Appendix Y-1

Technical Memorandum, February 11, 2009
Evaluation of Alternative Methods to Address MassDEP's Proposed Regulations for TOC Limits

STEARNS & WHELER LLC
Environmental Engineers & Scientists

TECHNICAL MEMORANDUM

To: Robert Duncanson, Ph.D

From: J. Jefferson Gregg, P.E.
Nathan C. Weeks, P.E.
Jan Salzman, P.E.

Date: February 11, 2009

Re: Evaluation of Alternative Methods to Address MassDEP's Proposed Regulations for Total Organic Carbon (TOC) Limits for the Chatham Wastewater Treatment Facility

BACKGROUND

The Town of Chatham (Town) has completed a Draft Comprehensive Wastewater Management Plan (CWMP) Report and has completed a preliminary design for the upgrade of the Chatham Wastewater Treatment Facility (WWTF) as part of that Project. The Draft CWMP/Draft Environmental Impact Report (EIR) was submitted to the Massachusetts Environmental Policy Act (MEPA) review process in April 2008. The review was successful and a minimal number of comments need to be addressed as part of the Final CWMP/Final EIR. In August 2008 the Town was informed that MassDEP was proposing changes to its groundwater discharge regulation and that the CWMP should be modified to address the proposed revisions. The proposed revisions could require that the upgraded WWTF meet a Total Organic Carbon (TOC) limit of 3 mg/L in the treated water. The current preliminary design for the enhanced nitrogen removal (ENR) process would not meet this limit.

The Town has asked Stearns & Wheler (S&W) to evaluate the following alternatives to address the proposed revised groundwater discharge regulation.

- Upgrade of the Chatham WWTF to include a membrane bioreactor (MBR) followed by granular activated carbon (GAC) adsorption to meet the proposed TOC discharge limit.
- Modifications to Chatham's water supply system to eliminate the need for the TOC limit at the WWTF including the following two sub-evaluations.
  - Abandonment of the Indian Hill Well to eliminate its Zone II area that extends to portions of the WWTF site and requires that the WWTF meet a TOC limit.
  - Installation of GAC adsorption at the Indian Hill Well to adsorb any TOC contaminants (from the WWTF or from other sources) in the Zone II area.

The purpose of this technical memorandum is to summarize these evaluations and recommend the needed next steps for the Town to proceed with finalizing its CWMP.

UNDERSTANDING THE PROPOSED TOC LIMIT

MassDEP is proposing the TOC limit for treated water recharged into Zone II areas in response to concerns of potential “new” trace contaminants that may exist in treated wastewater. These trace contaminants are referred to as “emerging contaminants” in their broadest categorization because the health risks and regulatory limits have not been developed for these recently-observed (emerging) chemical compounds in water supplies and the environment. This broad class of “emerging contaminants” includes sub-classes of compounds known as EDCs (endocrine disrupting compounds) due to the possible impacts they may have on endocrine and reproductive systems, and PPCPs (pharmaceuticals/personal care products) because many of them originate from pharmaceuticals and other personal care products that people consume and which are subsequently introduced into the environment through wastewater and other pathways.

Nearly all of these compounds contain organic carbon as part of their molecular structure. It is our understanding that MassDEP is applying a TOC limit with the belief that reducing the TOC load to very low levels in treated water will greatly reduce the chance that these compounds could enter the water supply system. This approach does not take into account the other pathways (other than WWTF effluent), i.e. septic systems, through which these compounds could enter the water supply system. MassDEP has not yet required that these compounds be monitored or controlled at the water supplies.

SUMMARY OF EVALUATIONS FOR THE UPGRADE OF THE CHATHAM WWTF TO MEET A TOC LIMIT OF 3 mg/L

A. **Introduction.** This section provides the basis of design to achieve an anticipated limit of 3 mg/L for TOC using membrane and GAC technologies. First, the process flow is described, followed by a summary of the major components, basic processes and operational considerations, building services, and concluding with a cost analysis.

B. **Process Flow.** The treatment system begins with pretreatment by a pre-engineered screen and grit system (as called out in the current preliminary design). The screen is a coarse screen with 6 mm (1/4-inch) spacing. The expected grit removal efficiency is 80 percent for 65-mesh. A bypass channel with a manually cleaned bar rack with spacing of 1-inch is also provided. The wastewater then flows through a fine screen with 2 mm spacing. Sodium hydroxide can be added to the fine screen effluent to provide sufficient alkalinity for nitrification if needed. This step precedes the MBR system.

The screened raw wastewater is combined with the nitrate recycle flow and is distributed to the biological reactor train. The wastewater flows through the pre-anoxic zone, through the aerobic zone, through the post-anoxic zone, and finally enters the membrane tanks. The wastewater flows through the membrane tanks and is recirculated to the head of the aerobic tank by horizontal centrifugal return activated sludge pumps. Submersible internal recirculation pumps return wastewater from the end of the aerobic zone to the pre-anoxic zone for denitrification. Methanol can be added to the post-anoxic zone if needed to provide a carbon source for the final denitrification process. Alum could be added to the membrane tank to precipitate out phosphorus; however, there is currently no permit limit for phosphorus[1]. Treated water (permeate) is withdrawn from the membranes using vacuum pumps. This process flow is shown on Figure 1, MBR/GAC Process Schematic.

After the MBR process, the wastewater flows to a wet well, where it is pumped to the GAC units to further reduce TOC to less than 3 mg/L. The wet well equalizes flow surges, and the pumps enable equal distribution of flow to the GAC units. Finally, the GAC effluent flows through ultraviolet disinfection before eventual distribution over the sand beds. This process flow is shown on Figure 2, MBR/GAC Process Schematic.

C. **Summary of Major Components.**

1. **Fine Screen.** The main objective of the fine screen is to protect the membranes. Membrane systems are sensitive to damage from fine solids. One example of a fine solid that damages membranes is hair. Hair, not removed by coarser screens, can accelerate membrane clogging. Another advantage to fine screens is that they remove inert solids and organic matter loadings to the bioreactor. Fine screens are also anticipated to remove about 10 to 15 percent of the chemical oxygen demand, thus reducing aeration requirements.

2. **Membrane Bioreactor.** MBRs combine biological treatment and membrane technology to provide enhanced removal of organics and suspended solids. The membrane replaces the secondary clarifier used for solid-liquid separation in conventional treatment facilities.

The membranes are submerged in the mixed liquor and are vacuum driven. They can either be immersed directly into the activated sludge reactor or placed in an external membrane tank. The vacuum pumps draw the permeate (water) through the membranes while leaving the solids in the reactor or the membrane tank. Cleaning the exterior of the membranes involves injecting air at the bottom of the membranes. The air bubbles scour the membrane surface and the rejected solids return to the bioreactor train. It is not necessary to remove the membrane cassettes from the basin for cleaning. A more detailed cleaning routine for the membranes is described in Section D: Basic Process and Operational Considerations.

Membrane system designs are not standardized and vary between manufacturers. For the purposes of this report, the GE Zenon system was proposed and is described. However, other MBR manufacturers should be evaluated and considered prior to the final design. The Zenon system utilizes cassettes composed of tubular hollow-fiber membrane modules that are submerged in an external (outside of the bioreactor) membrane tank. Each cassette can contain up to 48 membrane modules.

There are four membrane trains in the proposed design (see attached Site Plan). For Phase 1, each train will have four installed cassettes with an extra two cassette spaces for expansion. There will be a total of 164 modules installed per train, and a total of 288 module spaces per train. For Phase 2, an additional cassette will be installed per train for a total of 5 cassettes per train, and an additional 74 modules will be installed for a total of 238 installed membrane modules per train. The average flux rate of this system is

[1] Alum addition would only be needed if phosphorus removal is required in the future. The site plan provides future space for construction of an anaerobic selector tank (for biological phosphorus removal) located prior to the pre-anoxic tank, if needed.

10 to 15 gallons per square foot per day and the peak flux rate is less than 22 gallons per square foot per day. GE Zenon (as the MBR supplier) would supply the following components:

- membrane modules
- membrane cassettes and associated support frames and hardware
- permeate collection and air distribution header pipes
- membrane tank level transmitters and membrane tank level switches

The MBR supplier would also supply the following support facilities:

- permeate/backpulse pumping system with reversible rotary lobe permeate/backpulse pumps with isolation valves, ejector systems, trans-membrane pressure transmitters, permeate pump pressure gauges and flow meters, and turbidimeters
- membrane air scour system with membrane air scour blowers, complete with isolation valves, flow switches, and pressure gauges
- membrane cleaning system with sodium hypochlorite and citric acid chemical feed systems

The MBR manufacturer identified above also typically supplies the following biological treatment process equipment:

- anoxic mixers
- fine bubble diffusers
- process aeration blowers with isolation valves, flow switches
- dissolved oxygen meters
- pressure gauges
- methanol dosing equipment
- recirculation pumps
- internal recirculation pumps and associated valves
- waste sludge discharge valves

They will also be supplying a programmable logic controller with touch screen human-machine interface, and miscellaneous equipment, including air compressors for pneumatic valve operation and refrigerated air driers, and membrane tank drain pumps and associated valves.

Currently, the MBR and biological system is proposed as a packaged system by a single MBR manufacturer. The main advantage to this is coordination. A great deal of coordination is needed between the MBR system and biological system since they are interrelated. Having the MBR supplier design the biological system as well simplifies these coordination needs.

The anticipated effluent parameters following MBR treatment are shown in Table 1, Basis of Design. Biochemical oxygen demand and total suspended solids are less than 5 mg/L, ammonia is less than 0.5 mg/L, and total nitrogen is less than 3 mg/L.

A summary of the membrane equipment is included in Table 1.

3. **Granular Activated Carbon System.** The purpose of the GAC is as a tertiary treatment step to remove TOC to less than 3 mg/L. GAC technology removes dissolved contaminants, including organic compounds, by adsorbing them onto a carbon media. As the wastewater flows through the GAC, the residual organics (organic carbon and organic nitrogen) as well as heavy metals, and odor compounds are captured as they adsorb to the carbon. The carbon media is periodically replaced or regenerated.

The conceptual design as proposed for Phase 1 consists of four GAC systems, each one containing six carbon contactor tanks. During Phase 1, three of the carbon contactors would run in parallel operation, with the fourth on standby. During Phase 2, a fifth GAC system would be added and four systems would operate in parallel, with an additional system on standby. A summary of the GAC systems is shown in Table 1. This includes carbon contactor dimensions, loadings (flux rate) at maximum month and peak flows, and total carbon volume and weight.

D. **Basic Process and Operational Considerations.**

1. **MBR.** Cleaning the membranes is a vital step in the operation of an MBR. Membrane fouling occurs over time and causes a pressure drop over time. The proposed MBR system has three steps to control membrane fouling.

The GE MBR system utilizes coarse bubble aeration for membrane air scouring as a way to physically scour and agitate the fibers. Typically, the aeration is cycled 10 seconds on and 10 seconds off to conserve energy.

In addition, filtration is periodically stopped every 10 to 20 minutes and the membranes are backwashed with permeate for 30 to 45 seconds.

In addition to air scour and backwash, maintenance cleaning must also be performed. Maintenance cleaning involves backwashing the filters with either Sodium Hypochlorite or Citric Acid for about 45-60 minutes. The Sodium Hypochlorite inactivates and removes microorganisms that colonize the outer membrane surface. The citric acid is used to remove scaling off the outer membrane surface due to minerals in the water. After the chemical backwash, the system is backwashed with permeate for about 15 minutes. An additional permeate flushing is performed for about 15 minutes to purge the system of free chlorine prior to the system starting up again. The total down time during maintenance cleaning is about 75 minutes. The Sodium Hypochlorite cleaning frequency is anticipated to be two times per week utilizing about 2.8 gallons (per cleaning) of a 10.3 percent solution. The Citric Acid cleaning frequency is anticipated to be once per week utilizing 5.5 gallons (per cleaning) of 50 percent solution.

Unfortunately membrane air scour, backwashing, and maintenance cleaning are not adequate to control the fouling and further cleaning is necessary. Typically every six months, recovery cleaning is needed.

TABLE 1

BASIS OF DESIGN

FLOWS	PHASE 1	PHASE 2
Design Sumer Average	1.8 mgd	2.7 mgd
Maximum month	2.1 mgd	3.1 mgd
Peak day	2.4 mgd	3.5 mgd
Peak hour	3.5 mgd	5.1 mgd

LOADS				
	INFLUENT (MG/L)		INFLUENT TO GAC (MG/L)	EFFLUENT (MG/L) AVERAGE ANNUAL
	PHASE I	PHASE 2		
CBOD	258	286	<5	<5
TSS	246	271	<5	<5
TKN	38	43	<3	N/A
Ammonia	26	30	<0.5	<0.5
TN	--	--	<3	<3
TOC	--	--		<3
Turbidity				≤5 NTU
Fecal coliform				200 colonies/100 ML
pH				6 - 9

(continued)

TABLE 1 (continued)

	PHASE 1	PHASE 2 (INCLUDES PHASE 1 EQUIPMENT)
PROCESS EQUIPMENT		
Pretreatment (Influent Building)		
Screen (pre-engineered unit)		
Type	Mechanical/bar	Mechanical/bar
Number	1	2
Spacing	6 mm (1/4-inch)	6 mm (1/4-inch)
Capacity	2.8 mgd	2.8 mgd
Grit Removal (pre-engineered unit)		
Number	1	2
Efficiency	80% removal for 65 mesh	80% removal for 65 mesh
Bypass Bar Screen		
Type	Manual/bar	Manual/bar
Number	1	1
Spacing	1-inch	1-inch
Influent Sampler		
Number of units	1	1
Dewatered Screenings and Grit Conveyor		
Number	1	1
Approximate length	40 feet	40 feet
Fine Screen (Influent Building)		
Number	2 (1 duty, 1 standby)	2 (1 duty, 1 standby)
Size	2 mm	2 mm
Capacity	3.5 mgd/each	5.1 mgd/each
Bioreactor		
Number of trains	2	3
Pre-anoxic volume	164,00 gallons	246,000 gallons
Aerobic volume	903,000 gallons	1,354,500 gallons
Post-anoxic volume	245,400 gallons	368,000 gallons
MBR		
Number of trains	4	4
Tank volume	124,000	124,000
Tank dimensions	42’ x 10’ x S.W. 10’	42’ x 10’ x S.W. 10’
HRT @ 3.1 mgd	16 hours	16 hours
SRT @ 3.1 mgd	29 days	29 days

TABLE 1 (continued)

	PHASE 1	PHASE 2 (INCLUDES PHASE 1 EQUIPMENT)
MBR (continued)		
MLSS	8,000 to 10,000	8,000 to 10,000
Waste sludge	35,000 gpd	59,000 gpd
Membranes		
Installed cassettes per train	4	5
Installed modules per train	164	238
Granular Activated Carbon Filter (GAC)		
Type	Downflow filter	Downflow filter
Number of units	4 systems (6 tanks each); 3 active, 1 standby	5 systems (6 tanks each); 4 active, 1 standby
Diameter	54 inches	54 inches
Area of each	16 SF	16 SF
Total active area	286 SF	382 SF
Height	11 feet	11 feet
Bed depth	72 inches	72 inches
Maximum loading at peak flow	5.8 gpm/SF	6.4 gpm/SF
Loading @ 2.1 mgd	5.1 gpm/SF	---
Loading @ 3.1 mgd		5.6 gpm/SF
Carbon type	Calgon Filtersorb 300	Calgon Filtersorb 300
Volume per filter	63.5 CF	63.5 CF
Total volume	1,524 CF	1,905 CF
Total weight (lbs)	42,672 lbs.	53,340 lbs
UV Disinfection		
Type	Open channel/vertical	Open channel/vertical
Number of channels	1	1
Per lamp power consumption (watts)	165	165
Total of lamps required	160	160
Number of modules per channel	4	4
Number of lamps per module	40	40
Channel dimensions	26 feet x 24.5 inches x 72 inches	26 feet x 24.5 inches x 72 inches
Number of active lamps at peak hour flow	72	96
Number of active lamps at summer average flow	40	56

TABLE 1 (continued)

	PHASE 1	PHASE 2 (INCLUDES PHASE 1 EQUIPMENT)
METHANOL FACILITIES		
Methanol Storage Tank		
Type	Aboveground concrete encased steel	Aboveground concrete encased steel
Location	Methanol facility	Methanol facility
Capacity	6,000 gallons	6,000 gallons
Methanol Feed Pump		
Type	Peristaltic, on VFD	Peristaltic, on VFD
Location	Methanol facility	Methanol facility
Number of Units	2 (plus an uninstalled spare)	2 (plus an uninstalled spare)
Flow Range	0.002 to 34.8 gph	0.002 to 34.8 gph
ODOR CONTROL		
Activated Carbon Odor Control System		
Type	Radial flow	Radial flow
Location	Adjacent to Sludge Dewatering Building	Adjacent to Sludge Dewatering Building
Media	High capacity activated carbon	High capacity activated carbon
Capacity	20,000 cfm	20,000 cfm
Fan HP	50	50
Fan note	Fan provided with weather protection enclosure	Fan provided with weather protection enclosure
SLUDGE TREATMENT FACILITIES		
Waste Activated Sludge Holding Tank Note	Reuse existing	
Number of units	2	
Dimensions, each	37 feet x 37 feet x 10.2 feet side water depth	
Waste Activated Sludge Holding Tank Aeration System		
Type	Removable coarse bubble diffusers	Removable coarse bubble diffusers
Location	Waste activated sludge holding tanks	Waste activated sludge holding tanks
Design air flow	425 scfm for each tank	425 scfm for each tank

TABLE 1 (continued)

	PHASE 1	PHASE 2 (INCLUDES PHASE 1 EQUIPMENT)
Waste Activated Sludge Holding Tank Blower		
Type	Positive displacement, tri-lobe with sound enclosure	Positive displacement, tri-lobe with sound enclosure
Location	Chemical and Blower Building	Chemical and Blower Building
Number of units	2 (including 1 installed spare)	2 (including 1 installed spare)
Capacity, each	On VFD	On VFD
Belt Filter Press Feed Pump		
Type	Double disc	Double disc
Location	Control Building	Control Building
Number of units	2 (including 1 installed spare)	2 (including 1 installed spare)
Capacity, each	On VFD; 370 gpm	On VFD; 370 gpm
Belt Filter Press Feed Flow Meter		
Type	Magnetic type	Magnetic type
Location	Control Building	Control Building
Number of units	2	2
Size	4-inch	4-inch
Sludge Dewatering Equipment		
Type	Belt filter press	Belt filter press
Location	Sludge Dewatering Building	Sludge Dewatering Building
Number of Units	1 new + 1 existing	1 new + 1 existing
Size	New: 1-meter; existing: 1-meter	New: 1-meter; existing: 1-meter
Water Booster Pump		
Location	Sludge Dewatering Building	Sludge Dewatering Building
Number of units	1	1
Capacity, each	90 gpm @ 120 psi	90 gpm @ 120 psi
Dewatered Sludge Conveyor		
Type	Belt conveyor	Belt conveyor
Location	Sludge Dewatering Building	Sludge Dewatering Building
Number of Units	1	1
Approximate Length	22 feet	22 feet

TABLE 1 (continued)

	PHASE 1	PHASE 2 (INCLUDES PHASE 1 EQUIPMENT)
OTHER FACILITIES		
Plant Water Pumps		
Type	Skid-mounted	Skid-mounted
Location	RAS/WAS Pump Building	RAS/WAS Pump Building
Number of Units	3	3
Plant Water Hydropneumatic Tank		
Number of Units	1	1
Location	RAS/WAS Pump Building	RAS/WAS Pump Building
Recycle Flow Pumps		
Type	Submersible non-clog centrifugal	Submersible non-clog centrifugal
Location	Recycle flow pump station	Recycle flow pump station
Number of Units	2	2
Parshall Flume		
Type	FRP	FRP
Number of units	1	1
Location	UV and Parshall flume structure	UV and Parshall flume structure
Size (throat width)	12 inches	12 inches
Capacity	320 gpm	320 gpm
Influent Sampler		
Number of units	1	1
Location	Outside of the Influent Building	Outside of the Influent Building
Effluent Sampler		
Number of units	1	1
Location	UV and Parshall flume structure	UV and Parshall flume structure
Sodium Hypochlorite Storage Tank		
Type	FRP cylindrical	FRP cylindrical
Location	Chemical and Blower Building	Chemical and Blower Building
Number of units	1	1
Capacity	6,000 gallons	6,000 gallons
Tank diameter	10 feet	10 feet

TABLE 1 (continued)

	PHASE 1	PHASE 2 (INCLUDES PHASE 1 EQUIPMENT)
Sodium Hydroxide Storage Tank		
Type	FRP cylindrical	FRP cylindrical
Location	Chemical and Blower Building	Chemical and Blower Building
Number of units	1	1
Capacity	6,000 gallons	6,000 gallons
Tank diameter	10 feet	10 feet
Sodium Hydroxide Feed Pumps		
Type	Peristaltic	Peristaltic
Location	Chemical and Blower Building	Chemical and Blower Building
Number of units	2 (including 1 installed spare)	2 (including 1 installed spare)
TREATED WATER RECHARGE FACILITIES		
Sand Beds		
Number of existing sand beds	2	2
Area (SF) each	30,000	30,000
Area (SF) total	60,000	60,000
Capacity, total (30 gpd/SF)	1.8 mgd	1.8 mgd
Number of new sand beds	4	4
Area (SF) total	148,000	148,000
Capacity, total (30 gpd/SF)	4.4 mgd	4.4 mgd
Total capacity	6.2 mgd	6.2 mgd
Capacity with 50% beds resting	3.1 mgd	3.1 mgd

This involves draining the tank/cell, removing the cassette/membranes and soaking the membranes in a tank containing about a 1000 – 2000 mg/L solution of sodium hypochlorite. The cassette is soaked for about 24 hours. Cassettes weigh 2-3 tons, but the lifting device should be designed for at least 5 tons in case membranes are heavily caked. A spare cassette would be installed where the cassette that is being cleaned was located in order to maintain treatment capacity. Also, membranes become hydrophobic if they are removed from the water and become dry. It is important to periodically hose down membranes that are out of service so they stay wet.

One of the advantages to an MBR is an increased mixed liquor suspended solids (MLSS) concentration which creates an aggressive biological environment to degrade soluble organic carbon in the biological process. It also creates a more stable sludge which is less susceptible to upsets. The design MLSS is 8,000 to 10,000 mg/L (this is in comparison to 4,000 mg/L for a typical Orbal/oxidation ditch process). The design hydraulic residence time at maximum month flow is 16 hours, and the design solids residence time at maximum month flow is 29 days. The design waste sludge for Phase 1 is 35,000 gpd, and 59,000 gpd for Phase 2 as shown in Table 1. In comparison, the design waste sludge for the oxidation ditch process is 51,000 gpd for Phase 1, and 75,800 gpd for Phase 2. In general, an MBR process generates less sludge than a traditional activated sludge process due to the longer solids retention time.

During biological treatment, methanol will be added to the post-anoxic zone to enhance denitrification. Other sources of carbon could be used but this could increase the operations and maintenance costs associated with storing and maintaining additional carbon sources.

2. **GAC.** The proposed GAC system is configured for downflow design. The wastewater enters the top and is removed from the bottom. The carbon is held in place with an underdrain system at the bottom of the contactor. Provisions for backwashing and surface washing are provided in order to remove fines from the carbon after it is loaded into the tank and for general process control.

The adsorption front, also called the mass transfer zone, is the zone where adsorption occurs. It starts at the top of the bed and moves down as more and more adsorption sites take up contaminants. As the water passes through the carbon bed, the concentration of the contaminants is reduced to their minimum values within the mass transfer zone, and no further adsorption occurs. The adsorption front moves down the bed over time until breakthrough, which is said to occur when the effluent concentration is equal to 5 percent of the influent concentration. Exhaustion of the bed is said to occur when the effluent concentration is equal to 95 percent of the influent concentration.

In practice, there are two methods available to utilize the capacity at the bottom of the carbon contactors. One method is to operate the contactors in series. Initially, the wastewater is introduced to the top of the first contactor column (Bed 1). The water flows through the bed and the carbon adsorbs the contaminants. The wastewater then flows out the bottom and back into the top of the next contactor column (Bed 2) in series. During this time Bed 2 remains fresh because all of the contaminants are being adsorbed in Bed 1. After Bed 1 becomes exhausted (breakthrough), Bed 2 will begin to adsorb contaminants. At this time, Bed 1 is removed from service and the carbon in Bed 1 is completely replaced. The wastewater would then enter Bed 2 first. The contaminants would be adsorbed in Bed 2, and then the flow would be cycled through the newly replaced carbon in Bed 1, which would remain fresh until exhaustion in Bed 2. This cycle between two beds in series enables the complete capacity of the carbon contactor to be utilized.

The second method is to operate the carbon contactor columns in parallel. When multiple columns are run in parallel, breakthrough in one column does not affect effluent quality from the system. To do this effectively, the parallel beds must have different amounts of fresh carbon in them. For example, for three beds in parallel (Beds 1, 2, and 3), during initial startup (when all of the beds are fresh), only Bed 1 is active. The wastewater would enter the top of Bed 1, the contaminants would be adsorbed, and the effluent would exit the bottom of Bed 1 and flow to downstream treatment. After a short time, Bed 1 will have spent carbon at the top of the bed, and wastewater flow would be introduced to the top of Beds 1 and 2. After another short time Beds 1 and 2 would have spent carbon, but Bed 1 would have more because it has been used for a longer amount of time. Then flow would be introduced to the top of Bed 3, and at this time flow would be entering Beds 1, 2, and 3 in parallel from the upstream treatment unit. At this time, each of the carbon beds would have a different amount of fresh carbon. Because of this, poorer effluent water quality from Bed 1 would not affect the overall water quality because it would be combined with the effluent from Beds 2 and 3. As each bed becomes exhausted, it is replaced and the beds continue to run in parallel. Each bed is replaced with fresh carbon as it becomes exhausted.

The GAC manufacturer used for this conceptual design has proposed a parallel GAC system. However, the actual configuration used will be determined during piloting and the design phase of the project.

Another important operational consideration is how the granular activated carbon is replaced. It can either be regenerated on site, or it can be replaced by an offsite commercial facility. For the conceptual design, offsite generation is proposed because it is more economical for small plants (plants with less than 1 million pounds of carbon). To replace the carbon, the spent carbon is hydraulically transported from the contactor to a truck, and the regenerated or virgin carbon is hydraulically transported from the truck to the top of the contactor. Based on an EPA report, 1 million gallons of wastewater can be treated by approximately 400 lbs of granular activated carbon. During Phase 1, the total flow per year is approximately 475 million gallons, and based on the GAC proposal, the treatment plant capacity would be about 43,000 lbs of GAC, thus treating approximately 110 million gallons of wastewater. Therefore, based on the assumption of 400 lbs of GAC used per million gallons of water treated, 100% of the granular activated carbon would need to be replaced four times per year. However, prior to final design, tests should be performed on the treated water to find the optimal flow rate, bed depth, TOC removal capacity, and usage rate of the carbon to determine the number of columns and dimensions for continuous treatment, and how often the carbon would need replacement.

Backwashing is performed periodically as stated before with the wastestream pumped to a sludge holding tank, where the supernatant could be reintroduced to the head of the plant.

E. **Building Services.**

1. **MBR Process Building.** The MBR process building will house the membrane tanks, and all associated cleaning, maintenance, and operating equipment; aeration blowers; permeate pumps; return and waste activated sludge pumps; GAC units; and all associated cleaning, maintenance, and operating equipment associated with the GAC. The building will also house an electrical room, a mechanical room, some storage area, and a small control room with a plan table and bookshelves.

2. **Exterior Construction.** The structure's exterior construction (siding, roof, etc.) would be similar to the proposed Water and Sewer Building. The building will have a pre-engineered steel frame with a pitched roof. The side walls will be a combination of masonry to a few feet above grade with insulated metal panels above that.

F. **Cost.** A cost summary is presented in Table 2. This Table includes a comparison between the MBR/GAC process and an Orbal process ENR previously developed during preliminary design. Also included in Table 2 are total project capital costs, annual operations and maintenance costs, and 20-year present worth.

SUMMARY OF EVALUATIONS FOR THE MODIFICATION OF CHATHAM'S WATER SUPPLY SYSTEM TO ELIMINATE THE NEED FOR THE TOC LIMIT AT THE WWTF

A. **Introduction.** The potential threat of the "emerging contaminant" compounds could also be addressed by modifications to Chatham's water supply systems to ensure that no treated water from the Chatham WWTF enters a Zone II area by eliminating the Zone II area that affects the WWTF site; or that any "emerging contaminants" that enter the Zone II from the WWTF or from any other source is removed by a treatment process at the water supply.

B. **Abandon Indian Hill Well.**

1. **Background, Regulatory Considerations, and Estimated Costs.** This potential modification to Chatham's water supply system is the abandonment of the Indian Hill Well as a public water supply and abandonment of the Zone II area. Once the Zone II area is abandoned, the treated-water recharge at the WWTF site will not need to meet the proposed TOC limit of 3 mg/L.

Review of MassDEP regulations and subsequent discussions with MassDEP staff indicate the following regulatory considerations on this possible modification:

- "Abandonment" refers to the elimination of the Indian Hill Well's status as a public water supply source and its Zone II delineation.
- "Decommissioning" refers to the physical closure of the well.
- MassDEP approval of well abandonment is required through review of MassDEP Permit Application BRP WS 36: Abandonment of Water Source.
- The well is typically decommissioned after abandonment by removing the water supply connections and sealing the well.
- Once abandoned, the well no longer has any status as a public water supply source. Any future attempt by the Town to reactivate this well would be subject to all of the current requirements of the MassDEP Source Approval process.
- The BRP WS 36 application would need to demonstrate that the Town could meet its future peak day water demand with its largest water source (as well as Indian Hill Well) off line.

TABLE 2

ENGINEER'S ESTIMATE OF PROBABLE COST FOR CHATHAM WWTP ALTERNATIVES

DESCRIPTION	JANUARY 2008 DRAFT		MBR/GAC ALTERNATIVE	
	PHASE 1	PHASE 2[(1)]	PHASE 1	PHASE 2[(1)]
Preliminary Treatment				
Headworks	$1,700,000	$1,700,000	$1,700,000	$1,700,000
Influent Building addition for Fine Screens			$302,400	$302,400
Fine Screens			$780,000	$780,000
Activated Sludge Secondary Treatment System				
Oxidation Ditch (ORBAL)	$4,100,000	$5,700,000		
Post-Anoxic/Reaeration Tanks				
Clarifier Flow Distribution Box and Scum Pumping	$ 210,000	$230,000		
RAS and WAS	$1,800,000	$2,000,000		
Clarifiers	$2,000,000	$3,000,000		
MBR Membranes/Basins And Auxiliary Equipment			$7,540,000	$9,110,000
Lifting Equipment			$10,000	$10,000
Bioreactor Tankage			$2,970,000	$4,590,000
MBR/Process Building			$9,000,000	$9,000,000
Methanol Storage/Feed System	$180,000	$180,000	$180,000	$180,000
Effluent Filters				
Effluent filters	$2,500,000	$2,700,000		
Granular Activated Carbon				
Filter/Contactors (includes influent pumps/wet well, backwash pumps)			$1,270,000	$1,500,000
Recycle and Plant Drain Pumping Station				
Submersible Pumping Station	$200,000	$200,000	$200,000	$200,000
Disinfection				
Effluent Flow Monitoring/UV[(3)]	$230,000	$230,000	$787,000	$822,000

TABLE 2 (continued)

DESCRIPTION	JANUARY 2008 DRAFT		MBR/GAC ALTERNATIVE	
	PHASE 1	PHASE 2	PHASE 1	PHASE 2
Odor Control				
Odor control	$340,000	$400,000	$340,000	$400,000
Solids Handling				
Sludge Holding Tank and Equipment	$420,000	$1,100,000	$420,000	$1,100,000
Solids Processing Building and Equipment	$730,000	$1,900,000	$730,000	$1,900,000
Electrical Power Distribution and Auxiliary Power				
Major Electrical Power Distribution	$1,800,000	$1,800,000	$1,800,000	$1,800,000
Instrumentation				
Major Instrumentation/SCADA	$720,000	$720,000	$720,000	$720,000
Buildings				
Chemical Storage/Feed System (caustic, hypo, blowers and compressor)	$400,000	$400,000	$400,000	$400,000
Operations Building	$3,200,000	$3,200,000	$3,200,000	$3,200,000
General Modifications to Existing Buildings	$220,000	$220,000	$220,000	$220,000
Subtotal	**$20,800,000**	**$25,700,000**	**$32,600,000**	**$37,900,000**
Other				
Yard Piping	$1,400,000	$1,800,000	$2,282,000	$2,653,000
General, Electrical, and Instrumentation	$2,400,000	$2,900,000	$3,912,000	$4,548,000
Site Work	$820,000	$1,000,000	$1,304,000	$1,516,000
HVAC	$620,000	$760,000	$978,000	$1,137,000
Painting, Plumbing	$410,000	$510,000	$652,000	$758,000
Miscellaneous Metals	$310,000	$380,000	$489,000	$568,500
Construction Cost Subtotal	**$27,000,000**	**$33,000,000**	**$42,000,000**	**$49,000,000**
Contingency (20%)	$5,400,000	$6,600,000	$8,400,000	$9,800,000
Piloting Equipment			$30,000	$30,000
Design Engineering	$1,100,000	$1,800,000	$2,520,000	$2,940,000
Fiscal, Legal and Engineering (15%)	$4,100,000	$5,000,000	$6,300,000	$7,400,000

TABLE 2 (continued)

Description	January 2008 Draft		MBR/GAC Alternative	
	Phase 1	Phase 2	Phase 1	Phase 2
Total Project Capital Cost	**$38,000,000**	**$46,000,000**	**$59,000,000**	**$69,000,000**
Annual Operations and Maintenance Costs	**$1,000,000**	**$1,200,000**	**$2,520,000**	**$3,150,000**
20-year Present Worth(2)	**$51,000,000**	**$62,000,000**	**$93,000,000**	**$111,000,000**

(1) Phase 2 includes Phase 1 costs.
(2) 20-year present worth, I = 4.25%, n = 20.
(3) The costs in the January 2008 Draft CWMP did not include costs for the UV system, but did include costs for the flow metering system. The MBR/GAC Alternative costs include costs for both systems.

The estimated cost to abandon and decommission Indian Hill Well is approximately $20,000 to $50,000 depending on the desired level of demolition.

2. **Evaluation of Future Peak Day Demand and Capacities.** The future peak day demand has been evaluated three times in the recent past as summarized below.

The CWMP Project Needs Assessment completed an initial buildout analysis and future water demand analysis which was summarized in the August 1999 Needs Assessment Report. It was a conservative analysis that evaluated future water demand on a parcel-by-parcel basis with the following key assumptions:

- Future buildout and water consumption would occur at any vacant-undeveloped or under-developed properties as allowed by current zoning.
- Any existing property with a one- or two-bedroom house could add one additional bedroom with a proportional increase to the water demand.
- Peak day demand is calculated at 3.46 times the average annual demand as observed from historic well-pumpage and water-consumption data.

These evaluations projected future water demand at 5.2 million gallons per day (mgd). During the review of this buildout assessment by the Town, it was considered to be overly conservative due to its assumption of the water demand increasing proportionally to the number of bedrooms.

The CWMP Project evaluated buildout and its effects on future wastewater flow generation using a variation of the criteria. The main difference from the earlier analysis is the projection of wastewater generation on a future-property basis as opposed to a future-bedroom basis. The revised buildout analysis was centered on current zoning bylaws. This revised buildout analysis resulted in a projected peak-day water demand of 4.5 mgd.

In December 2001 Earth Tech completed a future water demand evaluation for the future design of the new Great Hill Standpipe. This evaluation was based on the original buildout analysis presented in the August 1999 Needs Assessment Report and a projection of the number of future water service connections. This evaluation resulted in a future peak day demand of 5.7 mgd.

The water supply capacities of all of the public water supply wells are summarized in the following Table 3:

TABLE 3

SUMMARY OF CHATHAM WATER-SUPPLY CAPACITIES

WELL NAME	CAPACITY	
	(gpm)	(mgd)
S. Chatham Well #1	200	0.29
S. Chatham Well #2	450	0.65
S. Chatham Well #3	700	1.0
Indian Hill Well #4	800	1.15
Training Field Well #5	450	.65
Town Forest Well #6	700	1.0
Town Forest Well #7	700	1.0
Training Field Well #8	550	0.79
Town Forest Well #9	700	1.0
Mill Pond Well #10	350	0.5
Mill Pond Well #11	350	0.5

The total installed capacity of these wells is 8.53 mgd.

If Indian Hill Well was abandoned, the total installed capacity would be 7.38 mgd.

A water supply system capacity is typically evaluated with its largest source out of service. For Chatham, the South Chatham Well Field (comprised of 3 wells) is the largest water source in the Chatham system. If this source was out of service (in combination with the Indian Hill Well being abandoned), the total installed capacity would be 5.44 mgd. This capacity exceeds two of the three estimates of peak-day demand.

3. **Potential Costs to Develop a New Water Supply Well.** Two potential additional future water supply wells have been identified by the Chatham Water Department as listed below with estimated capacities:

TABLE 4

POTENTIAL ADDITIONAL FUTURE WATER-SUPPLY WELLS

WELL NAME/LOCATION	CAPACITY	
	(gpm)	(mgd)
Godwin Well #12	700	1.0
Town Forest Well #13	500	0.72

Preliminary evaluations of these sites indicates the presence of iron and manganese in the water which would need to be removed with a filtration process similar to the iron and manganese removal process recently installed by the Dennis Water District, Mashpee Water District, and the Orleans Water Department.

Capital costs for the potential future development of one of these water supplies is estimated at $3.6 million as summarized below:

TABLE 5

ESTIMATED CAPITAL COSTS FOR ADDITIONAL POTENTIAL FUTURE WELL

COST COMPONENT	COST ($MILLION)
Construction Costs:	
Well and Pump Station	1.2
Iron and Manganese Facility	1.2
Total Construction Costs	**2.4**
Contingency (25%)	0.6
Fiscal, Legal, and Engineering (25%)	0.6
Total Capital Costs	**3.6**

C. **Treatment for TOC at the Indian Hill Well.** This potential water supply modification would involve installation of a GAC adsorption process at the Indian Hill Well. This alternative would have the following benefits:

- It would put the Indian Hill Well back in service because it would remove the trace amounts of tetrachloroethylene (PCE) that have been detected in the past (unrelated to the Chatham WWTF) and have caused the Chatham Water Department to take the well out of production.
- It would provide final polishing of the groundwater and any total organic carbon potentially coming from the Chatham WWTF.
- It would provide final polishing of the groundwater and any total organic carbon potentially coming from any source in the Zone II areas.

The main disadvantage of this alternative is the capital cost of the installation and the annual cost of its operation.

A total capital cost of $2.3 million is estimated as listed below.

TABLE 6

CAPITAL COST SUMMARY FOR INDIAN HILL WELL GAC TREATMENT

COST COMPONENT	COST ($MILLION)
GAC System Construction[1]	$1.5
Contingency (25%)	$0.38
Fiscal, Legal, and Engineering (25%)	$0.38
Total Capital Cost	$2.3
Annual Costs	$0.03/yr
Total Present Worth	$2.7

(1) Based on installed costs of similar facilities at the MMR Air Force Groundwater Cleanup Program and modified pump to allow pump through.

Annual operation and maintenance costs for the GAC system are based on similar facilities at the MMR. Cost will vary for the specific constituents at the Indian Hill Well site, and future testing is recommended for more precise cost estimating. This cost is based on a well production rate of 1 mgd.

COMPARISON OF THE THREE ALTERNATIVES AND RECOMMENDED NEXT STEPS

The comparison needed for the identified methods to address MassDEP's proposed regulations for TOC limits is to compare the following alternatives:

1. Oxidation ditch – ENR treatment process (as developed in the preliminary design) in combination with abandoning the Indian Hill Well and adding a new well.
2. Oxidation ditch - ENR treatment process and upgrade of the Indian Hill Well with GAC adsorption to treat for the PCE contamination and eliminate the need (if successfully negotiated with MassDEP) to meet 3 mg/L TOC at the WWTF.
3. MBR and GAC treatment at the WWTF to meet the TOC limit of 3 mg/L.

These costs are summarized in Table 7.

TABLE 7

ALTERNATIVE COST COMPARISON

	ALTERNATIVE 1 (WELL ABANDONMENT)	ALTERNATIVE 2 (WELL TREATMENT)	ALTERNATIVE 3 (WWTF MBR W/ GAC)
	CAPITAL COSTS		
WWTF (Phase 2)	46,000,000	46,000,000	69,000,000
Water System Modifications	3,650,000	2,300,000	-
	O&M COSTS ($/YR)		
WWTF (Phase 2)	1,200,000	1,200,000	3,200,000
Water System Modifications	-	30,000	-
	PRESENT WORTH (EACH COMPONENT)		
WWTF (Phase 2)	62,000,000	62,000,000	110,000,000
Water System Modifications	3,650,000	2,700,000	-
Total Present Worth ($Millions)	66,000,000	65,000,000	110,000,000
Note: Rounded to 2 significant figures			

In addition, advantages and disadvantages of each of the proposed alternatives have been provided as follows:

Alternative # 1 advantages include:

- Eliminates the Zone II at the WWTF and therefore removes the effluent quality limits associated with recharge within a Zone II
- Town can continue with its preliminary design and CWMP as previously developed
- Indian Hill well has not been used actively in over a decade as a public water supply and its abandonment may not have any impact on the existing water supply

Disadvantages include:

- MassDEP does not recommend abandonment of permitted water supply wells
- The Town would be abandoning a registered water supply that could be used in the future with minimal restrictions

Alternative #2 advantages include:

- This is the lowest cost alternative as compared to the other two alternatives
- Keeps Indian Hill Well in service and provides treatment that will also address PCE contamination

Disadvantages include:

- MassDEP negotiations required to gain approval, and MassDEP may be hesitant to set precedent

Alternative #3 advantages include:

- Very high level of treatment at the WWTF which will have both public health and environmental benefits
- Keeps Indian Hill Well in service

Disadvantages include:

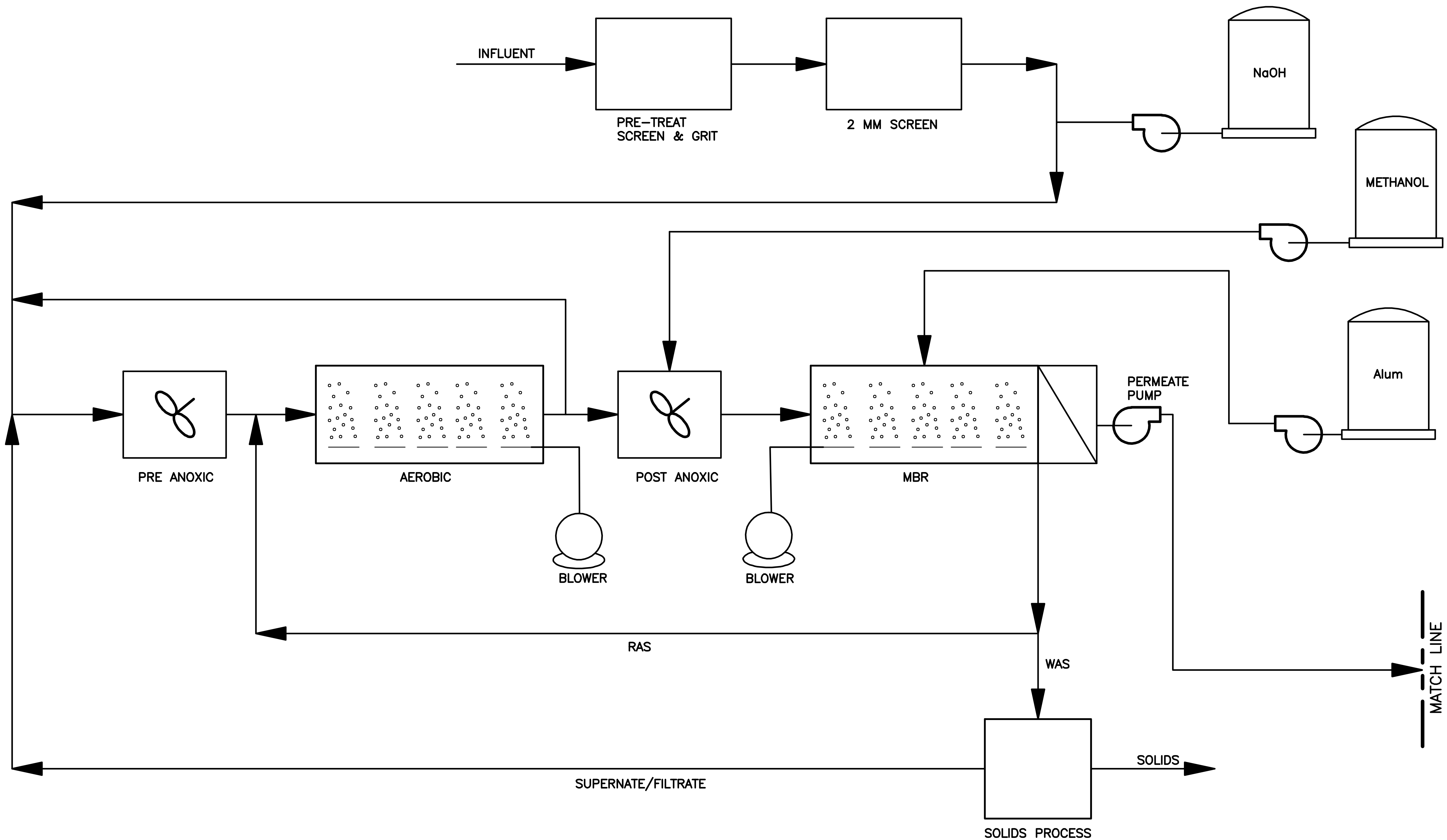
- Highest cost of all three alternatives
- A highly complex wastewater treatment process that will be operator intensive
- Abandonment of the preliminary design work and modifications to the recommended plan of the CWMP

This comparison indicates that Alternative 3 is significantly more expensive than Alternatives 1 and 2 which are similar in cost. Alternative 3 would additionally reduce TOC in the treated water flow from approximately 10 mg/L (from the oxidation ditch – ENR process) to less than 3 mg/L and may further reduce the total nitrogen to levels further below 3 mg/L. This is a small additional reduction for such a large additional cost.

Alternative 2 is expected to provide the best protection of public health because it would protect (and remediate) the Indian Hill Well source. It is also the lowest cost alternative.

Alternative 2 may be a good compromise for MassDEP and further discussions with them are warranted.

Figures



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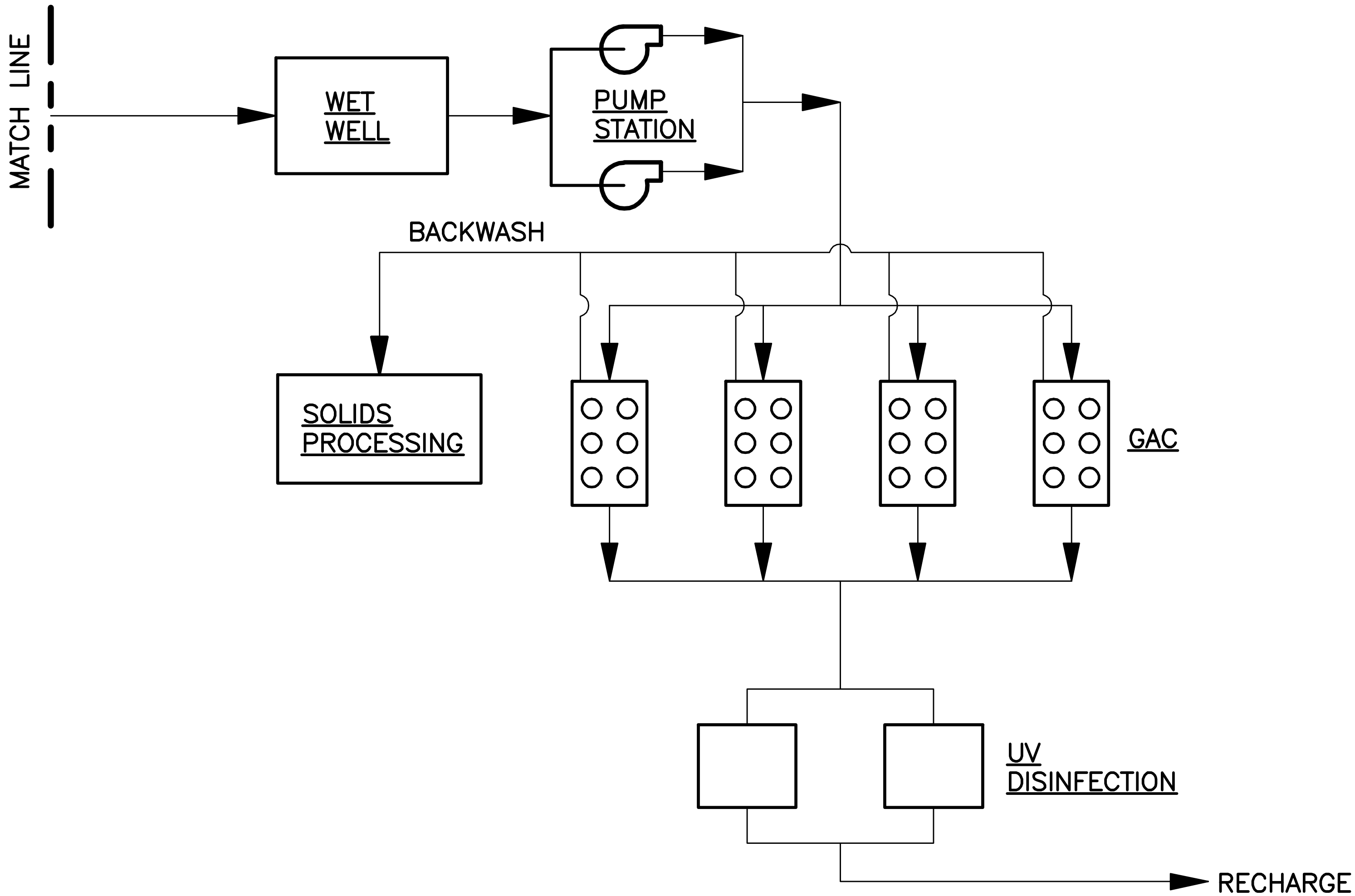
DATE:12/08 JOB No.:70098

CHATHAM
BIOREACTOR/MBR

FIGURE 1 MBR/GAC PROCESS SCHEMATIC

17.12.2008 PETER RENNE
\\FSHYANNIS-2\JOBS\70000\71045\JAN\FIG\70098 MBR-BIOREACTOR FIG-1.DWG

19.01.2009 PETER RENNE
\\FSHYANNIS-2\JOBS\70000\71045\JAN\FIG\70098 GRANULUR ACTIVATED CARBON-OPTION B.DWG



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DATE: 01/09 JOB No.:70098

CHATHAM
GRANULAR ACTIVATED CARBON

FIGURE 2 MBR/GAC PROCESS SCHEMATIC

SITE PLAN – OVERALL
SCALE: 1"= 60'-0"

ISSUE NO.	DRAWN	DATE	CHECKED	DESIGNER	APPROVED	DATE
2	REVISED PER OWNERS COMMENTS					
	RWS	9/06		RWS		
1	PRELIMINARY DESIGN – NOT FOR CONSTRUCTION					
	JJO/RWS	4/06		JJO/RWS		

PROJECT SUPERVISOR ______________ DEPARTMENT SUPERVISOR ______________

ISSUE NO.	DRAWN	DATE	CHECKED	DESIGNER	APPROVED	DATE

STEARNS & WHELER LLC
Environmental Engineers & Scientists
HYANNIS, MASSACHUSETTS

TOWN OF CHATHAM, MASSACHUSETTS
INTERIM IMPLEMENTATION
SITE PLAN–OVERALL

JOB NO. 70098 | CONTRACT | SHEET C–2