APPENDIX C

ASSESSMENT OF SOIL TREATMENT TECHNOLOGIES

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1.0 INTRODUCTION

A description, evaluation and a summary of the potential soil remedial response actions, technologies and process options for the COCs (acetone, aniline, chlorobenzene, BTEX, alpha-picoline, 2-aminopyridine, pyridine and pyridine-based TICs) at the Site is presented in this appendix.

A description of various potential soil remedial response actions, technologies and process options are provided in Section 2. In situ and ex situ treatment technologies are presented in Sections 2.1 and 2.2, respectively.

An evaluation of the different process options is presented in Section 3. The evaluation is based upon effectiveness, implementability and cost considerations. Based upon this evaluation one or more technologies and processes are selected to be considered throughout the FS.

The volume of material to be treated for in situ alternatives is estimated to be approximately 35,200 cubic yards (cu yds) consisting of the black-stained layer from Lagoons 1 to 5 and 10 percent of Lagoon 6 as discussed in Appendix A. For ex situ alternatives, the shale fragments and cobbles would be screened out prior to treatment resulting in an estimated volume of 21,120 to 32,460 cu yds or 38,020 to 58,430 tons to be treated.

2.0 SOIL REMEDIAL RESPONSE ACTION, TECHNOLOGY AND PROCESS OPTION DESCRIPTION

2.1 IN SITU SOIL TREATMENT

Four alternative process options were identified for consideration for in situ treatment of soils at the Site. These are:

i) Biological Treatment;

ii) Soil Vacuum Extraction;

iii) Soil Flushing; and

iv) Bioventing.

2.1.1 BIOLOGICAL TREATMENT

In situ biological treatment is a process where oxygen and nutrients are added to the soils to promote the breakdown of contaminants by naturally occurring microorganisms (usually bacteria). This is usually accomplished by adding nutrient-enhanced water to the system through infiltration basins at the ground surface or through recharge wells. The water is circulated through the soils to be remediated. The water used to transport the nutrients can also work to dissolve adsorbed contaminants. The extracted water would be treated on Site, if required, to remove dissolved chemicals prior to reinjection. This treatment technology can provide substantial reduction in organic contaminant levels in soils without the high cost of soil excavation.

Several factors influence the effectiveness of an in situ biological treatment process. These factors include:

- available oxygen concentration;
- appropriate levels of macronutrients and micronutrients;
- redox potential;
- soil pH;
- degree of water saturation;
- soil temperature;
- competition, predators, presence of toxins;

- chemicals to be treated and concentration; and
- hydraulic conductivity of soils.

In situ biodegradation is often used in conjunction with a groundwater pumping and reinjection system to circulate nutrients and oxygen through a contaminated zone. Under favorable conditions, introduced soil microorganisms are known to degrade many organic compounds. Microorganisms are capable of completely degrading organic compounds into water and carbon dioxide in the presence of sufficient oxygen and nutrients such as nitrogen and phosphorous, a near neutral pH, and warm soil temperatures. Anaerobic degradation of organics is possible, although the rates of degradation are generally too slow to constitute an active remediation. Bioreclamation is one of the in situ methods that is engineered to create favorable aerobic conditions in unfavorable conditions such as non-homogeneous soils, delicate geochemical balances and uncertain organic substrates.

This technology is not suitable for soil contaminated with organo-chlorine pesticide compounds and metals present in inhibitory concentrations but is well suited for soil contaminated by petroleum by-products (eg. aromatic hydrocarbons such as BTEX). Bench scale and/or pilot-scale tests are required to ascertain the effectiveness of biological treatment at any particular site.

2.1.2 SOIL VACUUM EXTRACTION

Soil vacuum extraction (or soil vapor extraction) (SVE) is a technique used to remove volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) from the vadose or unsaturated zone. SVE is an in situ process that makes use of vapor extraction wells or trenches installed in the contaminated zone. The extraction wells/trenches can be used alone or in conjunction with air injection wells that either passively take in atmospheric air or actively use forced air injection. The air strips the volatile compounds from the soil and carries them to the vapor extraction well/trench. An example of the SVE equipment layout is presented on Figure C.2.1.

The vacuum extraction process removes chemical vapors trapped in soil pore spaces, but also affects, to a limited extent, residual liquid contaminants and dissolved contaminants from the groundwater. Water in the collected air stream is condensed and separated from the air stream and is transferred to a water treatment system or to waste. The air stream is then treated, if required, prior to reinjection or exhausting to the atmosphere.

Several factors impact the effectiveness of in situ vacuum extraction at any particular site. These factors include:

- chemicals to be treated (concentrations and vapor pressure);
- soil temperature;
- soil air conductivity;
- moisture content;
- geological conditions; and
- soil sorption capacity.

The SVE process is very site specific. The process is best suited for use in permeable, well drained soils with low organic carbon content. Since SVE works only in the vadose zone, it is sometimes advantageous to lower the groundwater level to increase the volume of the unsaturated zone. One method of achieving this is by placing an impermeable cap over the treatment area to minimize surface water infiltration. An impermeable cap can also serve to increase the area of influence by preventing short circuiting of airflow directly to the surface. Factors such as stratigraphy and soil heterogeneities influence the flow of air as well as the location of contaminants. This will have a pronounced effect on the design of the SVE system but proper design of the vacuum extraction system may overcome these problems.

Once the area to be treated has been defined, the extraction wells/trenches can be strategically installed such that airflow within the area is maximized while airflow through other areas is minimized. The vapor extraction wells usually consist of screened pipe placed in a permeable packing. The top few feet of the well is grouted to prevent a short circuited airflow to the surface. Vacuum pumps or blowers reduce gas pressure in the extraction wells and induce subsurface airflow to the wells.

As the air travels through the soil, it passes through a series of pores providing the least resistance. Air that passes through pores containing vapor and liquids will strip the contaminants from the soil. Chemicals existing in a condensed phase will vaporize and this process will continue until the condensed phase organics are removed from the higher permeability soil.

The airflow draws chemical vapors and entrained water from the extraction wells to a vapor-liquid separator. In this unit, the liquid is separated and contained for treatment and vapor is conveyed to a vapor treatment unit. Monitoring probes can be installed to measure the soil vapor concentrations and sampling ports can be installed at many stages after extraction from the well.

The vapors are typically treated using carbon adsorption, thermal destruction or condensation. Carbon adsorption is the most common method and can be used to accommodate a wide range of VOC concentrations and airflow rates. Thermal incineration and catalytic oxidation are also effective for a wide range of compounds. Condensation by refrigeration can be used to separate the VOCs from the air. This method is most effective for high concentrations of vapors but becomes less effective as the cleanup progresses and vapor concentrations drop. When properly operated, SVE systems have demonstrated their ability for safe, continuous operation with minimal attention. Equipment used in the process can be either mobile or field constructed. Once the equipment has been mobilized, full-scale operations can usually be underway relatively rapidly.

2.1.3 SOIL FLUSHING

Soil flushing is an in situ process using a groundwater extraction/reinjection system. The soil flushing process consists of injecting a solvent or surfactant solution throughout the affected soil to enhance the contaminant solubility, which results in increased recovery of contaminants in the leachate or groundwater.

The soil flushing system uses extraction wells installed in the contaminated zone, a reinjection system located upgradient of the contaminated zone, and a wastewater treatment system. Proper control measures must be employed to prevent migration of contaminants via groundwater flow from the area being treated. Sandy soils, for example, may give rise to uncontrolled migration whereas a clay confining layer can be used to inhibit migration. The process can be quickened by the use of ponds or sprinklers over the contaminated zone to accelerate the flushing of chemicals.

The degree to which soil flushing is effective is primarily dependent upon the following factors:

- soil hydraulic conductivity;
- soil carbon content; and
- chemical-specific properties such as water solubility, adsorption characteristics, liquid viscosity and liquid density.

Surfactants can be added to the flushing water to help mobilize chemicals. Surfactants are natural or synthetic chemicals that have the ability to promote wetting, solubilization or emulsification of various organic chemicals.

The extracted water is treated using appropriate technology(ies) depending on the chemicals being removed. The soil flushing technology is chemical-specific and has the greatest success when applied to soils containing only a limited number of chemicals to be treated.

2.1.4 BIOVENTING

Bioventing is an effective technology for the biological degradation of VOCs and SVOCs in contaminated soil. This system, engineered to increase the rate of microbial biodegradation in the unsaturated zone using forced air as the oxygen source, is a potentially cost-effective alternative to conventional systems. Biodegradation enhanced by soil venting has proven effective at several sites.

Petroleum distillate fuel hydrocarbons are generally biodegradable if naturally occurring microorganisms are provided with an adequate supply of oxygen and basic nutrients. The natural process is frequently too slow to prevent the spread of contamination. To date, much attention has been given to waterborne enhanced bioreclamation processes. More recent studies have explored the use of air as a carrier of oxygen and nutrients.

By using air as an oxygen source, more complete recovery of contaminants can be achieved due to higher diffusivity of gases over liquids. At many sites, geological heterogeneities create a problem with waterborne oxygen sources because fluid pumped through the formation is channeled into the more permeable pathways. In a gaseous system, this diffusion can take place at several orders of magnitude greater. Studies have shown that by using air as an oxygen source, the minimum ratio of air pumped per hydrocarbon degraded is approximately 13 to 1 (on a weight basis). This compares to more than 1,000 lb of water per one pound of hydrocarbon for a waterborne process.

The technology relies on air flow through contaminated soils, being at rates and configurations that will ensure adequate oxygenation for aerobic biodegradation. The addition of nutrients and moisture may be desirable to increase biodegradation rates. Gas monitoring points can be installed to sample short vertical sections of the soil. These points are necessary to determine local oxygen concentrations. Monitoring of airflow rates is also important to ensure against volatilization while maintaining adequate biodegradation conditions.

2.2 EX SITU SOIL TREATMENT

A total of seven ex situ treatment process options were identified for potential soil remediation. These process options include:

i) on-Site biological treatment;

ii) on-Site soil vacuum extraction/bioremediation;

iii) on-Site low temperature thermal desorption;

iv) on-Site Incineration

v) off-Site Incineration;

vi) on-Site solvent extraction; and

vii) on-Site soil washing.

2.2.1 ON-SITE BIOLOGICAL TREATMENT

This technology uses biodegradation techniques to degrade the contaminants in the soil. The basic concept involves providing a favorable environment to enhance microbial metabolism of organic contaminants resulting in the breakdown and detoxification of those contaminants.

The biological treatment technology involves aeration and biological degradation of the soils by tilling on an engineered treatment pad. The soils would be placed in a lift of approximately 1 foot thickness on the treatment pad. Tilling would be conducted on a regular basis to aerate the soil. Tilling also promotes volatilization of the contaminants to the surrounding air. Additives can be used to enhance the biodegradation process. This process continues until acceptable contaminant levels are achieved.

The implementation of a biological treatment remedy utilizes common construction techniques, however, depending on the volume and physical nature of the material requiring treatment as well as climatic conditions, the remedy may require a long treatment duration. Biological treatment commonly requires anywhere from three months up to two years for completion per lift. The length of treatment time can be confirmed in treatability studies. Remediation of each batch is confirmed by sampling and analysis.

Remediation can be conducted by Liquid-Solids Treatment (LST) followed by biological treatment. LST treatment consists of slurrying the soil with water in a batch reactor and then seeding the slurry with microbes. LST pretreatment provides odor control and the initiation of biological breakdown of contaminants. The slurry is then pumped onto the treatment area for further biodegradation.

The major COCs detected in soils at the Site have a high potential for successful treatment under aeration and/or biological degradation.

2.2.2 ON-SITE SOIL VACUUM EXTRACTION/BIOREMEDIATION

This treatment technology is similar to biological treatment in that it involves providing a favorable environment to enhance the development of a bacteria culture in the soils. Likewise, this treatment usually involves the addition of nutrients and oxygen to the soil.

A soil vacuum extraction/bioremediation system employs a forced aeration system which replaces the mechanical turning used to aerate the soil during biological treatment.

Oxygen is added by mechanically pulling (negative pressure) or pushing (positive pressure) of air through the static soil pile. The advantage of a soil pile is that a cover can be placed over the pile and volatile materials can be controlled and treated (i.e. carbon absorption).

One of the various designs for vacuum extraction/bioremediation calls for constructing the soil pile upon an elevated, perforated base through which air is forced into the pile. Another approach involves embedding perforated ducts in a bottom layer of wood chips or other comparable material, upon which the soil is stacked.

For a soil vacuum extraction/bioremediation operation to be successful:

- the soil should be granular;
- particle size should be relatively uniform;
- particles should be resistant to compaction;

- the soil pile should not be compacted; and
- the soil must not be excessively moist.

In operations in which forced aeration is used for moisture removal and temperature regulation as well as aeration, amounts and rates of air input will depend upon oxygen demand, moisture content, temperature and their interrelationship. Drying and destruction of volatile solids are greatest at high aeration rates and low process temperatures.

2.2.3 ON-SITE LOW TEMPERATURE THERMAL DESORPTION

Low Temperature Thermal Desorption (LTTD) technology encompasses processes that are essentially physical separations based on the differences in vapor pressure between the organic contaminants and the affected matrix (i.e. soil). LTTD is a potential treatment technology for soils which have a high solid content with low to medium levels (<10 percent) of organic compounds. LTTD involves heating the soil to the appropriate temperature to cause volatilization of organic compounds into a carrier gas. The treatment process requires excavation of all contaminated soil with concentrations above chemical cleanup goals. Typical treatment rates for LTTD rotary kilns are approximately 75 to 150 tons of soil per day.

Excavated soils are placed into a desorber and are heated. Heating is used to increase the relative volatilities between the contaminants and the matrix enough to cause vaporization of the organics and moisture into a gas stream. Temperatures used for LTTD are related to the contaminants boiling points and generally range from 200 to 1100°F The carrier (purge) gas stream, usually an inert gas, is used to transport the volatilized compounds to a condenser where the gas stream is cooled in stages to low temperatures to condense the volatilized water and organics into liquids. An inert gas is used because it lowers the oxygen content in the desorber (heater) and results in the inhibition of combustion reactions.

A general flow diagram for the thermal desorption process is presented on Figure C.2.2. The soil is usually dewatered and screened to remove oversize (>2-inch) particles prior to processing. After the contaminants and water are vaporized into the gas stream in the LTTD process, the gas stream is treated for particulate removal. The vapors are then cooled to low temperatures to condense organics and water out as a liquid mixture. The organics are separated (by gravity) from the water and must be treated further to complete remediation (i.e. by incineration, chemical fixation, solidification). The separated water is generally treated by carbon adsorption, usually to allow discharge to surface or groundwater, or recycled and used for gas cooling via heat exchange or direct quenching systems.

The carrier gas, after particulate removal and cooling, is treated by scrubbers and carbon adsorption to allow venting to the atmosphere or recycling to the desorber for reuse in oxygen purging. The treated soil from the desorber contains low volatility inorganic compounds; i.e. metals. The metals will be marginally concentrated in the treated soils depending on the amount of water and organics in the untreated soil.

The LTTD process has been successfully applied to solids, sludges, sediments and filter cakes which contain greater than 10 percent organics and less than 30 percent solids. Contaminants which have been successfully treated by LTTD in laboratory, pilot or full-scale processes include VOCs, SVOCs, polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dioxins and petroleum contaminated wastes. Treated soils are backfilled on Site provided that they meet applicable soil cleanup levels.

2.2.4 INCINERATION: ON-SITE AND OFF-SITE

Incineration is a treatment method for organic compounds which uses high temperature oxidation under controlled conditions to degrade a substance into carbon dioxide, water vapor, sulfur dioxide, nitrogen oxides, hydrogen chloride gases, and ash. Other emissions representing incomplete oxidation in the incinerator include carbon monoxide, unoxidized organic gases and products of incomplete combustion (PIC). The hazardous products of incineration, such as particulates, sulfur dioxide, nitrogen oxides, hydrogen chloride, unoxidized organic gases and PICs require air emission control equipment. Incineration can be conducted either on Site or off Site.

Two common types of incinerators are the Circulating Bed Combustor (CBC) and the Rotary Kiln Incinerator (RKI). The CBC and RKI type incinerators, are presented on Figures C.2.3 and C.2.4 respectively. The CBC incinerator is based on fluidized bed technology and can be mobilized to treat the contaminated soil on Site. The RKI is commonly used for on- or off-Site incineration and consists of a cylindrical, refractory-lined shell on an incline.

The most common on- and off-Site system is the RKI. The contaminated soil is fed into the kiln at the top end and is passed through a combustion zone as the kiln rotates. The rotation creates turbulence which improves combustion. Incinerator residence times and temperatures are developed from the combustion characteristics and chemical properties of the waste. The units may be fueled by natural gas, propane or oil, and afterburners are often employed to ensure complete combustion.

When soil is incinerated, there is a small reduction in volume while the geologic nature of the soil remains the same, depending on the moisture and organic content of the soil. Inorganic contaminants (e.g. metals) are generally not destroyed by incineration but may be partially removed as a gaseous emission or adsorbed to particulates.

Both the CBC and the RKI have demonstrated removal efficiencies greater than 99.99 percent and, in many cases, contaminants are not detectable in the remaining ash.

2.2.5 ON-SITE SOLVENT EXTRACTION

Solvent extraction is a process that is suitable for the treatment of materials with varying compositions of water, oil and solids. This technology has not been widely used for full-scale operations and therefore its effectiveness and reliability for the reduction of hazardous constituents in soils are questionable.

The solvent extraction process involves mixing potentially contaminated soils with an aliphatic solvent, such as triethylamine (TEA), at low temperatures in a vessel equipped with steel paddles or plows for mixing. The first extraction of the potentially contaminated soil is conducted at a temperature below 40°F. At low temperatures the solvent is miscible in water and solubilizes hydrocarbons. The homogeneous liquid phase separates from the soil and is pumped into a decanter. The remaining solids portion is "washed" again in the solvent at higher temperatures of about 130°F. At these temperatures, solubility of the organic compounds in the solvent increases which enhances their removal from the potentially contaminated soils. The required number of "washes" varies depending upon soil conditions and contaminants present. Once the liquid phase from the last "wash" is removed from the solids, the solids are dried by injecting steam in the jacket surrounding the vessel. Steam is also injected into the solids to strip any remaining solvent, which is later recovered.

The liquid phase from the initial extraction is heated to the temperature at which the solvent and water becomes immiscible (130°F for TEA). The chemicals, however, remain with the solvent. The solvent-chemical portion is pumped into a solvent recovery system along with the liquid phase from the subsequent extractions at higher temperatures. The solvent recovery system may consist of an evaporator or an evaporator combined with a distillation column. The solvent is condensed and reused, and the chemicals that are removed from the soil are sent off for disposal or treatment.

The water portion is pumped to a stripping column to remove any traces of the solvent. The remaining water can be treated on Site through a carbon filter unit or collected and disposed of off Site.

2.2.6 SOIL WASHING

Soil washing can be conducted on excavated soil and involves contacting the soils with water to partition the contaminants from the solid phase to the liquid phase. Excavated soil is slurried with water to remove contaminants from the soil and pumped through a filter press to separate the soil from the water. The contaminated water is then collected for treatment.

The effectiveness of soil washing with water is determined by the water solubility of the chemical compound, the tendency of a compound to adsorb to the soil, the porosity of waste and the contact time between waste and water. This technology can be enhanced by the use of surfactants to increase contaminant removal.

On entry into the washing unit, the soil passes into a soil scrubber, where it is sprayed with the washing fluid. Soil particles greater than two millimeters (mm) in diameter are sorted, rinsed, leave the scrubber and are dewatered. The remaining soil enters a chemical extractor where washing fluid is passed countercurrent to the soil flow, removing the contaminants.

The soil washing process is associated with the generation of a wastewater stream which must be collected and treated. This treatment can include such technologies as incineration and biological degradation.

3.0 EVALUATION

An evaluation of each of the alternative process options based upon effectiveness, implementability and cost criteria is presented in this section. If the alternative is judged to be ineffective and/or not implementable for the Site-specific COCs, no further evaluation was carried out on the cost criteria basis. The comparative costs are based on engineering judgment and available technology vendor estimates rather than detailed estimates to assess the relative cost of each appropriate technology process option.

3.1 IN SITU SOIL TREATMENT

3.1.1 BIOLOGICAL TREATMENT

Effectivenes

Based on the results of the Treatability Study, biological treatment would be effective for the treatment of the COCs. However, as discussed previously, bioventing is a much more effective means of providing additional oxygen to promote biological degradation.

Implementability

The construction components of this system are readily implementable using common construction techniques.

Costs

Typical costs for biological treatment range from $60 to $125/cu yd resulting in a total cost of $2.1 to $4.4 million to treat the estimated 35,200 cu yds of soil with concentrations of COCs above NYSDEC Soil Cleanup Objectives.

3.1.2 SOIL VACUUM EXTRACTION

Effectiveness

In situ soil vacuum extraction would be an effective means of treating the more volatile organic compounds present at the Site. This technology could readily be combined with the bioventing process option to more effectively treat a broader range of chemicals.

Based on the results of the Treatability Study, SVE would be effective in treating the VOC COCs. Bioventing would enhance the degradation of the SVOC COCs.

Implementability

In situ soil vacuum extraction can be readily implemented and has been used effectively at many sites. Pilot tests would be required to develop the system design parameters.

Costs

Typical costs for an in situ soil vacuum extraction system range from $20 to $70/cu yd resulting in a total cost of $0.7 to $2.5 million to treat 35,200 cu yds of soil.

3.1.3 SOIL FLUSHING

Effectiveness

In situ soil flushing would be effective for treatment of the majority of the Site-related compounds. Care would have to be taken to prevent migration of flushed chemicals via the groundwater flow system from the treatment area.

Implementability

The construction components of this system are readily implementable using common construction techniques. Treatability analyses and pilot tests would be required to develop design parameters for the system.

Costs

Costs for soil flushing typically range from $60 to $150/cu yd which, based upon an estimated 35,200 cu yds of material, would result in a total cost ranging from $2.1 to $5.3 million.

3.1.4 BIOVENTING

Effectiveness

Bioventing would be effective for the treatment of the COCs. The effectiveness of this technology is based upon establishing controls on various biology-sensitive parameters such as nutrient levels, pH and oxygen demand. Based on the results of the Treatability Study. SVE would be effective for the VOC COCs and biodegradation would be effective for the SVOC COCs.

Implementability

Bioventing can be readily implemented. However, pilot studies would be required to develop the design parameters.

Costs

Typical costs for bioventing range from $30 to $80/cu yd, which would result in a total cost of approximately $1.1 to $2.8 million to treat 35,200 cu yds of soil.

3.1.5 SUMMARY

The potential effectiveness of any of the in situ technologies identified will depend upon Site-specific parameters such as soil type, permeability, degree of homogeneity, and the nature and degree of chemical impact. In general, all of the identified technologies have a documentable track record of laboratory and on-site success.

Many of the commercial vendors of these technologies can provide documentation of cases where they were applied successfully. The Treatability Study results indicate that biodegradation coupled with SVE would be effective for treating the COCs to levels below cleanup objectives. In many cases, a pilot-scale test, executed on Site, offers the optimal data for evaluating the effectiveness of a particular in situ treatment technology.

Based on the Treatability Study results, bioventing is expected to be the most applicable in situ technology for this Site. All of the COCs are considered to be reasonably biodegradable. SVE is appropriate for the VOC COCs. Bioventing is, in essence, a soil vacuum extraction technology augmented by establishing controls on various biology-sensitive parameters such as nutrient levels, pH and oxygen demand to enhance biodegradation.

Soil flushing and biological treatment, as defined in this Appendix, may be effective in situ techniques at this Site, but, in general, will be more cumbersome to apply and, therefore, more costly.

Based upon this evaluation, in situ soil vapor extraction combined with bioventing is selected as the optimal in situ soil treatment technology.

3.2 EX SITU SOIL TREATMENT

All of the ex situ treatment options would require excavation of the soils to be treated.

Due to the primarily sandy (or rocky) composition and relatively shallow depth (~20 feet) of overburden soil that may require treatment, all ex situ treatment technologies are considered implementable. Excavation to this depth to make the soil available for ex situ treatment can be readily accomplished. Due to potentially high emission rates from the soils, mitigation may be required to control chemical emissions during excavation.

3.2.1 BIOLOGICAL TREATMENT

Effectiveness

Based on the results of the Treatability Study, biodegradation would be effective in reducing the chemical concentrations to acceptable levels. During the biological treatment process, some of the chemicals (VOCs) will be more susceptible to volatilization (aeration) whereas other chemicals will be treated primarily by bioremediation (SVOCs). One of the disadvantages of this technology is the potential for excessive air emissions due to the volatilization of chemicals and fugitive dust emissions during the treatment process. If required, mitigative measures could be used to control emissions such as covering the treatment area with a polyethylene cover, minimizing the area of soil tilled at any one time, or conducting the treatment process within an enclosed area(s). Alternatively, biodegradation may be conducted in a below-grade biocell to minimize emissions.

Implementability

This alternative would use common construction techniques. Due to the potential high emission rates from the soils, workers may be required to wear respiratory protection during the treatment process.

Cost

Biological treatment costs would be approximately $40 to $90/cu yd. The cost to treat 21,120 to 32,460 cu yds of material using this technology would be approximately $0.8 to $3.0 million.

3.2.2 SOIL VACUUM EXTRACTION/BIOREMEDIATION

Effectiveness

Based on the results of the Treatability Study, this technology would be effective in reducing the chemicals to acceptable levels. A cover can be placed over the soil pile or biocell to reduce chemical emissions during treatment. One disadvantage of this technology is the fact that a somewhat increased volume of material requiring backfilling is generated due to the addition of moisture retention material (e.g., wood chips).

Implementability

This alternative would use common construction techniques and, therefore, is readily implementable.

Cost

The cost for treatment of the soils using the soil vacuum extraction/bioremediation technology is approximately $50 to $100/cu yd. The cost to treat 21,120 to 32,460 cu yds of material would be approximately $1.1 to $3.3 million.

3.2.3 LOW TEMPERATURE THERMAL DESORPTION

Effectiveness

LTTD is an effective means of removing organic compounds from contaminated soils. It is expected that low ppb concentrations can be obtained using this treatment technology, however, pilot tests would be required to optimize the treatment process and determine obtainable soil cleanup levels.

As this treatment process is conducted in an enclosed unit, and exhaust gases are treated prior to discharge, chemical emissions to the atmosphere during treatment would be insignificant.

Implementability

Mobile LTTDs are available from several suppliers and, therefore, the technology can be readily implemented.

Cost

The cost for treatment of soil using a low temperature thermal unit is approximately \$150 to \$300/cu yd. The cost to treat 21,120 to 32,460 cu yds of soil would range from approximately \$3.2 to \$9.7 million.

3.2.4 ON-SITE INCINERATION

Effectiveness

Incineration is a proven technology with a demonstrated removal efficiency greater than 99.99 percent. Trial burns are required to optimize the temperature and residence time for maximum efficiency. As the treatment occurs within an enclosed unit, chemical emissions to the atmosphere during the treatment process would be insignificant. However, hazardous products of incineration such as particulates, sulfur dioxide, nitrogen oxides and hydrogen chloride require air emission control equipment and disposal as a hazardous waste.

Implementability

On-Site incineration would require a trial burn and permitting which translates to a Remedial Design/Remedial Action period of approximately two years for capital works. Soil remediation would take an additional 4 to 8 months. The necessity to comply with permitting requirements could present a significant obstacle to the implementation of on-Site incineration.

Cost

On-Site incineration costs are in the range of $200 to $400/cu yds. The cost to treat 21,120 to 32,460 cu yds using on-Site incineration would be approximately $4.2 to $13.0 million.

3.2.5 OFF-SITE INCINERATION

Effectiveness

The off-Site incineration option would have the same effectiveness as the on-Site incineration option discussed in Section 3.2.4.

Implementability

Approvals would be required from the selected incineration facility to permit off-Site incineration. Obtaining these approvals could result in substantial delays in implementation.

Costs

Off-Site incineration typically costs approximately $400 to $800/cu yds plus an additional $200/ton for transportation. Therefore, the off-Site incineration of 21,120 to 32,460 cu yds of soil would cost approximately $12.7 to $32.5 million.

3.2.6 SOLVENT EXTRACTION

Effectiveness

Solvent extraction is a technology developed for removing organic chemicals. This technology is not widely used and, therefore, its effectiveness and reliability are questionable. A laboratory treatability and/or pilot test would be required to ascertain the effectiveness on a site-specific/chemical-specific basis.

As the solvent extraction treatment process is conducted in an enclosed unit, chemical emissions to the atmosphere will not occur from the treatment process. Compounds removed from the soil would be transported off Site for permanent disposal.

Implementability

Due to the limited number of mobile solvent extraction units currently available, a lengthy delay may be incurred between the time at which a decision to utilize this technology is made and the time when a unit can be mobilized to the Site.

Cost

Costs for treatment of soil using a solvent extraction treatment unit is approximately $150 to $500/cu yd. The cost to treat 21,120 to 32,460 cu yds of soil is estimated to range from $3.2 to $16.2 million.

3.2.7 SOIL WASHING

Effectiveness

Soil washing would be effective for the COCs. This process generates an additional waste, contaminated water, which must then be treated and disposed.

Implementability

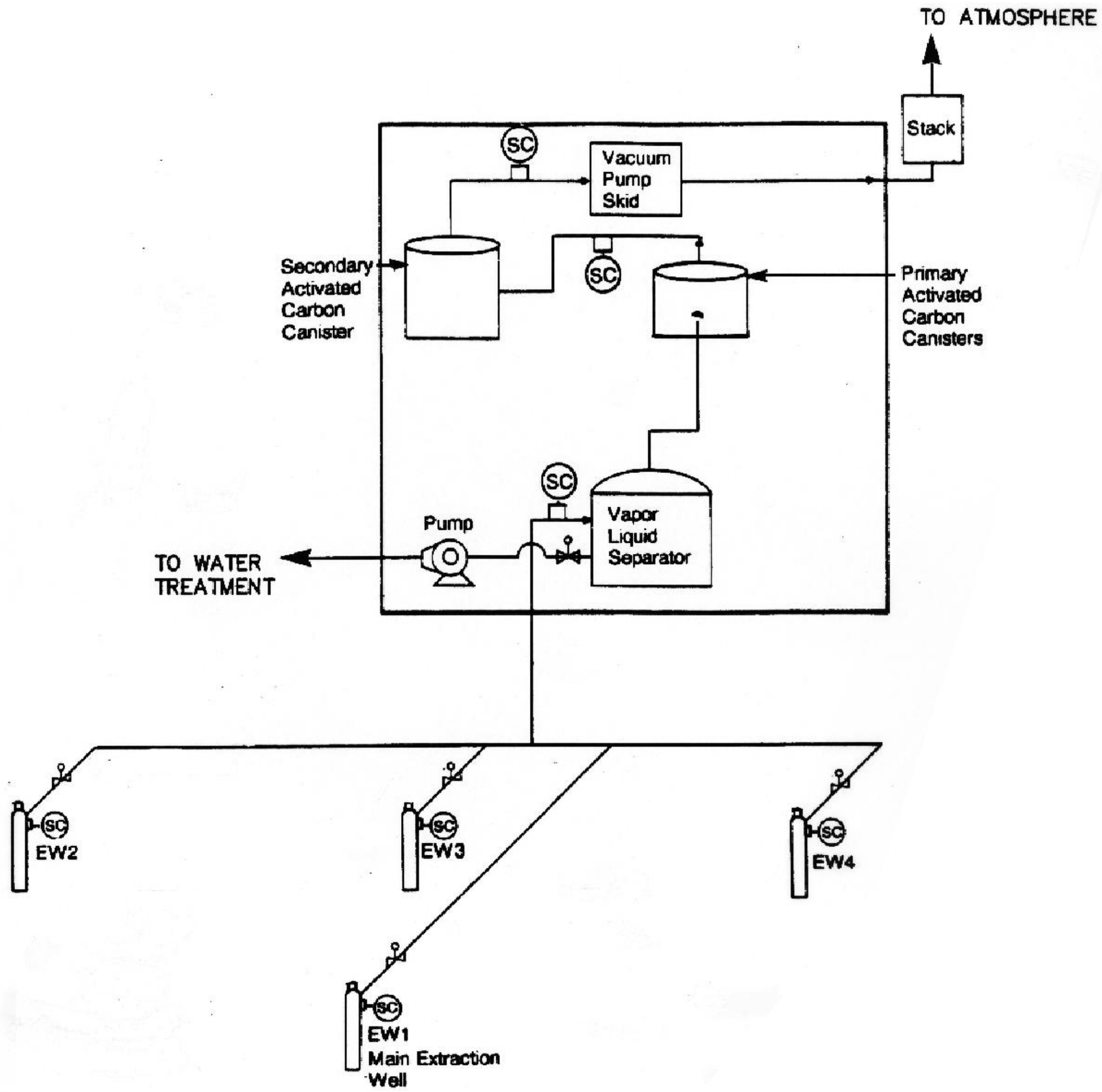
Soil washing is readily implementable. A treatability study would be required to evaluate the effectiveness of this treatment process.

Costs

Costs for treatment of soil using soil washing is approximately $150 to $300/cu yd. The cost to treat 21,120 to 32,460 cu yds of soil is estimated to range from $3.2 to $9.7 million.

3.2.8 SUMMARY

Based upon this evaluation, it is concluded that soil vacuum extraction/bioremediation technology is the most cost-effective ex situ treatment technology for the Site. This alternative is suitable for treatment of the COCs at the Site as demonstrated by the Treatability Study. This alternative is considerably less costly than any of the other treatment technologies, other than biological treatment, which has slightly lower costs but would not be as effective without a SVE component.



SOURCE: SITE REPORT TERRA VAC IN – SITU
VACUUM EXTRACTION SYSTEM

NOTES:
SC – SAMPLING COCK
EW – EXTRACTION WELL

figure C.2.1

SOIL VACUUM EXTRACTION
SAMPLE EQUIPMENT LAYOUT
FORMER LAGOON SITE
Hamptonburgh, New York

CRA

03698-00(032)GN-WA002 JUN 23/2006

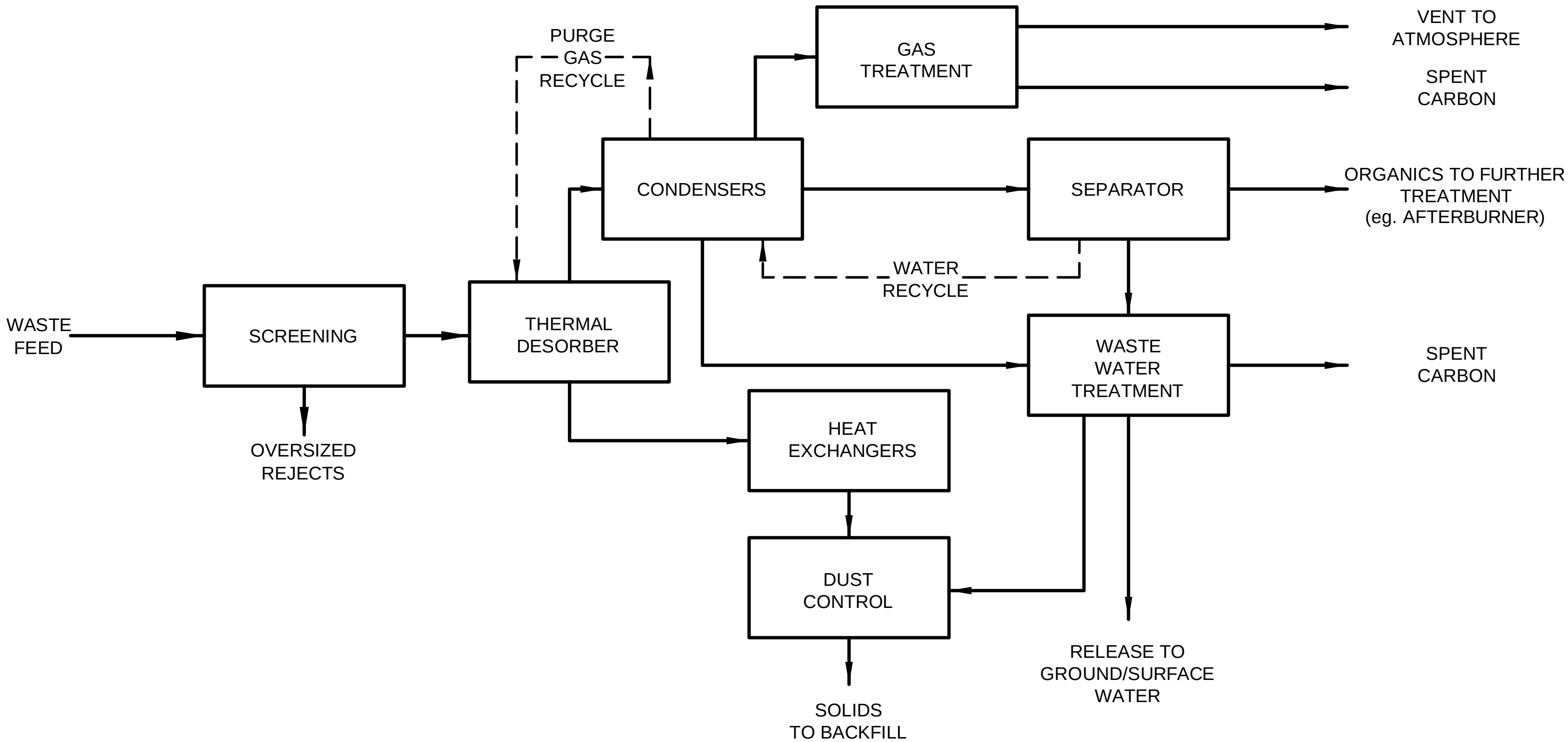
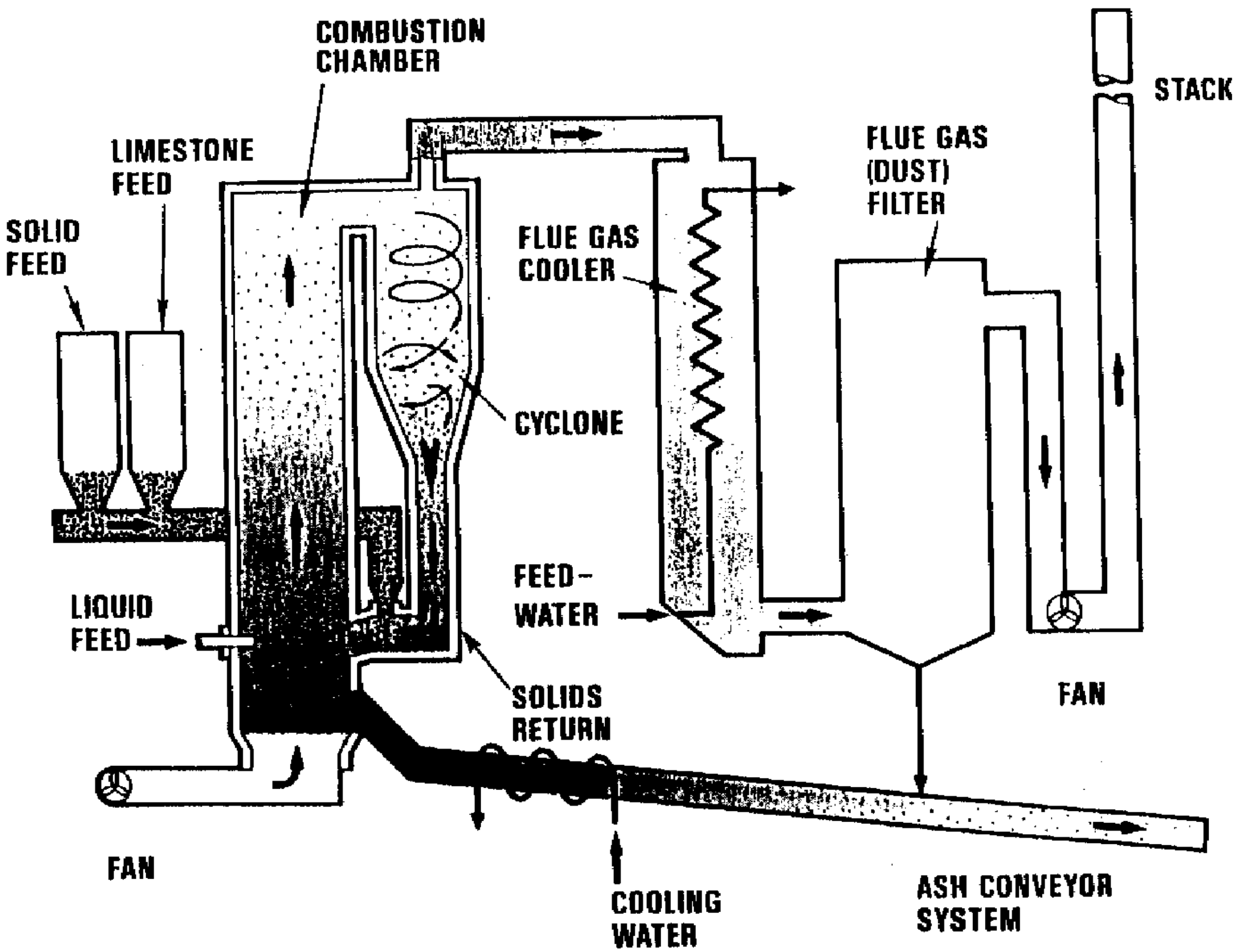


figure C.2.2

THERMAL DESORPTION PROCESS
GENERAL FLOW DIAGRAM
FORMER LAGOON SITE
Hamptonburgh, New York

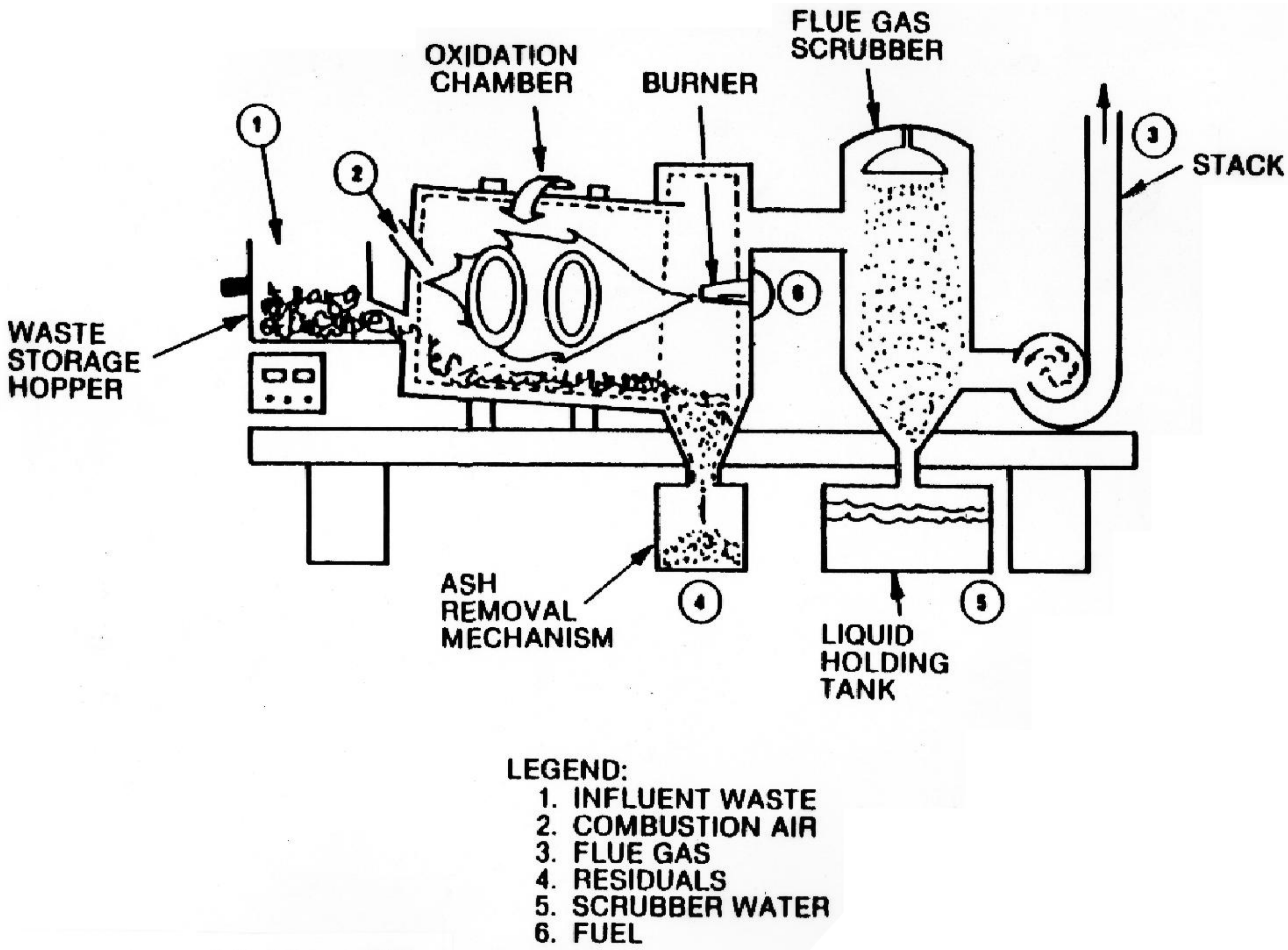
03698-00(032)GN-WA003 JUN 23/2006



SOURCE: OGDEN ENVIROMENTAL SERVICES INC.

figure C.2.3

CN-SITE INCINERATION - SCHEMATIC
OF CIRCULATING BED COMBUSTION
FORMER LAGOON SITE
Hamptonburgh, New York



Source: Ghassami, Yu, and Quinlivan, 1981

figure C.2.4

OFF-SITE INCINERATION
SCHEMATIC OF ROTARY KILN
FORMER LAGOON SITE
Hamptonburgh, New York