total P application for the Montpelier, VT WWTP. This proposal is based on the CoMag system handling the max flow of 3.97 MGD of secondary effluent from the existing facility. The scope of supply is summarized within the proposal and includes the mechanical equipment for the CoMag unit processes as well as much of the instrumentation required. However they did not include the chemical feed systems as those typically are an owner preference and can be supplied locally by a chemical feed system vendor. We could provide an estimate for those systems if you need it for your study. Also note that although they have provided their recommendations for reaction tank size/volumes they assume that those would be provided as concrete by a GC during construction. It looks like there would be room to fit these tanks within the area of the sludge holding tanks although you would need to fit the clarifiers on site in an adjacent parcel. As was the case for Waterbury, VT WWTP CoMag system Evoqua could provide the clarifier tanks in steel or stainless steel construction which could save a little room and facilitate their being able to fit within an existing area of the plant.

Please look this proposal over and feel free to call or email with any questions or if you need further information. Note that some of the information on how Evoqua sizes these systems is provided in the email below. Thanks for your interest in the CoMag process for the Montpelier, VT WWTP low P application.

Regards,

Michael D Sullivan
David F Sullivan & Assoc.
19 Batchelder Rd., Suite 2B
Seabrook, NH 03874
www.davidfsullivan.com
ph: 508-878-1016

From: Miles, Thomas S [mailto:thomas.miles@evoqua.com]
Sent: Friday, February 20, 2015 6:14 PM
To: Michael D. Sullivan
Cc: Biase, Robert; Nemec, Adam
Subject: RE: Montpelier, VT WWTP CoMag proposal

Mike - please find attached our CoMag proposal for Stantec's evaluation of Montpelier VT's low TP limits. Highlights of the proposal are as follows:

- The design was based on their current ADF flow of 1.88 MGD and max flow of 3.97 MGD (note this is much lower than their design criteria last February).

- Our proposal includes internals for two clarifiers (with one being redundant).
- Below are answers to their questions
    - Headloss through the CoMag system. The plant has screw pumps that lift the primary effluent to the secondary process and the CoMag would have to be squeezed in (physically and hydraulically) between the sec clarifiers and the UV system.
        - Minimal headloss is experienced since the process consists of forward-flow through the reaction tanks and into the clarifier. Typical headloss range is 6" to less than 1' across all flow scenarios.
    - Provide Operating Costs for CoMag (chemicals/magnetite/energy)
        - Usage included in section 6 of proposal.
    - Provide the basis for design of the clarifier sizing (SOR/SLR) This is more for the benefit of the students to include with their report.
        - Clarifier was sized with a maximum SOR of 5 gpm/ft² during ADF and 15 gpm/ft² at peak flow assuming the use of one clarifier. For these flows the average flow was the limiting factor. A second clarifier using the same criteria was added to give 100% redundancy.

The budget price for the CoMag system along with the 2 clarifiers is $925,000. Coagulant/Polymer feed systems are not included at this time as they are usually specified by the engineer or are an owner-preference but we would be glad to add them to our Scope once they are defined.

Please review and forward onto Stantec. Please don't hesitate to contact us if you should have any questions or require additional information. Thanks for your effort on this project.

Tom Miles
Biomag / Comag Group
Evoqua Water Technologies LLC
(267) 218-4334
thomas.miles@evoqua.com