APPENDIX D

ASSESSMENT OF GROUNDWATER TREATMENT TECHNOLOGIES

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1.0 INTRODUCTION

If groundwater extraction is included as a component of Site remediation, the extracted groundwater may require treatment prior to discharge/disposal. A description and analysis of potential groundwater treatment technologies that may be applicable for treating the chemicals in the groundwater at the Site is presented in this appendix.

A summary of the estimated concentrations of the chemicals in the extracted groundwater and a summary of the effluent criteria is presented in Section 2.0. A description of the alternative groundwater treatment options is presented in Section 3.0. An analysis of the groundwater treatment alternatives with respect to effectiveness, implementability and cost is presented in Section 4.0 and summarized in Section 5.0.

2.0 ESTIMATED GROUNDWATER TREATMENT SYSTEM INFLUENT CONCENTRATIONS

As discussed in Appendix E, the influent flow rate to a groundwater treatment system under steady-state pumping conditions was estimated to be approximately 70 gallons per minute (gpm) as outlined below:

- 9 gpm from each of five bedrock extraction wells (i.e., 45 gpm) along the boundary of the Site;
- 7 gpm from an overburden tile collection system in the northern section of the Site; and
- 15 gpm from an overburden tile collection system in the southern section of the Site.

Based on the above flow rates and the groundwater sampling data collected during 1991 and 1995, the average concentrations of the chemicals of concern in each bedrock extraction well and tile collection system were calculated. The average groundwater concentrations for the bedrock extraction wells and tile collection systems were combined proportionately to estimate the influent concentrations of the COCs to the groundwater treatment system. The estimated influent concentrations were based on the average groundwater concentrations for the 2001/2002 sampling programs. These concentrations are considered to represent average concentrations for the duration of groundwater containment and treatment. The estimated influent concentrations are summarized in Table D.1 and were used as a basis for evaluating the potential groundwater treatment technologies.

3.0 ALTERNATIVE GROUNDWATER TREATMENT PROCESS OPTION DESCRIPTIONS

The response actions, groundwater remediation technologies and process options evaluated for the Site are listed below:

Response Action	*Technology*	*Process Options*
Removal/Treatment	• On-Site Physical	• Carbon Adsorption • Air Stripping • Aeration
	• On-Site Chemical	• UV/Oxidation
	• On-Site Biological	• Biological
	• Off-Site Treatment	• Discharge to POTW • Treatment at a RCRA Facility

3.1 CARBON ADSORPTION

The process of adsorption onto activated carbon involves contacting the influent water stream with activated carbon, usually through a series of contractors operated in series. Activated carbon adsorbs organic constituents in the water by a surface/pore diffusion phenomenon whereby organic molecules get entrapped in the pores of the carbon granules. The adsorption process depends on such factors as polarity and molecular weight of the adsorbate (organic contaminant), type and characteristics of the adsorbent (activated carbon), and pH of the solution, amongst other factors.

Once the carbon is saturated with organics, its adsorptive capacity has been depleted and the carbon is said to be "spent" and, therefore, must be replaced either with virgin carbon or regenerated carbon. Carbon is considered saturated when it reaches "breakthrough" or exhaustion. The time to reach breakthrough is the single most critical operating parameter.

Adsorption on activated carbon is used to treat single-phase aqueous organic wastes that contain organics with high molecular weights and boiling points, and low solubilities and polarities. It is also used to capture chemicals in the vapor phase such as those emitted from an air stripping process. Limitations are usually economic and relate to the rapidity with which the carbon becomes spent. Presence of suspended matter, oil and grease, and metals such as iron can greatly reduce the efficiency of the carbon adsorption process. Pre-treatment may be required to reduce the impact of these parameters prior to treatment with carbon.

A schematic representation of a typical carbon adsorption system is presented on Figure D.1.

3.2 AIR STRIPPING

Air stripping is a method of aeration in which chemicals in the water are brought into intimate contact with an air stream. This is a mass transfer process which is impacted by several parameters such as temperature, pressure, air to water ratio and the presence of suspended matter, amongst other factors. The resulting residuals from an air stripping tower are the off gases and the stripped effluent.

Air strippers usually consist of a stripping tower that utilizes a counter-current flow arrangement. The influent water stream is introduced at the top of the tower and allowed to flow downward through packing media while the air stream flows upward. The treated water exits at the bottom of the tower while the air stream exits at the top of the tower. Where necessary, the off gas is directed through vapor phase treatment to control volatile emissions to the atmosphere.

The air stripping process is used to treat waters that contain organic chemicals that exhibit low water solubility and high volatility. Air to water ratios applied in stripping processes are usually much higher than those applied in simple aeration processes and, therefore, treatment efficiencies are usually much higher than those obtained from simple aeration. Since the process is temperature dependent, stripping efficiencies can be impacted by changes in ambient temperature. The presence of suspended solids in the water stream could also impact the treatment efficiency due to possible formation of scaling. Also, the presence of metals such as iron, calcium and magnesium in the influent stream may cause additional scaling due to changes in the water chemistry during the process. Pre-treatment may be required to reduce the impact of these parameters prior to air stripping.

A typical air stripping system is presented on Figure D.2.

3.3 AERATION

Aeration is a mass transfer process in which chemicals present in water are evaporated into the air. There are a number of factors that are important in the removal of chemicals, namely organics, via aeration from water. Temperature, pressure, air to water ratio, and surface area available for mass transfer are some of the parameters involved in an aeration process. Air to water ratios applied in simple aeration processes are usually low in comparison to other methods of aeration such as air stripping. Process efficiencies, therefore, tend to be low in comparison to treatment efficiencies obtained using other methods.

An aeration basin usually consists of an above or below ground tank fitted with an air distribution system that is typically located at the base of the tank. Air under pressure is pumped into the tank through a number of air diffusers which create fine bubbles. The chemicals (volatile organic compounds) diffuse into the air bubbles and are removed by the air bubbles which travel to the surface of the tank.

The process is used to treat groundwaters which contain organic compounds that exhibit high volatility and low water solubility (such as chlorinated hydrocarbons and aromatics). However, the process is limited by factors such as bubble surface area, bubble size, and contact time. The process is also impacted by changes in water temperature. The presence of suspended solids material also may reduce the efficiency of the mass transfer process. Also, presence of metals such as iron, calcium and magnesium may cause additional scaling and plugging of the diffusers system. However, aeration tanks and diffusers are less prone to plugging and scale formation than other aeration systems and, therefore, are easy to maintain. Aeration basins may be expensive to operate because air has to be compressed and pumped against the static water head that is equal or greater than the depth of the tank.

A schematic representation of a typical aeration system is presented on Figure D.3.

3.4 ULTRAVIOLET/CHEMICAL OXIDATION

Ultraviolet/chemical oxidation is an enhanced chemical oxidation process whereby chemicals in the liquid stream are destroyed or detoxified upon the application of a high energy ultraviolet (UV) light in combination with a strong oxidant. Adsorption of energy in the UV spectrum results in a molecule's elevation to a higher energy state that increases the ease of bond cleavage and subsequent oxidation. Strong oxidants such as ozone and/or hydrogen peroxide are often applied throughout the process to enhance oxidation. The ultimate end products of the oxidation reaction are dependant on the particular chemicals in the waste stream.

A number of parameters can affect both performance and cost of such a process. Some of these include the amount of UV and oxidant applied, hydraulic retention time, temperature, pH, mixing efficiency and the usage of catalysts.

A process flow diagram for a UV/chemical oxidation treatment system that could be used at the Site is presented on Figure D.4. The system entails primary treatment to remove and filter metal and solid contaminants, enhanced UV/oxidation using hydrogen peroxide, and storage of the effluent in one of two tanks. While a second tank is filled, the first is tested to determine if it can be discharged or if it must be sent back into the UV/oxidation treatment.

3.5 BIOLOGICAL

A biological treatment system is a living bacteria system that must operate 24 hours per day, 7 days per week in a relatively balanced, toxic free environment. The biological system must have a constant source of food (an organic contaminant) and sufficient available nutrients (nitrogen and phosphorus) to maintain a continuous life and growth cycle at sufficient concentrations to effectively remove and digest the compounds that are present. The biological technologies include anaerobic bacteria and aerobic bacteria systems. Anaerobic systems are generally suited for degrading high strength organics (14,000 mg/L) whereas aerobic systems are generally suited for degrading organics at concentrations typically below 4,000 mg/L.

Organics are put in contact with the bacteria and are metabolized by the bacteria along with the nutrients to create additional bacteria cell mass. Excess cell mass must be removed from the system on an ongoing basis. The biological treatment systems require that toxic organics and/or inorganics, such as metals or refractory chemicals, be below inhibitory or toxic levels. Pre-treatment may be required.

Biological reactors may be further classified as suspended growth reactors and fixed film reactors. Suspended growth reactors mix organics with bacteria. In the fixed film reactor, the organics are passed over (through) a film of bacteria. Suspended growth reactors (aerated lagoons, activated sludge and sequence batch reactors) typically have long retention times and require the bacteria in a form that readily settles. Biological treatment systems typically achieve removal rates of 30% for lagoons to as much as 95% or more for activated sludge and sequence batch reactor systems. A fixed film aerobic digester system and the layout of an activated sludge treatment plant are presented on Figures D.5 and D.6, respectively.

3.6 OFF-SITE TREATMENT AT POTW

This treatment involves transportation and discharge of the collected groundwater to a publicly owned treatment works (POTW). A number of potential POTWs in the general vicinity of the Site were identified and are listed in Table D.2. The groundwater would be transported into the sanitary sewer system, or else directly to the treatment plant via forcemains or tankers. The groundwater would then undergo treatment and be discharged with other wastewater from the facility. Based upon an initial screening of the potential POTWs, it has been determined that the Newburgh POTW may be suitable for treating collected water at the Site. The facility has a high average operating capacity, and has treatment processes that would be effective for treating the chemicals in the extracted groundwater. The additional chemical loading from the Site groundwater would have a negligible impact on the influent concentrations at this facility.

3.7 OFF-SITE TREATMENT AT RCRA FACILITY

This treatment option would involve transporting the collected groundwater to an approved RCRA facility for treatment and/or disposal. A potential RCRA treatment facility is the Clean Harbors facility in Braintree, Massachusetts.

4.0 ANALYSIS OF GROUNDWATER TREATMENT OPTIONS

This section provides an analysis and evaluation of the groundwater treatment process options identified in Section 3.0. The treatment process options are evaluated with respect to effectiveness, implementability and cost.

4.1 CARBON ADSORPTION

Effectiveness

All of the compounds identified in Table D.1 are effectively adsorbed by activated carbon with the exception of ketones (2-butanone, 2-hexanone, 4-methyl-2-pentanone, and acetone). The influent concentrations to the treatment system were estimated to be below applicable MCL levels for these ketones so that treatment of these parameters to lower levels would not be required. Adsorption capacities range from 1 mg/gram of carbon for benzene to approximately 85 mg/gram for xylene. Based on this information, carbon adsorption is an effective treatment technology for Site groundwater, and will treat all of the contaminants (VOCs and SVOCs) to levels under the most stringent MCLs. Preliminary carbon consumption calculations indicate that approximately 25 lbs/day would be required to treat the groundwater to the discharge levels.

Implementability

Carbon adsorption is an easily implemented treatment technology. A system of fixed tank carbon adsorbers could be designed to provide suitable hydraulic capacity and contact time for effective treatment. Both carbon adsorbers and activated carbon are commercially available. Carbon adsorbers could be easily operated and maintained and require minimum operator supervision. Based on the groundwater data available to date, a pretreatment system may be required to reduce the concentration of any solids and/or metals that would otherwise interfere with the performance of the carbon adsorbers by reducing their efficiency and, possibly, causing them to fail mechanically. The design and requirement for pretreatment would be determined during the remedial design stage. A carbon adsorption groundwater treatment system could be designed and constructed in approximately one year.

Cost

A carbon adsorption system that would treat the anticipated groundwater flow at the Site would cost approximately $230,000. The estimated first year annual operation and maintenance costs is $75,000. A breakdown of the costs is presented in Table D.3. Costs for pretreatment have been included for the purposes of the FS.

4.2 AIR STRIPPING WITH CARBON ADSORPTION

Effectiveness

All of the VOCs identified in Table D.1, with the exception of ketones (2-butanone, 2-hexanone, 4-methyl-2-pentanone and acetone) can be removed from the groundwater to an excess of 95% using air stripping treatment. Removal rates for toluene, methylene chloride, and xylenes may exceed 99%. Air stripping will not effectively remove the SVOCs from the groundwater. Therefore, a carbon adsorption system would be required to remove these compounds. This carbon adsorption system would be a scaled down version of the system required if carbon treatment was used alone (Section 4.1), and would operate at a carbon consumption rate of approximately 3 lbs/day.

Implementability

An air stripping/carbon treatment system could be readily implemented. An air stripping unit is relatively easy to operate and maintain. A pretreatment system may be required for the removal of any solids and/or metals that may negatively impact the performance of the carbon units. The design and requirement for pretreatment would be determined during the remedial design stage. A vapor phase carbon air emission control system may be required for treatment of the off gas from the air stripping tower. The design and construction of an air stripping/carbon treatment system would take approximately one year.

Cost

An air stripping/carbon adsorption system that would treat the anticipated groundwater flow at the Site would cost approximately $518,000. The estimated first year annual operation and maintenance cost is $87,000. A breakdown of these costs is presented on Table D.4. Costs for pretreatment have been included for the purposes of the FS.

4.3 AERATION

Effectiveness

The concentrations of the VOCs identified in Table D.1, with the exception of ketones (2-butanone, 2-hexanone, 4-methyl-2-pentanone, and acetone), are generally reduced by simple aeration techniques (as applied in aeration basins). However, to achieve acceptable effluent levels for discharge, high air to water ratios, along with long retention times would be required. The same levels of reduction could be achieved more effectively with lower air to water ratios using a stripping tower. Therefore, simple aeration as a treatment alternative will not be further evaluated.

4.4 UV/OXIDATION

Effectiveness

Ultraviolet (UV) enhanced oxidation (an advanced oxidation process) is an effective method of treating organic chemicals in waters and wastewaters. Depending on the nature of the mixture, UV/oxidation treatment may be enhanced by adding additional chemicals to the waste stream. UV enhanced oxidation is effective in treating all of the organic compounds identified in Table D.1 to below the most stringent MCLs. However, methylene chloride is considered slow to oxidize by conventional enhanced oxidation processes.

Implementability

A UV/oxidation system as described is readily implementable. Pretreatment would be required for the removal of any solids and/or metals which would negatively impact the operation of the system. The detailed design and construction of a UV/oxidation treatment system would take approximately one year.

Cost

A UV/oxidation system which would treat the anticipated groundwater flow at the Site would cost approximately $511,000. The estimated first year annual operation and maintenance cost is $180,000. A breakdown of these costs is presented in Table D.5. Costs for pretreatment have been included for the purposes of the FS.

4.5 BIOLOGICAL

Effectiveness

The majority of contaminants identified in Table D.1 are treatable by biological technologies, however, the concentrations of these chemicals are generally too low for a biological treatment system to be effective. The quantity of organic compounds in the extracted groundwater is insufficient to sustain the environment required by the biological organisms. Therefore, biological technologies as a treatment alternative will not be further evaluated.

4.6 OFF-SITE TREATMENT AT POTW

Effectiveness

Off-Site treatment at a POTW would be an effective means of dealing with collected groundwater from the Site, providing that the chemical loading will not adversely affect the treatment plant.

Implementability

Preliminary screening of POTWs located in the vicinity of the Site indicated that the pumped groundwater may potentially be treated by the Newburgh POTW.

Tanker trucks would be used to transport pumped groundwater from the Site to the sanitary sewer system used by the POTW, or directly to the POTW. The estimated flowrate from the groundwater collection system is 70 gpm, or approximately 100,800 gallons per day. This volume of groundwater could not be practically transported to the POTW by tanker trucks for an extended period of time. Therefore, this treatment alternative will not be further evaluated.

4.7 OFF-SITE TREATMENT AT RCRA FACILITY

Effectiveness

Off-Site treatment at a RCRA facility would be an effective means of dealing with collected groundwater for the Site.

Implementability

Due to the estimated volume of pumped groundwater (100,800 gallons per day), transport of the groundwater to a RCRA facility by tanker trucks would not be practical, therefore, this alternative will not be further evaluated.

5.0 SUMMARY OF EVALUATION

Carbon adsorption, air stripping, UV/oxidation, off-Site treatment at a POTW and off-Site treatment at a RCRA facility are all considered to be effective treatment alternatives for the majority of the chemicals at the Site. Neither carbon adsorption nor air stripping would be effective for treating acetone, however, the estimated influent concentration of acetone is significantly lower than health risk levels.

Aeration and biological treatment were eliminated from further evaluation as they were determined to be ineffective for treating the groundwater at the Site. Off-Site treatment of the groundwater at a POTW or a RCRA facility were determined to be impractical due to the high volume of groundwater which would require transportation by tanker truck (approximately 100,800 gallons per day).

Carbon adsorption, air stripping with carbon adsorption, and UV/oxidation are considered to be easy to implement. Pretreatment, however, may be required to remove metals and suspended solids for these on-Site treatment options.

Capital costs for the installation of carbon adsorption, air stripping/carbon adsorption and UV/oxidation systems are estimated to be $230,000, $518,000, and $511,000, respectively. First year annual operation and maintenance costs are estimated to be $75,000 for carbon adsorption, $87,000 for air stripping/carbon adsorption and $180,000 for UV/oxidation.

Based upon this evaluation, it is concluded that a carbon treatment system would be the most cost effective groundwater treatment technology to treat the Site-related compounds in the groundwater at the Site. Carbon treatment is, therefore, retained for inclusion in remedial alternatives for groundwater in the FS.

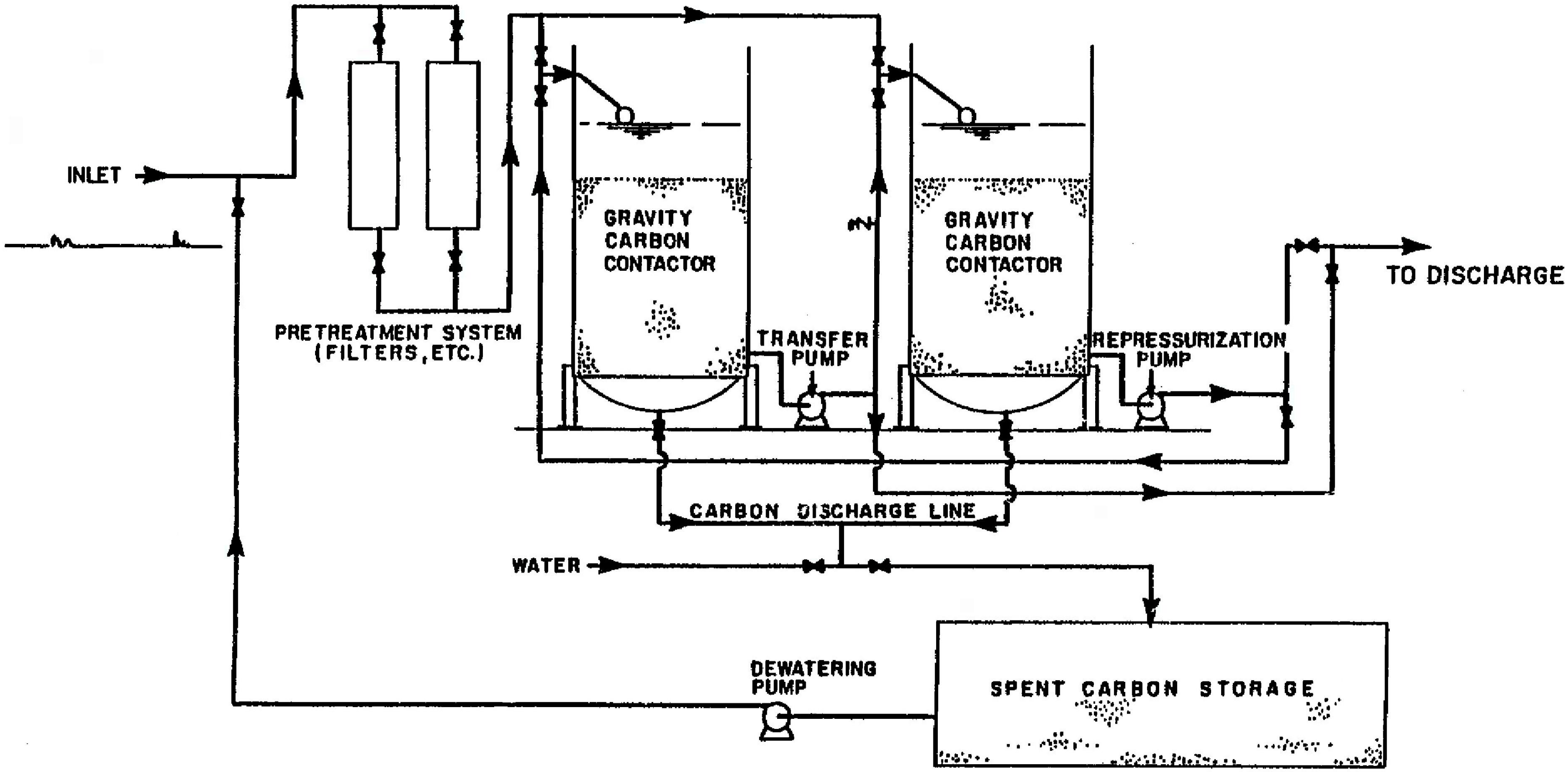

figure D.1

CARBON TREATMENT SCHEMATIC
GRAVITY SYSTEM
FORMER LAGOON SITE
Hamptonburgh, New York

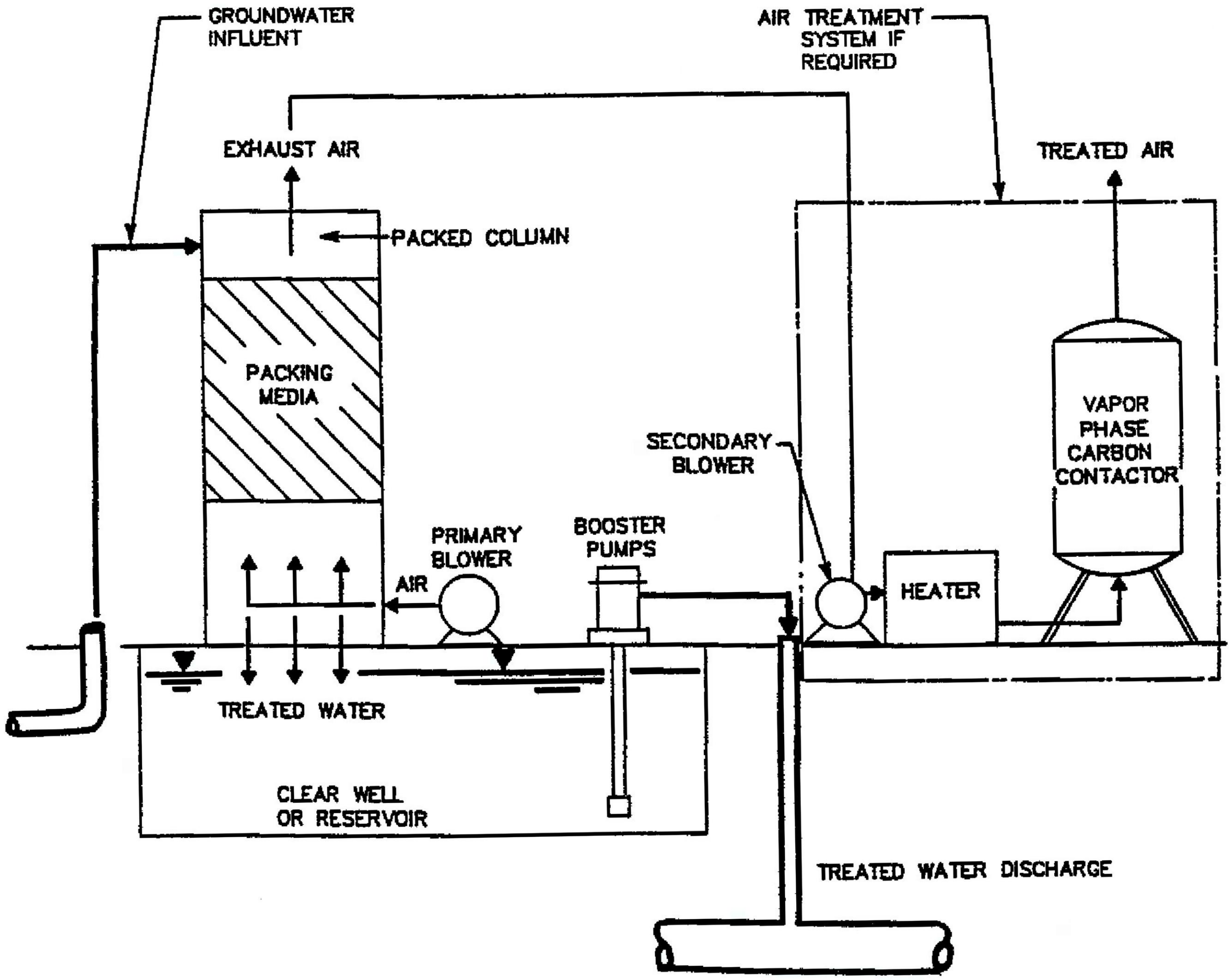

figure D.2

AIR STRIPPING TOWER SCHEMATIC
FORMER LAGOON SITE
Hamptonburgh, New York

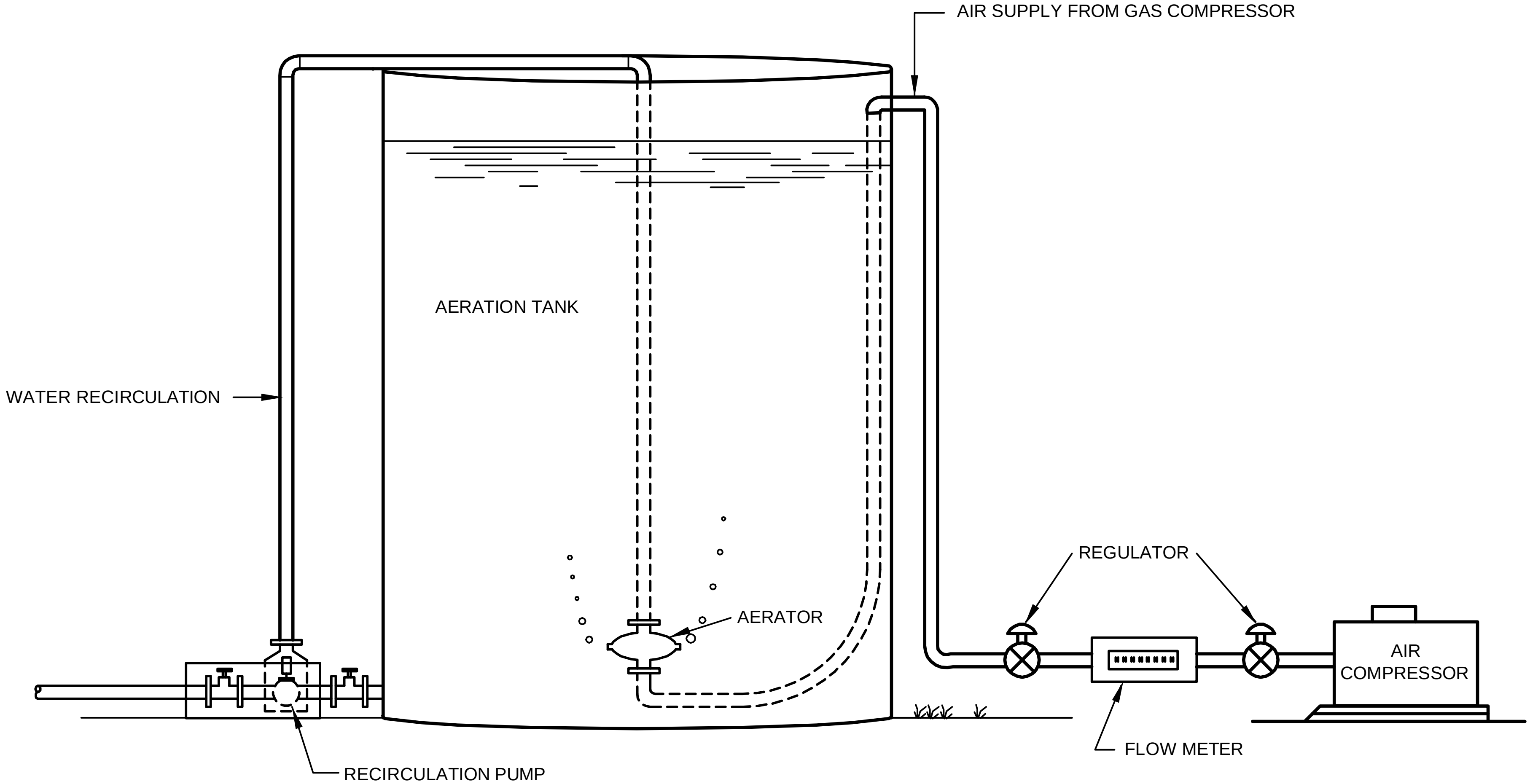

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figure D.3

AERATION TANK SCHEMATIC
FORMER LAGOON SITE
Hamptonburgh, New York

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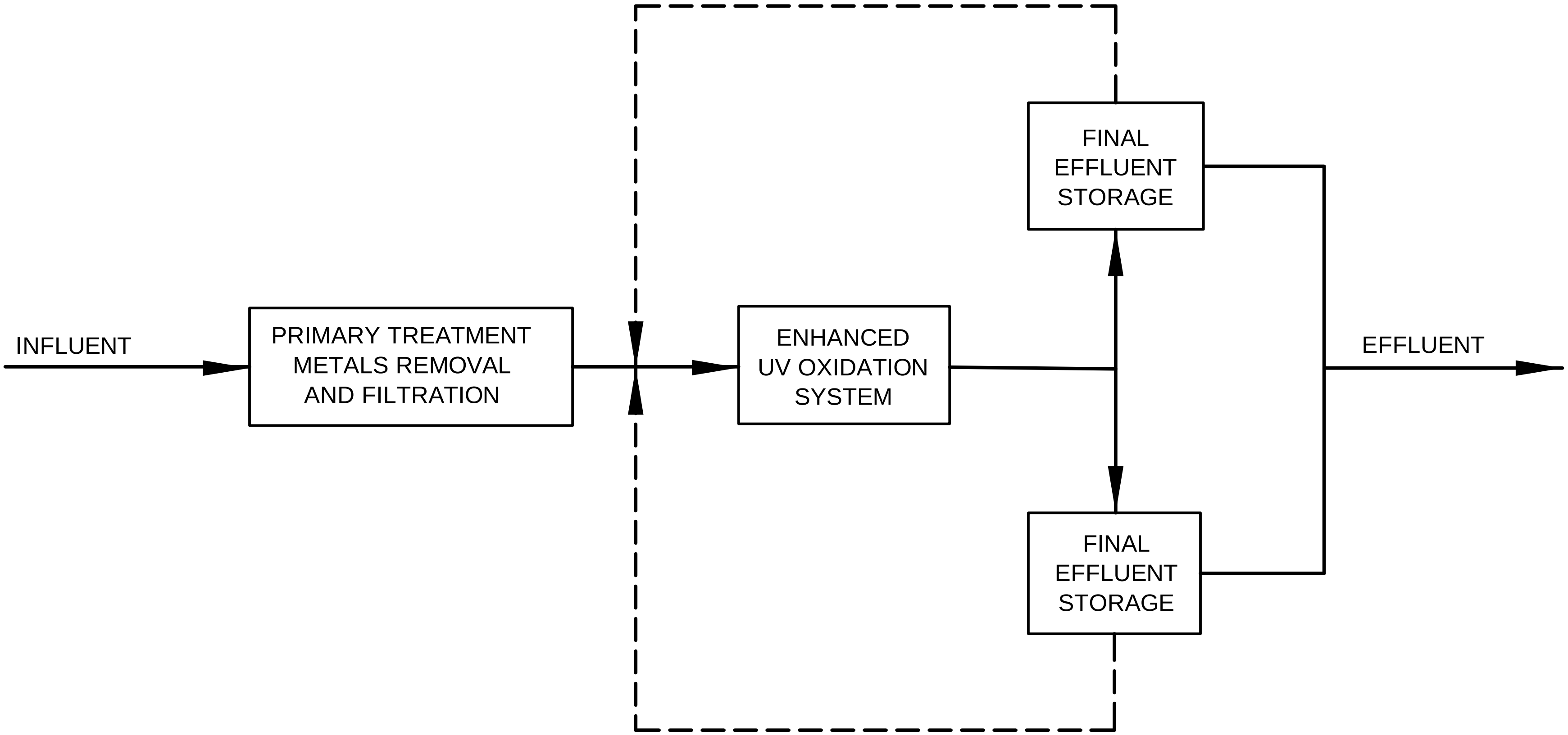
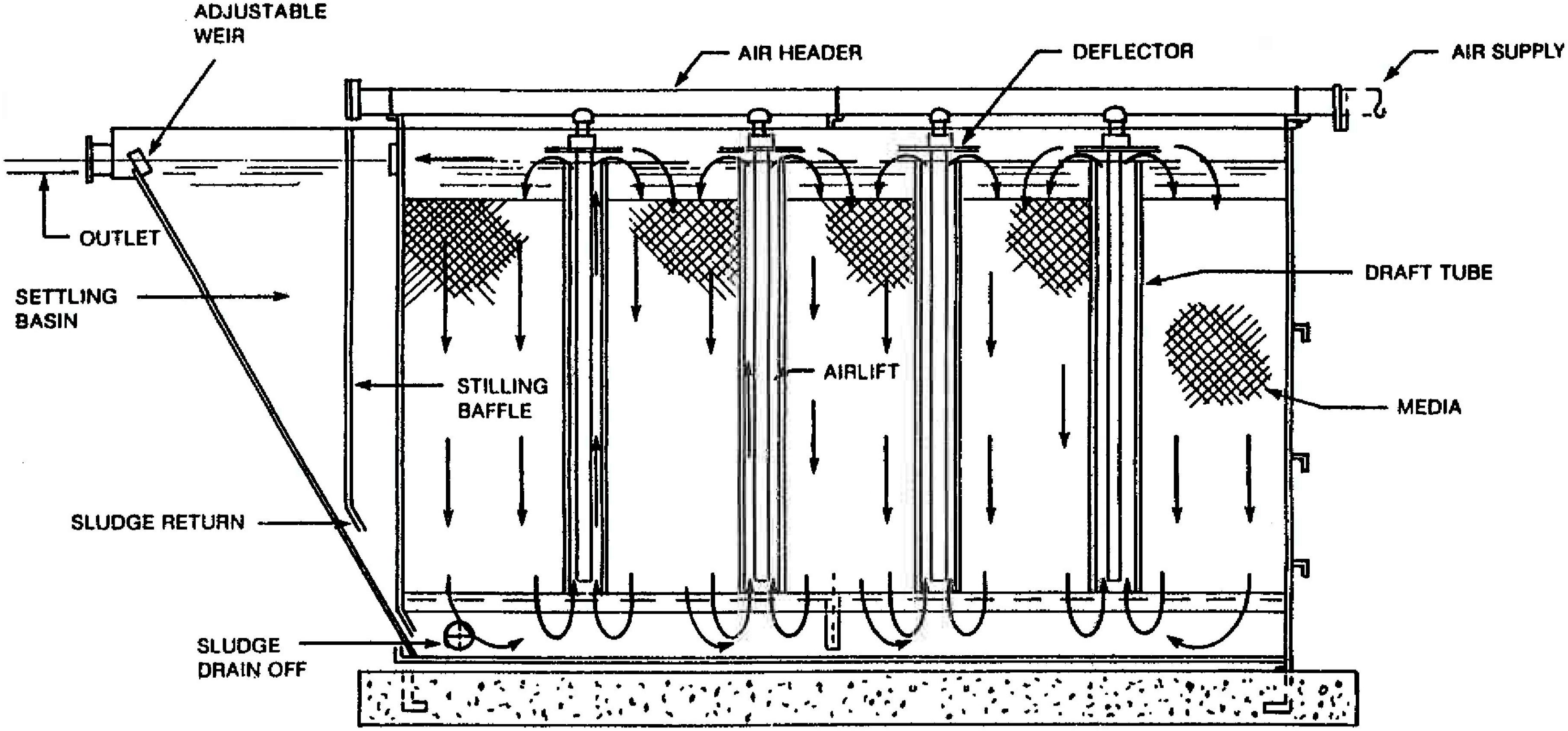


figure D.4

UV/CHEMICAL OXIDATION SCHEMATIC
FORMER LAGOON SITE
Hamptonburgh, New York



SOURCE: NYER, 1985

figure D.5

FIXED FILM BIOLOGICAL
TREATMENT SYSTEM SCHEMATIC
FORMER LAGOON SITE
Hamptonburgh, New York

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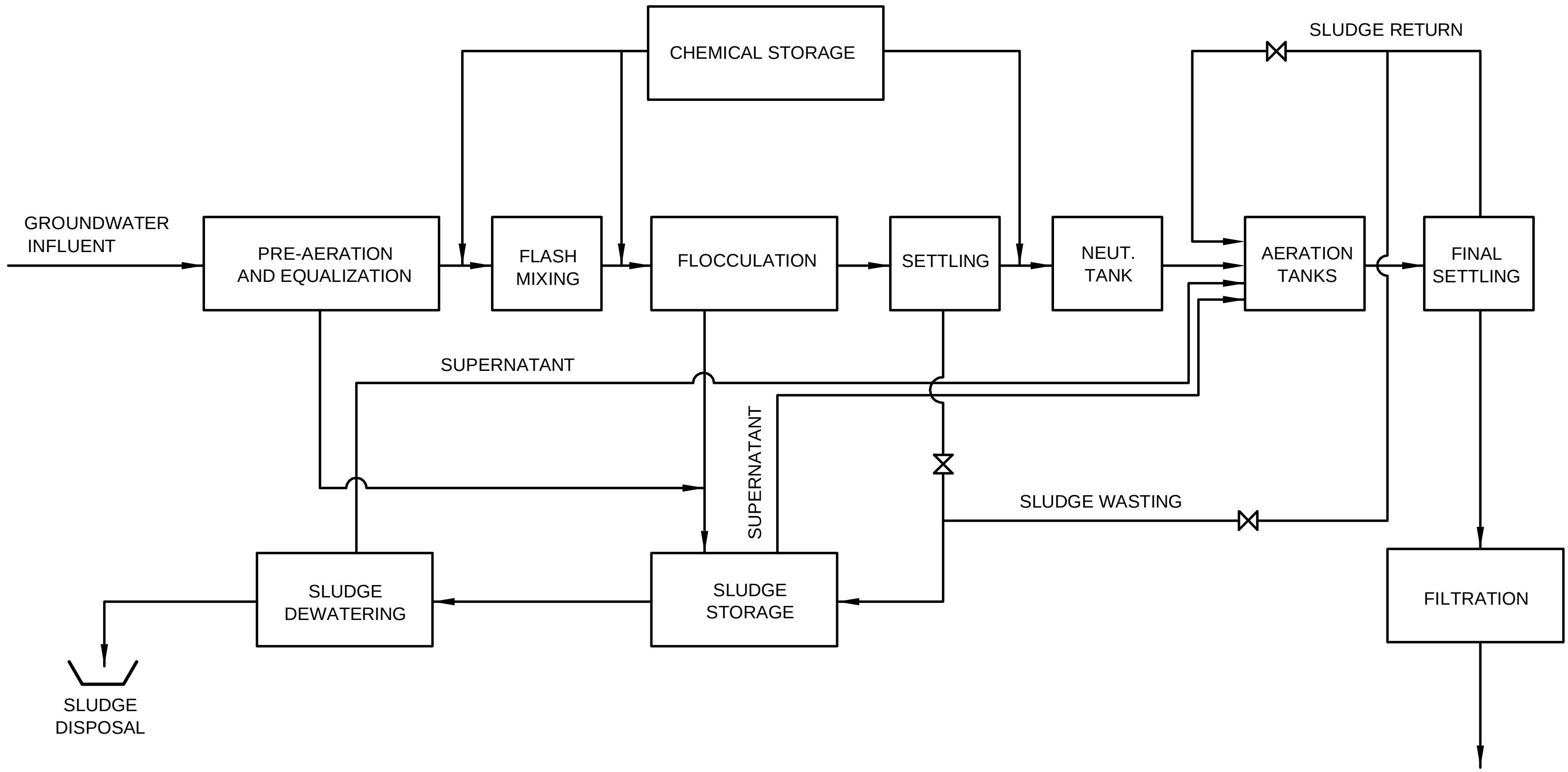

figure D.6

ACTIVATED SLUDGE SYSTEM SCHEMATIC
FORMER LAGOON SITE
Hamptonburgh, New York

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TABLE D.1

ESTIMATED GROUNDWATER TREATMENT SYSTEM AVERAGE INFLUENT CONCENTRATIONS FOR THE COCs (1)

FORMER LAGOON SITE
HAMPTONBURGH, NEW YORK

Parameter	*Estimated Influent Concentration (µg/L)*
VOCs	
Acetone	47
Benzene	72
Chlorobenzene	8
1,2-Dichloroethane	1
Ethylbenzene	12
Toluene	2
Xylenes (Total)	25
SVOCs	
Alpha-picoline	11
2-Aminopyridine	43
Pyridine	10

Note:
(1) Concentrations are the average of the results for the 2001/2002 groundwater sampling programs.

TABLE D.2

SCREENING OF POTENTIAL POTWs FOR EXTRACTED GROUNDWATER TREATMENT
FORMER LAGOON SITE
HAMPTONBURGH, NEW YORK

Name/Location	*Distance from Site (Miles)*
Village of Florida	12
Goshen	8
Village of Maybrook	3
Montgomery	4
Newburgh	16
New Windsor	18
Orange County Sewer District (Harriman)	20
Valley Forge Woodbury	20

TABLE D.3

COST ESTIMATE
GRANULAR ACTIVATED CARBON ADSORPTION
GROUNDWATER TREATMENT SYSTEM
FORMER LAGOON SITE
HAMPTONBURGH, NEW YORK

I. Capital Costs

1. Mobilization and Demobilization	$25,000
2. Carbon Treatment System	$50,000
3. Pretreatment System	$10,000
4. Treatment Building	$45,000
5. Electrical Services	$30,000
Estimated Capital Costs	**$160,000**
Engineering (20%)	$32,000
Sub-Total	$192,000
Contingency (20%)	$38,000
Total Estimated Capital Costs	**$230,000**

II. Annual Operation and Maintenance Costs

1. Liquid Phase Carbon Replacement and Disposal	$20,000
2. Pretreatment System Maintenance	$15,000
3. Maintenance	$30,000
4. Power	$10,000
Total Estimated Annual O&M Costs	**$75,000**

TABLE D.4

COST ESTIMATE
AIR STRIPPING/CARBON ADSORPTION
GROUNDWATER TREATMENT SYSTEM
FORMER LAGOON SITE
HAMPTONBURGH, NEW YORK

I. Capital Costs

1.	Mobilization and Demobilization	$30,000
2.	Air Stripping/Carbon Treatment Unit	$125,000
3.	Pretreatment System	$75,000
4.	Treatment Building	$100,000
5.	Electrical Services	$30,000
	Estimated Capital Costs	**$360,000**
	Engineering (20%)	$72,000
	Sub-Total	$432,000
	Contingency (20%)	$86,000
	Total Estimated Capital Costs	**$518,000**

II. Annual Operation and Maintenance Costs

1.	Air Stripper Packing Cleaning	$10,000
2.	Liquid Phase Carbon; Replacement and Disposal (5 lb/day @ $3/lb)	$2,000
3.	Pretreatment System Maintenance	$30,000
4.	Maintenance	$30,000
5.	Power	$15,000
	Total Estimated Annual O&M Costs	**$87,000**

TABLE D.5

COST ESTIMATE
UV/OXIDATION TREATMENT SYSTEM
FORMER LAGOON SITE
HAMPTONBURGH, NEW YORK

I. Capital Costs

1.	Mobilization/Demobilization	$30,000
2.	UV/Oxidation System	$225,000 (1)
3.	Treatment Building	$70,000
4.	Electrical Services	$30,000
	Estimated Capital Costs	**$355,000**
	Engineering (20%)	$71,000
	Sub-Total	$426,000
	Contingency (20%)	$85,000
	Total Estimated Capital Costs	**$511,000**

II. Annual Operation and Maintenance Costs

1.	Pretreatment	$50,000
2.	UV/Oxidation System	$75,000 (2)
3.	Sludge Collection, Treatment, Disposal	$25,000
4.	Maintenance	$30,000
	Total Estimated O&M Costs	**$180,000**

(1) Includes pretreatment system and sludge storage/dewatering system.
(2) Includes cost for chemical addition, power consumption and lamp replacement.