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REPORT

June 2017

CITY OF
Portsmouth
NEW HAMPSHIRE

Pease Treatment Cost Alternative Report

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EXECUTIVE SUMMARY

The presence of Per- and Polyfluoroalkyl Substances (PFASs) compounds detected initially in the Haven Well in May of 2014, dictate the need for treatment of three valuable groundwater sources serving the Pease Tradeport Water System. Following the detection of PFASs and the subsequent shut down of this well, testing at the Harrison and Smith Wells indicated total PFAS was present. An initial feasibility study for treatment technologies in the fall of 2015 indicated that granular activated carbon filtration (GAC) was a viable method for removal of PFASs for potable drinking water. In September of 2016, a demonstration study consisting of two 20,000 lb GAC filter vessels was put online to treat the Harrison and Smith Wells. Since the implementation of the demonstration study, over 51 million gallons of water has been treated to non-detect levels of PFOS and PFOA. Valuable information has been learned from this study as well as from surveying other drinking water utilities that are treating to remove PFASs. This information was used to develop design criteria for an appropriate treatment process to treat the combined water flows from Haven, Harrison, and Smith Wells and to evaluate the merits of retrofitting the existing water treatment plant on Grafton Road or constructing a new facility on an adjacent lot.

1.0 GENERAL

1.1 Existing System

The Pease International Tradeport is home to commercial and industrial developments with over 250 companies and is continuing to grow. The near 10,000 employees in this area create a significant daytime water demand. The Tradeport and some abutting residential areas in Newington represent the Pease Pressure Zone. Average day demand (ADD) and maximum day demand (MDD) for the Pease Pressure Zone system for 2016 were 0.64 million gallons and 1.28 million gallons, respectively. The projected MDD for the Tradeport at maximum buildout was estimated by Underwood Engineers (Pease Wastewater Treatment Facility Evaluation, January 2014) to be 1.578 million gallons. The 0.6 million gallon Hobbs Hill Tank, with an overflow elevation of 230 feet, is used as the hydraulic tank in the Pease Pressure Zone. This tank combines with the Air National Guard Tank for a total storage capacity of 1.0 million gallons.

The City of Portsmouth's Harrison, Smith, and Haven municipal wells have historically provided drinking water to the Pease Tradeport system. In addition, portions of Newington were connected to the Tradeport in 2014. The Tradeport supply is supplemented through the Pease booster pumps which are connected to the City of Portsmouth's main pressure zone. All of these sources are piped through the Pease WTP located on Grafton Road. The water is currently treated at the Pease WTP with chlorine, fluoride, and an orthophosphate/polyphosphate blend for corrosion control.

1.2 Background and Work to Date

The Pease WTP was originally designed in the early 1980s for the treatment of Volatile Organic Compounds (VOC's). The total hydraulic capacity of the system was estimated to be between 1,200 and 1,500 gpm. Little is known about the design parameters regarding carbon usage rates or empty bed contact times. Aeration and vapor phase carbon were added as pretreatment processes after the plant's original construction. An extension of the east end of the facility housed the aeration units and an associated clearwell. These facilities were constructed as part of the Haven Well contingency plan for potential VOC contamination removal. A monitoring program managed by the Air Force tracked VOCs and dictated whether or not the system had to be activated. That level never triggered the need to turn the facility on.

The Haven Well is the largest producer of the three wells and an original public drinking water source for the City of Portsmouth that dates back to 1875. Following extensive testing in 2002, NHDES approved the Haven Well for use at 250 gpm and later allowed an increase up to 700 gpm. The treatment plant process equipment however, remained unused and was deemed unusable and subsequently demolished. Since 2002, the Pease Tradeport demand was satisfied using Haven, Smith, and Harrison Wells with the Portsmouth system booster pumps available as emergency supply. Following the detection of PFAS, the Haven Well was hydraulically disconnected from the Tradeport at the Pease WTP. The booster pumps were then utilized to replace the lost Haven Well capacity. This balancing of sources allowed Pease to be supplied with 50% of its water coming from the City system and 50% provided by the Harrison and Smith Wells. The current treatment process schematic is shown in Figure 1-1. The subsequent need to identify, design, and construct appropriate treatment for the water quality concerns is described in the next subsection. Specific design criteria are described in Section 2.0 of this report, while infrastructure components are provided in Section 3.0; associated costs are described in Section 4.0.

1.3 Proposed Project

The treatment for the combined three well sources, the Pease WTP and the booster pump operation is considered to be “the Project”. The upgrades associated with the Project are necessary to reduce PFASs levels to below the health advisory limit currently set at 0.07 μg/L combined PFOA/PFOS.

The regulating force behind this project is driven by the discovery of PFASs in the well water which are on the Environmental Protection Agency’s (EPA) Contaminant Candidate List (CCL). The EPA originally established preliminary health advisory (pHA) limits for two specific PFASs, perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA). Long term limits were set as a current health advisory level (HA) for PFOA and PFOS in May 2016. In addition, four other PFASs were monitored under EPA’s Third Unregulated Contaminant Monitoring Rule (UCMR 3). These include: perfluorononanoic acid (PFNA), perfluorohexanesulfonic acid (PFHxS), perfluoroheptanoic acid (PFHpA), and perfluorobutanesulfonic acid (PFBS). A list of 23 different PFASs that have been monitored by the Air Force at the Harrison and Smith Wells is shown in Appendix A.

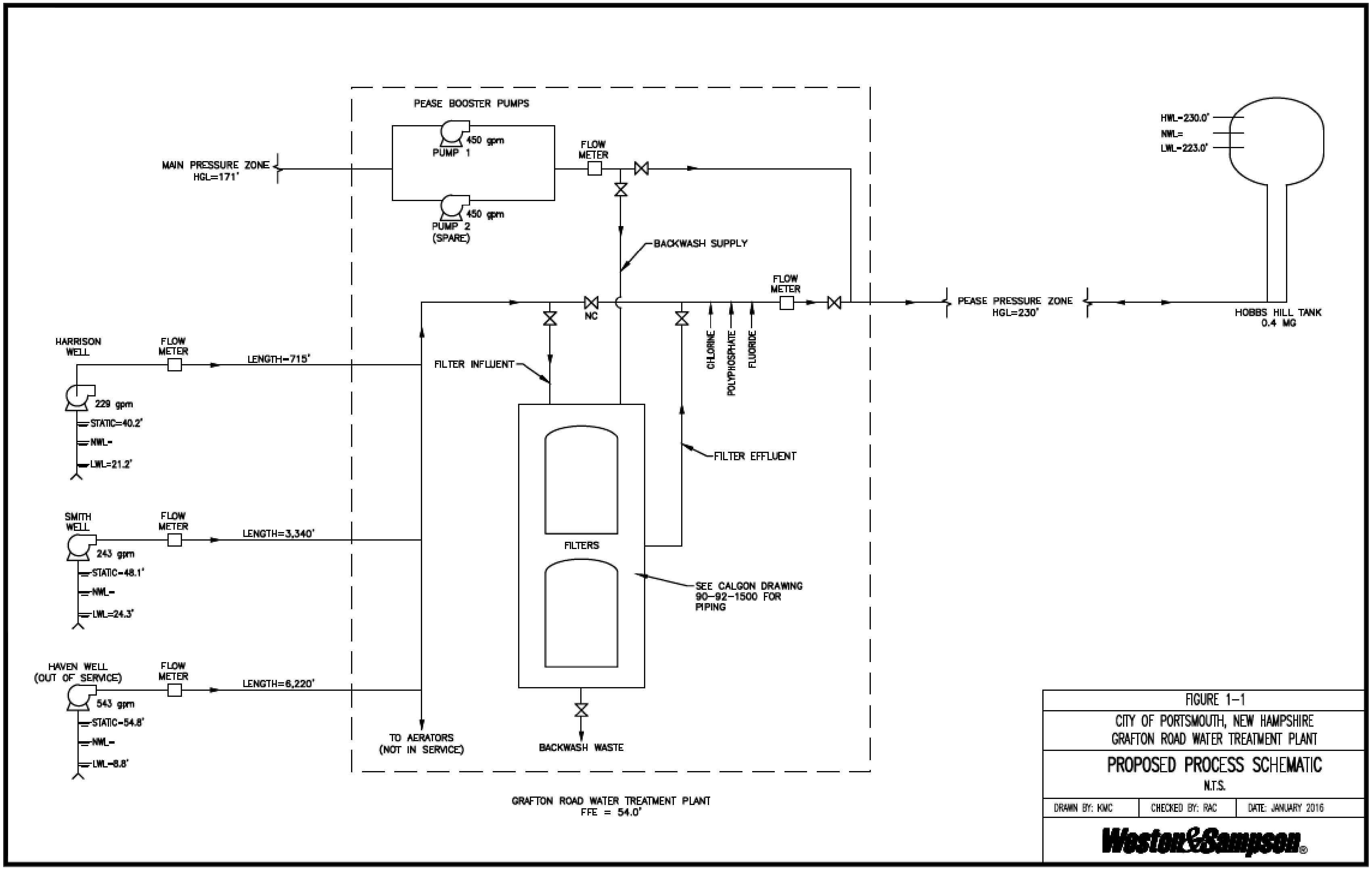

Figure 1-1 – Current Temporary Treatment Process Flow Schematic

2.0 DESIGN CRITERIA

2.1 Water Supply

The City of Portsmouth maintains three wells that discharge to the water system that supplies the Pease International Tradeport (Pease Pressure Zone). The Pease pressure zone also uses supplemental water from the City's Main Pressure Zone through the Pease booster pumps located at the Pease WTP as necessary. The Pease water supply well capacities are presented in Table 2-1.

Table 2-1 – Well Water Supply Summary

Well	Design Capacity
Harrison Well (gpm)	286
Smith Well (gpm)	343
Haven Well (gpm)	534
Total Flow (gpm)	1,163

The proposed design capacity of the WTP was estimated with consideration for the safe yield of the wells and the actual pumping capacity of the wells and pumps. The Harrison and Smith wells have potential capacities in excess of the safe yield. These capacities allow operators to pump the wells less than 24-hours a day at higher rates to meet variable system demands and remain within the safe yield volumes. The planned WTP design capacity is 125% of the safe yield of Harrison well and at the existing pump capacity of the Smith well. Given the groundwater treatment scheme presented for the Haven well by the Air Force, it currently will not be possible to peak the Haven well above its safe yield, therefore the WTP design capacity is the same as the safe yield for that well.

It is recommended that the Pease Booster Pumps be upgraded to provide emergency redundancy to the well water capacity of the WTP and be sized to supply water to the Pease Pressure Zone. The estimated maximum flow rate of these pumps would be equivalent to the current maximum day demand of 1.2 MGD plus 25%, or 1,040 gpm.

PFASs were found in Harrison, Haven, and Smith Wells, with the Haven Well containing significantly higher levels of PFAS than the other two wells. The sample results of 14 PFASs, approved for analysis under EPA Test Method 537 Rev. 1.1, is summarized in Table 2-2.

From 2014 through 2016, background water quality data was collected and compiled to more accurately estimate the life of the carbon filtration media. In particular, the presence of organic material in the raw water may compete for adsorption sites in the carbon media bed and may reduce the longevity of the carbon. Iron and manganese may impact carbon life by blinding the carbon media. Using aeration for the removal of any potential VOCs that may be present will extend the life of the carbon, as well as to strip any radon from the water is recommended. Tetrachloroethylene (PCE) has been identified in monitoring wells near the Haven Well and an estimated value of PCE will be used to size the aeration towers. Although VOCs have not been detected at the Harrison and Smith Wells, radon is present in the wells. These select water quality parameters are also listed in Table 2-2.

Table 2-2 – Raw Water Quality Characteristics

Parameter	Blended Water*	Haven Well
Sampling Period	9/2016-3/2017	PFAS: 4/2014-5/2014 Non-PFAS: 11/2016
NEtFOSAA (µg/L)	ND	-
NMEFOSAA (µg/L)	ND	-
PFBS (µg/L)**	0.024	0.051
PFDA (µg/L)	ND	0.004
PFDoA (µg/L)	ND	ND
PFHpA (µg/L)**	0.055	0.120
PFHxS (µg/L)	0.423	0.900
PFHxA (µg/L)**	0.158	0.340
PFNA (µg/L)	0.008	0.017
PFOS (µg/L)***	1.134	2.45
PFOA (µg/L)***	0.155	0.335
PFTA (µg/L)	ND	-
PFTrDA (µg/L)	ND	-
PFUnA (µg/L)	ND	ND
Radon (pCi/L)	1036	1203
pH	7.5	7.4
Iron (mg/L)	0.11	0.15
Manganese (mg/L)	0.14	0.31
Total Organic Carbon (mg/L)	0.40	0.40
PCE (µg/L)	4.59	10

*Blended water ratio: 24.6% Harrison Well, 29.5% Smith Well, 45.9% Haven Well
**Designates "short chain" compounds
***MCL for combined PFOA and PFOS is 0.07 µg/L

2.2 Demonstration Study Results

Treatment effectiveness is shown through the water quality sampling taken throughout the demonstration study. Results from the demonstration study to date show seven months of operation without identifiable breakthrough at the 25% sampling port. This period of operation corresponds to approximately 10,000 bed volumes and approximately 51.5 million gallons of water treated. Occasional "J" values have been detected at various locations within the treatment system. These values are results between the method detection limit and the reporting limit and should not be considered quantifiably accurate. No trend has been identified with these J value results. All PFASs results are reported in Appendix A.

The demonstration study has shown that GAC works well for treating the PFAS concentrations in the Harrison and Smith wells. Information gleaned from the demonstration study include the necessity of having the ability to filter to waste, the advantages of below ground storage tanks, the need to recycle backwash waste water back to the wet wells so that all water containing PFASs is treated.

2.3 Finished Water

Select finished water requirements and other parameters are shown in Table 2-3. PFOS and PFOA will be removed with GAC to levels below the health advisory (HA) of 0.07 μg/L (total combined PFOA and PFOS). The most current HA was established in May of 2016. In addition, the pH of the finished water must remain between 7.3-7.8 to comply with the Lead and Copper Rule and the residual orthophosphate in the water should be greater than 1.0 mg/L. Iron and Manganese concentrations will remain unaltered through the treatment system. Radon in the raw water will be removed in the aeration tower; any residual radon will be removed by the GAC. Total organic carbon will initially be removed by the GAC, however, it is anticipated that TOC breakthrough of the GAC will occur before PFOS/PFOA breakthrough.

Table 2-3 – Finished Water Quality Requirements

Parameter	Finished Water
Select Requirements	
PFOS (ng/L)	<70
PFOA (ng/L)	<70
PCE (µg/L)	<5
pH	7.3-7.8
Orthophosphate (mg/L)	>1
Other Select Water Quality Goals	
Iron (mg/L)	Same as influent
Manganese (mg/L)	Same as influent
Radon (pCi/L)	ND
Total Organic Carbon (mg/L)	Same as influent

2.4 Analogous System Research

A list of the drinking water utilities that were contacted to gather analogous water quality data are listed in Table 2-4; further information on these system is reported in Appendix B. Of the 15 systems listed, none have PFAS concentrations similar to the concentrations of PFOS and PFOA in the blended water at the Pease system. Nine of the 15 systems have, or will soon have, GAC treatment, 1 system will utilize GAC and resin, 1 system will focus on point of use GAC treatment, 3 will not be treating their wells (raw water concentrations below the HA levels), and 1 did not provide information. Treating water to remove PFASs with carbon is currently the standard method of treatment. Carbon allows for the capture of the contaminant and the shipment of the contaminated carbon offsite for safe incineration. From the limited operational data available, it appears carbon can last 20,000+ bed volumes provided total organic carbon levels are not high. What is important to note from this gathering of information is the necessity to tailor the carbon selection to the individual water sources. For example, piloting by some systems such as Suffolk County Water Authority has shown the failure of coconut based carbon to sufficiently capture PFOS and PFOA (Figure 2-1) while the Issaquah system is using coconut carbon in their full scale system, and has reported successful removal. Bituminous coal-based GAC has been shown to be effective at removing PFASs from water from the Harrison and Smith Wells in the Demonstration Study.

Table 2-4 – Drinking Water Utilities Contacted for Information

Drinking Water Utility
Aqua America (PA)
Barnstable (MA)
Bennington (VT)
Hoosick Falls (NY)
Horsham (PA)
Issaquah (WA)
Joint Base McGuire-Dix-Lakehurst (NJ)
Little Hocking (OH)
Merrimack Valley District (NH)
New Castle (DE)
Oakdale (MN)
Oatman Water Co. (AZ)
Suffolk County (NY)
West Morgan-East Lawrence (AL)
Wurtsmith (MI)

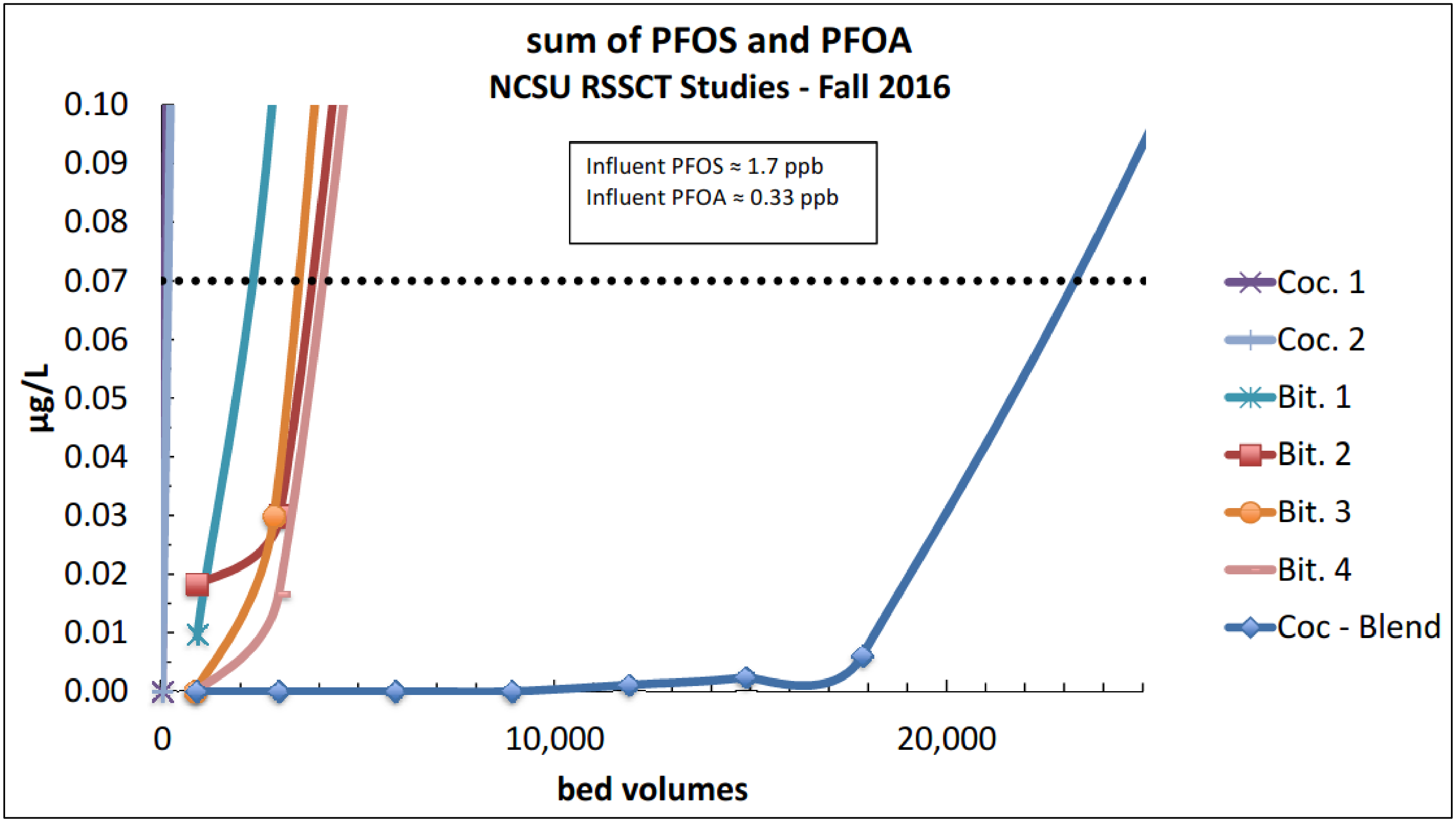

Figure 2-1 – Suffolk County Column Test

3.0 TREATMENT FACILITY DESCRIPTION

3.1 Design Criteria

The combined flow will enter the treatment plant and will be treated as a blend with water quality shown in Table 2-2. New Hampshire follows the Ten States Standards which requires “n-1” redundancy for treatment plant equipment. This redundancy standard states that if an asset were to be taken offline, there must be enough capacity in the remaining assets to handle maximum flow conditions. Due to this design requirement, two aeration towers are needed with two wet wells, two pumps to pump from each wet well, and four pair of GAC vessels are needed (three pair are necessary for full flow). Having this redundancy creates a more resilient plant but requires more space necessitating building expansion. A flow diagram of the proposed schematic is shown in Figure 3-1.

As discussed earlier, the treatment plant will have aeration towers to strip radon and potential VOCs that may arise in the Haven Well. Water will be pumped out of the wet wells through the GAC vessels. The vessels will have an EBCT of at least 10 minutes to allow for proper PFAS adsorption. Water will then recombine in a header before being treated with fluoride, phosphate, and hypochlorite. Upon installation of new carbon, the filters will be backwashed to remove carbon fines. The backwash waste water will be stored in a backwash waste tank. To minimize the volume of PFAS contaminated water, a recycle system will pump the supernatant water from the waste tank back to the wet wells. The filter vessels will also have the ability to filter to waste on startup to minimize pH fluctuations associated with virgin carbon that may impact compliance with the Lead and Copper Rule.

3.2 Sequence of Construction

3.2.1 Retrofitting Existing Building

Retrofitting the existing water treatment plant on Grafton Road poses several unique challenges. Due to water supply requirements, the demonstration filters, booster pumps, and all ancillary equipment must remain in operation during construction. Demolition and construction of new equipment would need to occur around these vital features. A plan view of the retrofitted building and a site plan are shown in Figures 3-2 and 3-3, respectively. The approximate sequence of construction is detailed below.

- Excavate and form below grade tanks
- Place two pair of GAC vessels and two aeration towers in new portion of building
- Expand front of building to include chemical storage rooms and new restroom
- Install remaining equipment necessary to start up new GAC vessels
- Upgrade and reposition existing GAC vessels and install final pair of GAC vessels in the old portion of the building
- Upgrade lab space

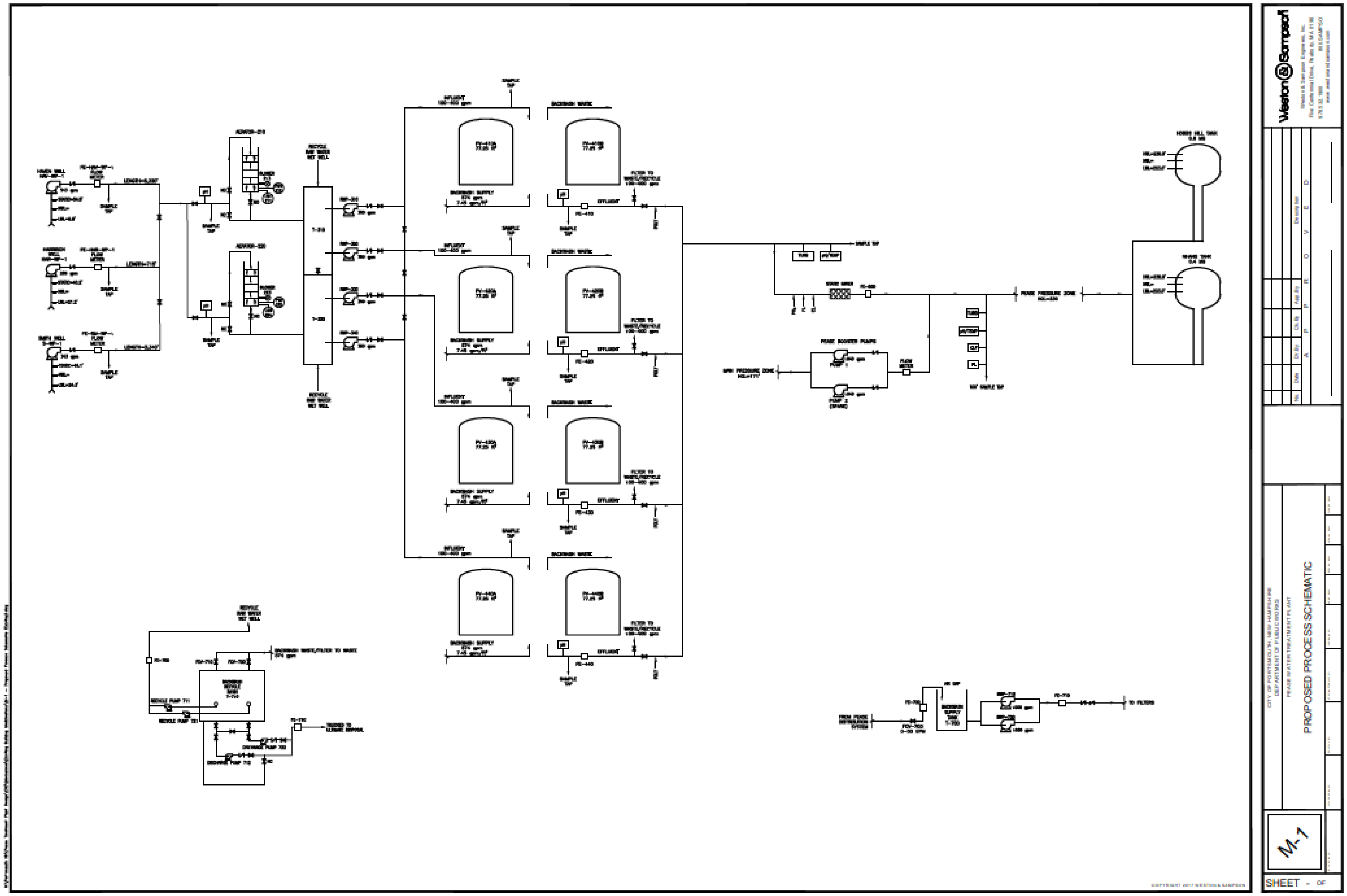

Figure 3-1 – Proposed Process Flow Schematic

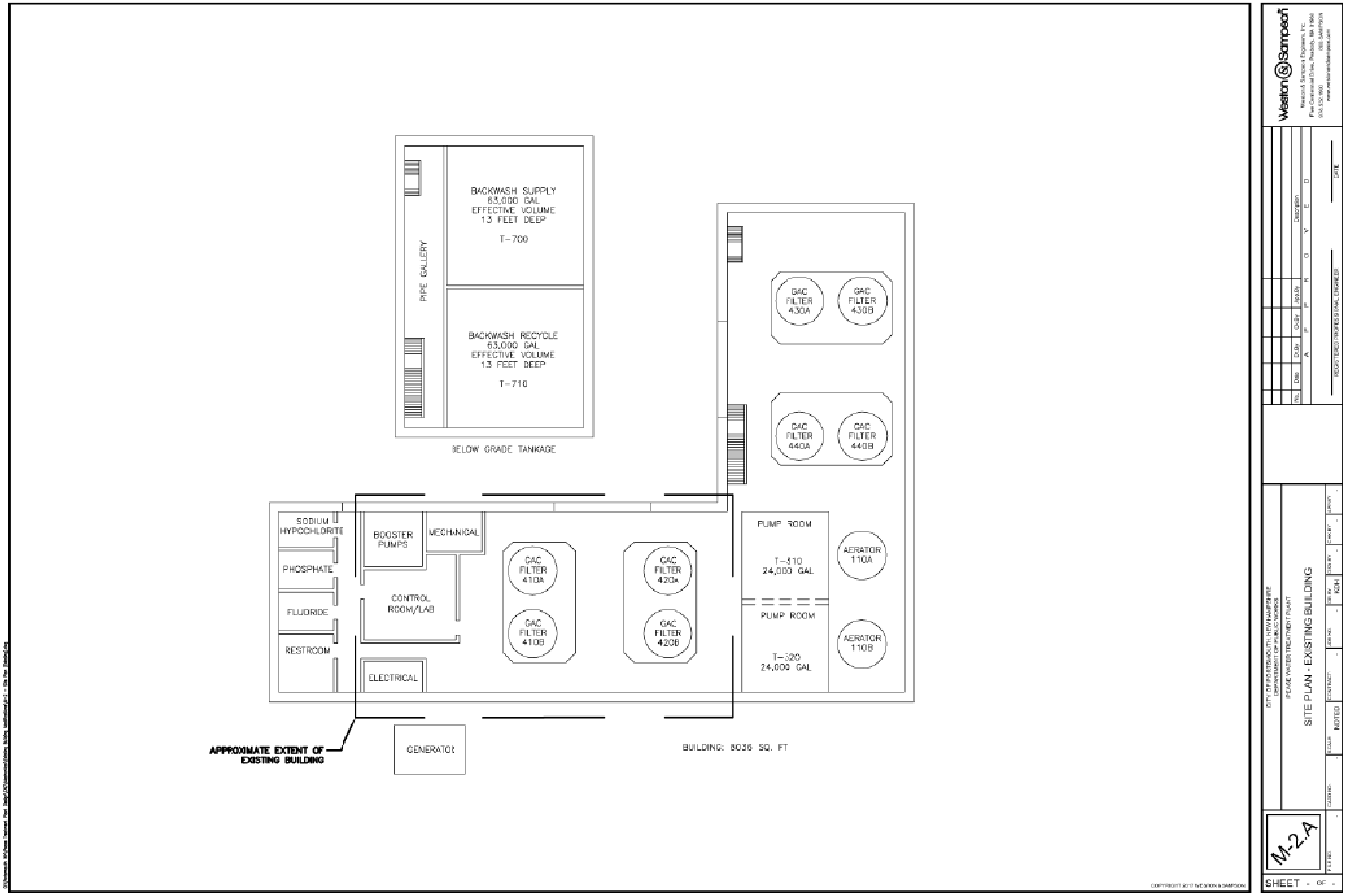

Figure 3-2 – Retrofit Building Layout

Figure 3-3 – Building Retrofit Site Plan

3.2.2 New Building

In comparison to the building retrofit, construction a new facility on the adjacent lot is simpler from a sequencing standpoint. The demonstration study GAC filters would need to remain in operation until the new facility can produce sufficient flow to meet water demands of the Pease Tradeport. Once enough water can be produced from the new facility, the demonstration filters can be moved and the existing facility can be demolished. A plan view of the retrofitted building and a site plan are shown in Figures 3-4 and 3-5, respectively. The approximate sequence of construction is detailed below.

- Excavate and form below grade tanks
- Place three pair of GAC vessels and two aeration towers
- Construct the front end of the building housing the lab/control room, chemical storage rooms, mechanical and electrical rooms and the new restroom
- Install all remaining equipment necessary to start up new GAC vessels
- Move the demonstration GAC vessels from the existing building to the new facility
- Demolish the existing facility

3.3 Carbon Life Projection

General industry information suggests GAC systems are designed for and expected to effectively remove PFASs for 20,000 bed volumes. This however, is dependent on several factors including (1) which perfluorinated compounds are being analyzed, (2) the interactions between the specific water source and (3) the PFAS makeup, and the acceptable amount of breakthrough or reserve carbon.

(1) Short chain compounds do not adsorb to GAC as efficiently as long chain compounds. If treating for short chain compounds in addition to long chain compounds, breakthrough could be expected to occur much earlier in the bed life.

(2) GAC interacts differently with different source waters and their respective water quality constituents. Coconut carbon works well for some water sources, as is being shown in Issaquah, while not well with other waters, as shown in the column study performed using water from the Suffolk County Water Authority. Tailoring the carbon to the specific water source is vital to ensuring long bed life.

(3) The final determination in carbon life revolves around carbon changeout procedures. Some utilities will not accept any breakthrough of any constituents while other may allow some unregulated short chain compounds to breakthrough. Most utilities treat for PFOS/PFOA and only to the HA. Almost all analogous systems ran their filters in a lead/lag orientation. Some of these utilities were experimenting with flipping the lead and the lag vessels to try to promote longer carbon life.

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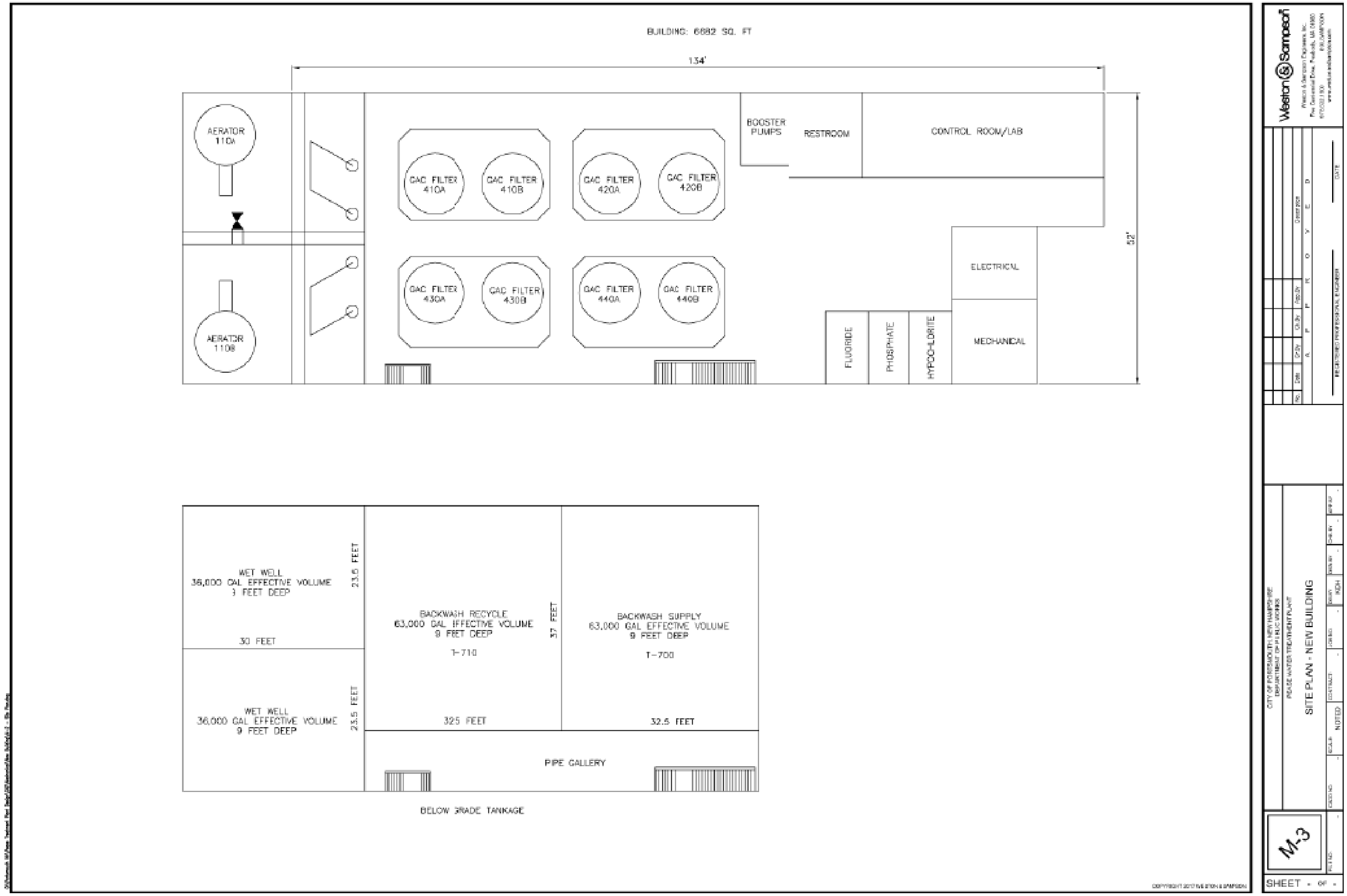

Figure 3-4 – New Building Layout

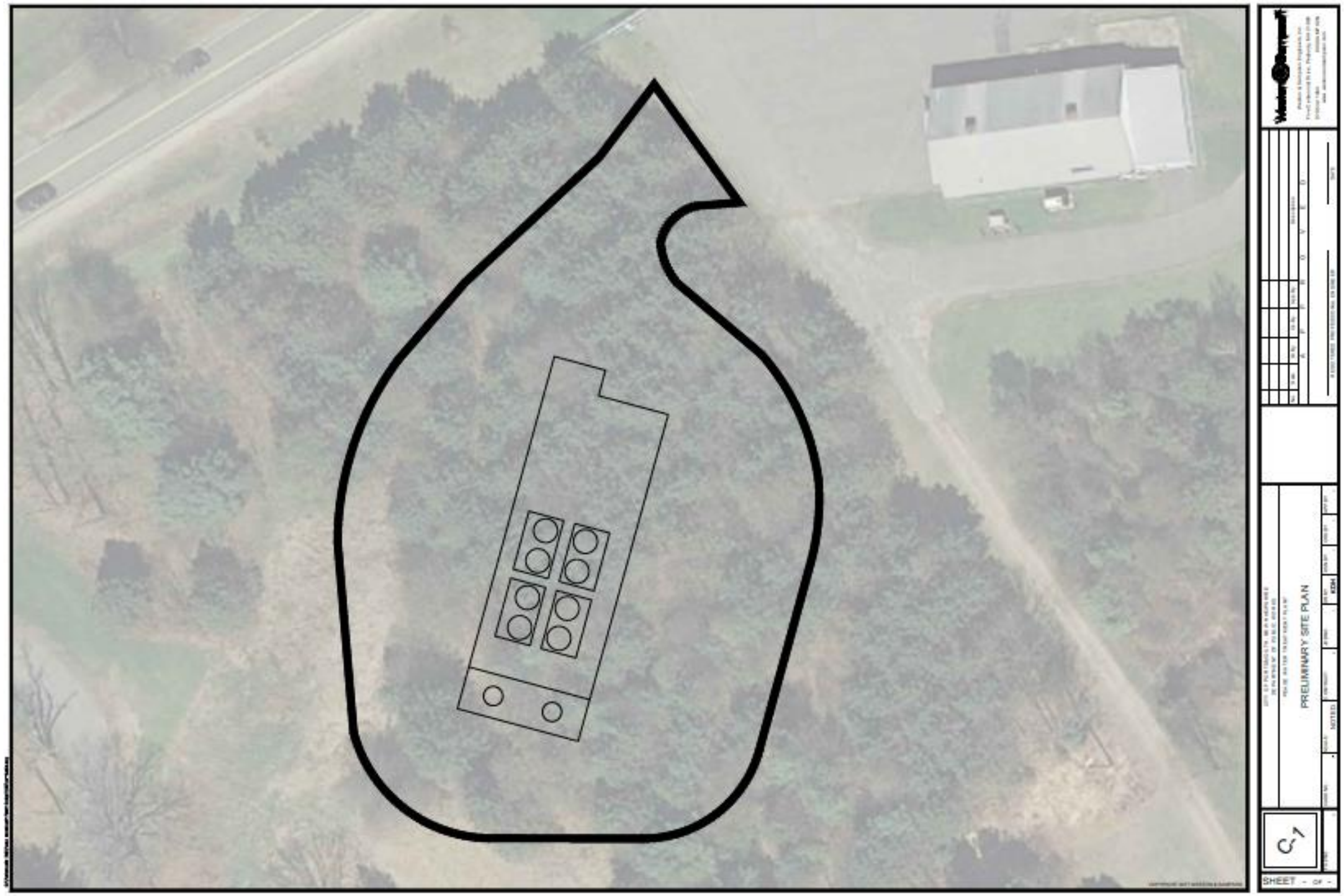

Figure 3-5 – New Building Site Plan

4.0 ESTIMATED PROJECT COSTS

4.1 Cost Estimate

4.1.1 Capital Costs

Retrofitting the existing building is estimated to have a capital cost of approximately $13,170,000. Design costs for this alternative are estimated to be $1,317,000 with a recommended budget for construction administrative and resident representative costs of 10-15% of the total construction cost.

Constructing a new facility on the adjacent lot to the current facility is estimated to have a capital cost of approximately $12,906,000. This construction cost includes demolition of the existing facility including structures, piping, and foundation components. Design costs for this alternative are estimated to be $1,291,000 with a recommended budget for construction administrative and resident representative costs of 10-15% of the total construction cost.

A detailed breakdown of the costs in located in Appendix C.

4.1.2 Annual Costs

The retrofitted building and the new facility are expected to have near identical annual operating and maintenance costs of approximately $163,000. This covers costs associated with electrical, chemical, and staffing costs (48 hours/week average). This excludes GAC replacement which should be identical between the different alternatives. The new facility would require a land lease from the Pease Development Authority on the order of $16,500/acre/yr.

4.1.3 Present Worth Comparison

A present worth comparison using the above capital and annual costs for 30 years at an interest rate of 3% is shown below in Table 4-1.

Table 4-1 – Present Worth Comparison of Design Options

Design Option	Present Worth Cost
Building Retrofit	$19,658,000
New Facility	$19,651,000

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APPENDIX A

Demonstration Study Results

Sample Location	Sample ID	Collection Date	6:2 Fluorotelomer sulfonate (6:2 FTS)	8:2 Fluorotelomer sulfonate (8:2 FTS)	N-Ethyl perfluorooctane sulfonamide (EtFOSA)	N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE)	N-Methyl Perfluorooctane Sulfonamide (MEFOSA)	N-Methyl Perfluorooctane Sulfonamidoethanol (MEFOSE)	Perfluorobutanesulfonic acid (PFBS)	Perfluorobutanoic acid (PFBA)	Perfluorodecane sulfonate (PFDS)	Perfluorodecanoic acid (PFDA)	Perfluorododecanoic acid (PFDoA)	Perfluoroheptane sulfonate (PFHpS)	Perfluoroheptanoic acid (PFHpA)	Perfluorohexanesulfonic acid (PFHxS)	Perfluorohexanoic acid (PFHxA)	Perfluorooctanoic acid (PFOA)	Perfluorononanoic acid (PFNA)	Perfluorooctane sulfonamide (PFOSA)	Perfluorooctanesulfonic acid (PFOS)	Perfluoropentanoic acid (PFPeA)	Perfluorotetradecanoic acid (PFTeDA)	Perfluorotridecanoic acid (PFTrDA)	Perfluoroundecanoic acid (PFUnA)	PFOS+PFOA
USEPA Health Advisory (HA):			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.07	-	-	0.07	-	-	-	-	0.07
Method Detection Limit (MDL)			0.0065	0.0055	0.0053	0.0049	0.0040	0.0061	0.0019	0.0066	0.0043	0.0066	0.0057	0.0036	0.0047	0.0040	0.0046	0.0053	0.0046	0.0058	0.0033	0.0036	0.0052	0.0032	0.0037	
Reported Detection Limit (RDL)			0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	
Harrison Well		13-Sep-16	ND	ND	NA	NA	NA	NA	0.0029 B	ND	NA	NA	NA	ND	ND	0.0260 B	0.0071 J	0.006 J	ND	ND	0.022 B	0.008 B	NA	NA	NA	0.028
Smith Well		19-Sep-16	ND	ND	NA	NA	NA	NA	0.0072 J	0.0067 J	NA	NA	NA	ND	ND	0.0150 J	0.0053 J	0.006 J	ND	ND	0.013 J	0.007 J	NA	NA	NA	0.019 J
Harrison Well		26-Sep-16	ND	ND	NA	NA	NA	NA	0.0040 J	ND	NA	NA	NA	0.0042 J	ND	0.0340	0.0100 J	ND	ND	ND	0.024	0.014 J	NA	NA	NA	0.024
Smith Well		26-Sep-16	ND	ND	NA	NA	NA	NA	0.0029 J	ND	NA	NA	NA	0.0036 J	ND	0.0140 J	0.0050 J	ND	ND	ND	0.010 J	0.008 J	NA	NA	NA	0.010 J
Harrison Well		19-Oct-16	ND	ND	NA	NA	NA	NA	0.0038 J	0.0069 J	NA	NA	NA	ND	0.0057 J	0.0320	0.0059 J	ND	ND	ND	0.022	0.009 J	NA	NA	NA	0.022
Smith Well		19-Oct-16	ND	ND	NA	NA	NA	NA	0.0035 J	ND	NA	NA	NA	ND	ND	0.0130 J	ND	ND	ND	ND	0.010 J	0.005 J	NA	NA	NA	0.010 J
Harrison Well		17-Nov-16	ND	ND	NA	NA	NA	NA	0.0026 J	0.0072 J	NA	NA	NA	ND	0.0059 J	0.0350	0.0085 J	0.006 J	ND	ND	0.026	0.013 J	NA	NA	NA	0.032
Smith Well		17-Nov-16	ND	ND	NA	NA	NA	NA	0.0020 J	ND	NA	NA	NA	ND	ND	0.0140 J	ND	ND	ND	ND	0.011 J	0.008 J	NA	NA	NA	0.011 J
Harrison Well		14-Dec-16	ND	ND	NA	NA	NA	NA	0.0062 J	0.0068 J	NA	NA	NA	ND	ND	0.0350	0.0120 J	0.0078 J	ND	ND	0.026	0.012 J	NA	NA	NA	0.034
Smith Well		14-Dec-16	ND	ND	NA	NA	NA	NA	ND	ND	NA	NA	NA	ND	ND	0.0150 J	0.0065 J	ND	ND	ND	0.012 J	0.0059 J	NA	NA	NA	0.012 J
Smith Well (Dup)		14-Dec-16	ND	ND	NA	NA	NA	NA	0.0055 J	ND	NA	NA	NA	ND	ND	0.0150 J	0.0057 J	ND	ND	ND	0.012 J	0.006 J	NA	NA	NA	0.012 J
Filter 2 Effluent	S1	22-Sep-16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 1 - 25%	PV1-25	06-Oct-16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 2 Effluent	PV2-100	06-Oct-16	ND	ND	ND	ND	0.0065 J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 1 - 25%	PV1-25	14-Oct-16	ND	ND	ND	ND	ND	ND	0.0022 B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 1 Effluent	PV1-100	14-Oct-16	ND	ND	ND	ND	ND	ND	0.0021 B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 2 Effluent	PV2-100	14-Oct-16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0053 J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 1 - 25%	PV1-25	20-Oct-16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 1 Effluent	PV1-100	20-Oct-16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 2 Effluent	PV2-100	20-Oct-16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 1 - 25%	PV1-25	28-Oct-16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0082 J	ND	ND	ND	0.0062 J	ND	0.0052 J	ND	ND	ND	ND	0.0082 J	0.0084 J	ND
Filter 1 Effluent	PV1-100	28-Oct-16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0049 J	ND	ND	ND	ND	0.0078 J	0.0081 J	ND
Filter 2 Effluent	PV2-100	28-Oct-16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0040 J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 1 - 25%	PV1-25	10-Nov-16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 1 Effluent	PV1-100	10-Nov-16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 1 - 25%	PV1-25	28-Nov-16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 1 Effluent	PV1-100	28-Nov-16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 1 - 25%	PV1-25	27-Dec-16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 1 Effluent	PV1-100	27-Dec-16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 1 - 25%	PV1-25	16-Jan-17	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 1 Effluent	PV1-100	16-Jan-17	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 1 - 25%	PV1-25	10-Feb-17	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 1 Effluent	PV1-100	10-Feb-17	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 1 - 25%	PV1-25	07-Mar-17	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 1 Effluent	PV1-100	07-Mar-17	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 1 - 25%	PV1-25	20-Mar-17	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 1 Effluent	PV1-100	20-Mar-17	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 1 - 25%	PV1-25	27-Mar-17	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 1 - 50%	PV1-50	27-Mar-17	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0056 J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Filter 1 Effluent	PV1-100	27-Mar-17	ND	ND	0.0097 J	ND	ND	0.0052 J	ND	ND	ND	ND	ND	ND	ND	0.0068 J	ND	ND	ND	ND	0.0036 J	ND	ND	0.0033 J	ND	ND

Notes:
Grey text indicates the parameter was not analyzed or not detected.
All concentrations in µg/L - micrograms per liter (ppb)
J - The result is an estimated value.
B - Detected in Blank.

USEPA - Environmental Protection Agency
NA - Not Analysed or Not Applicable
ND - Not detected
— - No Health Advisory available

- Denotes 'B' value, detected in blank
- Denotes raw water influent sample
- Denotes short chain compound

APPENDIX B

Analogous System Data

	Treatment Date	*Treatment Type*	*PFAS Concentration (ppb)*	*Flow Rate (gpm)*	*Type of Carbon*	*Approximate Carbon Life*	*Sampling Frequency*	*Changeout Criteria*
Pease (NH)	**2016**	**GAC**	**Blend** **PFOA: 0.155** **PFOS: 1.134**	**1163**	**F400**	**-**	**-**	**-**
Aqua America (PA)	N/A	N/A	All PFAS < 0.07	N/A	N/A	N/A	Every Other Week to Monthly	N/A
Barnstable (MA)	2015	GAC	PFOA: 0.18 PFOS: 0.11	-	-	-	-	-
Bennington (VT)	2016	GAC (POE)	PFOA: 1.0	N/A	-	N/A	-	-
Hoosick Falls (NY)	2016	GAC	PFOA: 0.45	0.45 MGD	F400	-	Weekly	-
Horsham (PA)	2016	GAC + Resin	PFOS: 1.0	-	-	N/A	-	-
Issaquah (WA)	2016	GAC	PFOS: 0.40	0.33 MGD	TIGG 5DC 1230 NSF	14,700+ BV	Every Other Week	-
Joint Base McGuire-Dix-Lakehurt (NJ)	N/A	N/A	Combined PFOA/PFOS<0.07	N/A	N/A	N/A	-	-
Little Hocking (OH)	2007	GAC	PFOA: 0.37-21	-	F600	2-3 Months	Every Other Week	Quantifiable PFOA breakthrough of lead filter
Merrimack Valley District (NH)	N/A	GAC	PFOA: 0.09	-	-	N/A	-	-
New Castle (DE)	2015	GAC	PFOA: 0.14 PFOS: 1.3	1100	F400	1.5+ years	Several Times per Year	-
Oakdale (MN)	2006	GAC	PFOA: 0.64 PFOS: 0.71	2400	F600	53,000 BV	Monthly	When PFOA effluent from lead filter is 50% raw water concentration, let other compounds pass through
Oatman (AZ)	-	-	PFOA: 0.032 PFOS: 0.30	-	-	-	-	-
Suffolk County (NY)	2016	GAC	PFOA: 0.33 PFOS: 1.7	-	F23	20,000 BV (Column)	-	-
West Morgan-East Lawrence (AL)	2016	GAC	PFOA: 0.15 PFOS: 0.12	3500	-	N/A	-	-
Wurtsmith (MI)	N/A	N/A	Combined PFOA/PFOS<0.07	N/A	N/A	N/A	-	-

APPENDIX C

Detailed Cost Estimate

April 2017 Estimate of Probable Construction Cost				
Refurbish / Expand Grafton Rd Plant				
Alternative 1				
Portsmouth, NH				
Item		Unit Cost	Units	Total
1	General Conditions	$1,000,000	1	$1,000,000
2	Site Work	$200,000	1	$200,000
3	Sewer Work	$250	1000	$250,000
4	Demolition	$250,000	1	$250,000
5	Site Piping & conduit	$150	800	$120,000
6	Masonry	$75	12324	$763,125
7	Roofing	$35	9353	$327,355
8	Trusses	$16	8036	$128,576
9	Temporary Const & sequencing constrai	$750,000	1	$750,000
10	Painting	$250,000	1	$250,000
11	Well Pumps	$60,000	3	$180,000
12	Raw Water pumps	$60,000	4	$240,000
13	Emergency Supply Pumps	$90,000	2	$180,000
14	Backwash Pumps	$40,000	2	$80,000
15	Waste Pumps	$20,000	2	$40,000
16	Chemical Feed Equipment	$60,000	3	$180,000
17	GAC Filters & media - (4 pair filters)	$535,000	4	$2,140,000
18	Concrete Slab on Grade	$125,000	1	$125,000
19	BW Holding and Storage Below Ground Tanks (2) inc. piping gallery	$1,000,000	1	$1,000,000
20	Aeration	$230,000	2	$460,000
21	Lab Furnishings	$75,000	1	$75,000
22	Bathroom	$80,000	1	$80,000
23	Instrumentation	$50,000	1	$50,000
24	SCADA Controls	$125,000	1	$125,000
25	Analyzers	$15,000	5	$75,000
26	Valves	$10,000	20	$200,000
27	Interior Piping	$200	1300	$260,000
28	HVAC and Plumbing	$300,000	1	$300,000
29	Electrical	$750,000	1	$750,000
30	Sprinkler system	$96,000	1	$96,000
31	Emergency Generator w/ ATS	$300,000	1	$300,000
	Construction Subtotal			$ 10,975,056
	Contingency (20%)			$ 2,195,011
	Total Construction			**$ 13,170,067**
	Engineering Design / Permitting (10%)			**$ 1,317,007**
	CA&RR (Recommend 10-15% of Total Construction)			
Assumptions				
Below Ground Backwash storage and holding tanks				
Four new pair of GAC filter vessels				
Treatment of 1163 gpm blended raw water				

April 2017 Estimate of Probable Construction Cost				
New Facility				
Alternative 2				
Portsmouth, NH				
Item		Unit Cost	Units	Total
1	General Conditions	$1,000,000	1	$1,000,000
2	Site Work	$500,000	1	$500,000
3	Sewer Work	$250	700	$175,000
4	Demolition	$750,000	1	$750,000
5	Site Piping & conduit	$150	3000	$450,000
6	Masonry	$75	9672	$725,400
7	Roofing	$35	7730	$270,550
8	Trusses	$16	6682	$106,912
9	Painting	$200,000	1	$200,000
10	Well Pumps	$60,000	3	$180,000
11	Raw Water pumps	$60,000	4	$240,000
12	Emergency Supply Pumps	$90,000	2	$180,000
13	Backwash Pumps	$40,000	2	$80,000
14	Waste Pumps	$20,000	2	$40,000
15	Chemical Feed Equipment	$60,000	3	$180,000
16	GAC Filters (4 pair filters)	$535,000	4	$2,140,000
17	BW Holding and Storage Below Ground Tanks (2) inc. piping gallery	$1,300,000	1	$1,300,000
18	Aeration	$230,000	2	$460,000
19	Lab Furnishings	$75,000	1	$75,000
20	Bathroom	$80,000	1	$80,000
21	Instrumentation	$50,000	1	$50,000
22	SCADA Controls	$125,000	1	$125,000
23	Analyzers	$15,000	5	$75,000
24	Valves	$10,000	20	$200,000
25	Interior Piping	$200	1000	$200,000
26	HVAC and Plumbing	$250,000	1	$250,000
27	Electrical	$600,000	1	$600,000
28	Sprinkler system	$80,000	1	$80,000
29	Emergency Generator w/ ATS	$300,000	1	$300,000
30	Concrete Slab on Grade	$210,000	1	$210,000
	Construction Subtotal			$ 11,222,862
	Contingency (15%)			$ 1,683,429
	Total Construction			**$ 12,906,291**
	Engineering Design (10%)			**$ 1,290,629**
	CA&RR (Recommend 10-15% of Total Construction)			
Assumptions:				
Below ground backwash storage and holding tanks				
Four new pair of GAC filter vessels				
Treatment of 1163 gpm blended raw water				