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Technology Summary for Remediation of PCB-Bearing Soils and Sediments at Tennessee Gas Pipeline Compressor Stations New York

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Prepared for

Tennessee Gas Pipeline Company
Houston, Texas

For Submission to

New York State
Department of Environmental Conservation

Prepared by

ENVIRON Corporation
Princeton, New Jersey

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CONTENTS

1 INTRODUCTION

In accordance with the Consent Orders issued by The New York State Department of Environmental Conservation (NYSDEC), Tennessee Gas Pipeline Company (TGPL) is in the process of conducting a Remedial Investigation/Feasibility Study (RI/FS) at its Compressor Stations 224, 229, 237, 241, 245, and 254 in New York. As a part of the FS activities, TGPL has identified the remedial alternatives that are applicable to PCB-bearing soils and sediments, in areas where remediation is necessary. Detailed screening and evaluation of remedial alternatives for PCB soils and sediments will be provided in the formal FS submittal. The objective of this submittal is to provide a preliminary review and summary of the alternatives considered by TGPL and to describe in some detail a subset of alternatives that are considered most applicable for soils and sediments at TGPL sites. The alternatives considered in this document include:

- Institutional actions (fencing, deed restrictions)
- Containment (capping and surface control)
- Treatment (solidification, quicklime treatment, solvent extraction, bioremediation, soil washing, chemical dechlorination, thermal desorption, vitrification, on- and off-site incineration)
- Disposal (on- and off-site TSCA landfills, on- and off-site industrial landfills)

A summary of each of these remedial alternatives is presented in Section 2. Descriptions for a subset of the remedial alternatives that are considered most appropriate for PCB soils and sediments at TGPL sites in New York are provided in more detail in Section 3. The alternatives presented in Section 3 are:

- Treatment
  - Solidification
  - Quicklime treatment
  - Solvent extraction
  - Thermal desorption
- Disposal
  - Off-site landfill disposal

2 IDENTIFICATION OF REMEDIAL ALTERNATIVES FOR SOILS AND SEDIMENTS

Several remedial alternatives are potentially feasible and applicable for remediation of PCB-bearing soils and sediments at the TGPL compressor stations in New York State. These remedial alternatives are identified and discussed briefly below.

2.1 Institutional Actions

2.1.1 Fencing

The objective of this option is to reduce the potential exposure to PCBs by restricting access to the areas with PCB-bearing soils. This alternative involves construction of fences around the areas where PCB levels do not exceed the criterion for restricted access.

2.1.2 Deed Restrictions

At locations where the soils with PCBs above the levels of potential concern are left in place (e.g., areas where remediation is not feasible due to the presence of site structures), deed restrictions may be considered. The deed restrictions would place an encumbrance on the property which would be identified at the time of any property title transfer.

2.2 Containment Technologies

2.2.1 Capping and Surface Control

Capping involves covering the PCB-bearing soils or sediments in place with a clay cap, a synthetic membrane, or an asphalt cap. The surface controls for stream sediments include diverting the stream over a clean area, capping the sediments, and implementing erosion control measures.

2.3 Treatment/Disposal Technologies

This section summarizes treatment and disposal alternatives considered for soils and sediments that contain PCBs. Some of the on-site treatment technologies presented in this section may be implemented at a regional facility or by employing a sequential remediation approach. The regionalized approach would involve construction of the treatment process train at a centralized location where remediation can be implemented more cost-effectively and efficiently for all the compressor stations than would be possible with a treatment unit at each compressor station. The sequential approach would involve initiating remediation at one station on one end of the state (e.g., Station 224) and then mobilizing and treating soil at each sequential station (e.g., 229, 237 and so on).

2.3.1 Solidification

The solidification process involves aboveground mixing of soil or sediment with cement-based materials. Solidification is offered by a number of vendors who use a variety of mixing agents, depending on the waste characteristics and matrix type.

All soil and sediment exceeding the cleanup goals are required to be excavated and stockpiled for treatment. The soil would then be mixed with cement-based materials, fly ash, and water and allowed to set in concrete forms in a designed placement area. The final solidified mass may also be redeposited in the excavated area.

2.3.2 Quicklime Treatment

This process involves mixing PCB-bearing soils and sediments with quicklime and water. Some modified processes involve addition of dechlorination agents. The resulting product is a homogeneous, pulverized material with increased surface area for reaction with dechlorination agents. This treatment process can be implemented either *in situ* by spreading the treatment chemicals on the soil surface and working it with heavy-duty milling machines, or on-site aboveground by using mobile treatment units. In the case of surface soils, the *in situ* method would be applicable. Sediments, subsurface soil, and surface soil in locations where milling is not practical would require excavation/removal and treatment in an aboveground reactor. Treated soil/sediment or clean soil may be used as backfill material.

2.3.3 Solvent Extraction

PCBs associated with soils and sediments can be extracted by chemical solvents under appropriate environmental conditions. The extractant with PCBs is removed from soil by physical separation techniques and processed to concentrate PCBs; the recovered extractant is reused in the process. PCBs present in the extractant require final disposal.

In applying the solvent extraction method to the compressor stations, all the soils and sediments exceeding the cleanup goals would have to be excavated and stockpiled for treatment. Following the extraction of PCBs using solvents, the soils and sediments could be either returned to the excavated area or placed elsewhere on-site.

2.3.4 Bioremediation

PCBs are reported to be degraded and/or dechlorinated by indigenous microorganisms. Generally, the congeners with higher chlorine contents are dechlorinated by anaerobic organisms. Aerobic organisms appear to be more effective in degrading congeners with lower chlorine contents. Bioremediation may be implemented *in situ* or aboveground.

The remedial approach considered here is the aboveground, on-site biological degradation of PCBs. This involves excavation of soils and sediment with PCBs above the cleanup goal, mixing with appropriate additives in a mixing unit, and allowing the bioremediation to occur in a reactor or a pile. Biologically-treated soils may be redeposited in the excavated area provided the treatment effectively degrades PCBs to levels below the cleanup goals. However, the available information on successful bioremediation of PCB soils and sediments is presently very limited.

2.3.5 Soil Washing

Soil washing systems involve aboveground treatment of excavated soils/sediments with chemical reagents or surfactants. PCBs are transferred into the liquid medium and then concentrated or adsorbed onto carbon. The concentrated liquids or spent carbon containing PCBs would require regeneration, treatment or final disposal depending on the PCB content.

For soil washing, all the soils and sediments containing PCBs above the cleanup levels would be excavated and stockpiled. Soil washing would be performed with dilute solutions of chemical reagents. Sediments and the treated solids could be redeposited in the excavated area.

2.3.6 Chemical Dechlorination

Alkaline/polyethylene glycolate (APEG) used in this process cleaves chlorine atoms from the PCB molecules to form aromatic ethers as the treatment end-products. The chemical dechlorination process operates in batch or semi-batch modes at elevated temperatures. Chemical additives (catalysts) are reportedly used in some instances to improve the process efficiency.

All soils and sediments exceeding the cleanup goals would be excavated and stockpiled prior to chemical dechlorination. Following treatment, the soils could be returned to the excavated area.

2.3.7 Thermal Desorption

Thermal desorption technology involves heating the soils and sediments to volatilize PCBs and removing the volatilized PCBs with a heated air stream. The vapor stream is either condensed or adsorbed onto solvents to remove PCBs. The off-gas stream and liquid stream are treated to remove PCBs and other organic compounds of concern. Condensed PCBs or PCB-sorbed solvents require disposal.

In this process, PCBs in the excavated and stockpiled soils/sediments would be thermally desorbed, and the treated solids could be redeposited in the excavated area.

2.3.8 Vitrification

In situ vitrification uses electrical energy to melt and then solidify soils. Uniformly spaced electrodes are inserted into the ground at depths up to 50 feet. Since soil is not initially conductive, a mixture of glass grit and graphite is used as a starter path. The soil is heated above its melting point, and a durable, obsidian-like product is formed as it cools. Vitrification can also be performed in tanks.

Due to specific station characteristics (e.g., distribution of high-pressure air and gas lines below the grade), *in situ* vitrification of soils and sediments may not be acceptable at all locations of a compressor station. However, this alternative may be implemented if the material is excavated and treated in tanks or in remote locations where there are no underground or aboveground structures.

2.3.9 On-site Incineration

On-site incineration has been used to treat PCB-bearing soils, sediments, and sludge. The most common incineration processes for PCB treatment are infrared, rotary kiln, and circulating bed combustion. These thermal destruction processes use high temperatures in the presence of oxygen to oxidize PCBs into products such as carbon dioxide, water vapor, nitrogen oxides, hydrogen chloride gas, and ash. On-site incineration involves mobilizing a permitted (40 CFR 761.70) process unit to the site. All soils and sediments exceeding the cleanup goals would be excavated and treated by incineration. The excavated area would be backfilled with treated or clean soil.

2.3.10 Off-site Incineration

Similar to on-site incineration, off-site incineration has been used to treat PCB-bearing soils, sediments, and sludge. Under this remedial option, all soils and sediment exceeding the cleanup goals would be excavated and transported to an incinerator permitted (40 CFR 761.70) for treatment of PCB-bearing soil and sediments.

2.3.11 Off-site Landfill

PCB-bearing sediments and soils may be disposed of in landfills. Off-site industrial landfills may accept only soils and sediments with PCB levels below 50 ppm. Soils and sediments with PCB levels greater than 50 ppm must be disposed of in Toxic Substances Control Act (TSCA) or Chemical Waste Landfills (40 CFR 761.60 (a)(2)(ii)). Therefore, soils and sediments with PCBs can be disposed of in an off-site industrial landfill and/or a TSCA landfill, depending on the PCB content.

(a) Off-site TSCA Landfill of Soil with Greater than 50 ppm PCBs and Off-site Industrial Landfill of Soil with Less than 50 ppm PCBs

Within the volume of soils and sediments exceeding the cleanup level, delineation would take place to separate soils/sediments containing PCBs above 50 ppm from the remainder. The volume of material exceeding 50 ppm PCBs would be excavated and transported to a TSCA landfill; the remainder would be excavated and transported to an industrial landfill that is permitted to accept material containing PCBs at levels below 50 ppm. The excavated area would be backfilled with clean fill.

(b) Off-site TSCA Landfill

All soils and sediments exceeding the cleanup levels would be excavated and transported to a TSCA landfill. The excavated area would be backfilled with clean fill.

2.3.12 On-site Landfill

Disposal of PCB-bearing soils and sediments may be acceptable in on-site TSCA or industrial landfills, depending on the PCB concentrations. Design and construction of an on-site TSCA landfill should meet the specifications and guidelines given in 40 CFR 761.60. The excavated soil is placed in the landfill, and a cover meeting the above regulations is then constructed. The excavated area is backfilled with clean fill. All components of the landfill (e.g., the cover, the leachate collection system) require maintenance on a regular basis. Ground water monitoring is required to verify the effectiveness of the leachate collection system.

Soils and sediments with PCB concentrations that do not exceed 50 ppm may be disposed of in an industrial landfill that is designed, constructed, and maintained as given in 40 CFR Parts 241 and 257 and 6 NYRR part 360.

(a) On-site TSCA Landfill

All soils and sediments exceeding the cleanup levels would be excavated and stockpiled at the site. A TSCA landfill of the appropriate size to accommodate that volume would be constructed. The excavated soil would be placed into the landfill, and a cover meeting the applicable regulations would be constructed. The excavated area would be backfilled with clean fill. All components of the landfill (e.g., the cover, the leachate collection system) would undergo maintenance on a regular basis, and ground water monitoring would take place to verify the effectiveness of the containment system.

(b) On-site Industrial Landfill of Soil with Less than 50 ppm PCBs and Off-site TSCA Landfill of Soil with Greater than 50 ppm PCBs

Within the volume of soils and sediments exceeding the cleanup levels, delineation would be performed to separate soils containing PCBs above 50 ppm from the remainder. The entire volume of soils would be excavated and the portion exceeding 50 ppm PCBs would be transported to a TSCA landfill. The remainder would be stockpiled on-site.

A landfill of the appropriate size to accommodate the remaining soils would be constructed according to the regulations for industrial landfills. The excavated soils would be placed in the landfill, and a cover meeting the applicable regulations would be constructed. The excavated area would be backfilled with clean fill. All components of the landfill (e.g., the cover and the leachate collection system) would undergo maintenance on a regular basis, and ground water monitoring would take place to verify the effectiveness of the containment system.

3 REVIEW OF SELECT REMEDIAL ALTERNATIVES

The remedial alternatives presented in the previous sections were reviewed and a set of treatment/disposal options considered more appropriate for TGPL sites in New York were identified for further investigation. These remedial alternatives include:

- Treatment
  - Solidification
  - Quicklime treatment
  - Solvent extraction
  - Thermal desorption
- Disposal
  - Off-site landfill disposal

These alternatives were identified based on current information available from the technology vendors. Other options may be identified or re-evaluated in the future based on new technology developments. The FS will provide a formal evaluation of all appropriate technologies.

Some treatment processes may result in a reduced potential for environmental release and migration of PCBs, destruction of PCBs, or removal of PCBs from soil and sediment; PCB removal would result in a concentrated waste stream of a relatively small volume requiring final treatment and disposal. Each of these alternatives and activities included in the detailed review process are described below. As discussed in the previous section, some of these treatment technologies may be implemented at a regionalized facility.

3.1 Solidification

The solidification technology involves mixing PCB-containing soils and sediments with a cement-based pozzolanic mixture, resulting in a solidified mass of extremely low permeability. This technology is offered by a variety of vendors. The solidification process by QUALTEC was successfully employed by the U.S. Environmental Protection Agency (USEPA) at the Pepper's Steel and Alloys Superfund site in Miami, Florida to solidify 120,000 cubic yards of soils containing PCBs and heavy metals.

The two primary objectives in solidification of soils are assuring that the solidified material can effectively isolate PCBs from the biosphere and assuring that it can continue to do so permanently. These two concerns are addressed through control of the leachability and durability of the monolith.

The leachability of PCBs from the solidified mass is controlled through several mechanisms:

- Chemical Binding: Organophilic additives are mixed in the pozzolanic grout formula to chemically bind with the PCBs and immobilize them within the solidified mass.

- Low Permeability: The use of Portland Cement fly ash and other additives gives the waste form a dense, closed-cell structure that reduces porosity. Reduced porosity results in low permeability, and this low permeability virtually eliminates the ability of water to percolate through the mass and act as a transport medium for PCBs.

- Surface Area to Mass Ratio: The conversion of soil from small particles to a large solidified mass greatly decreases the surface area to mass ratio. Reduction of this ratio works to inhibit PCB mobility due to surface contact mechanisms.

The leachability of PCBs can be measured using EPA's Toxicity Characteristic Leaching Procedure (TCLP) test. The durability of this solidified mass is characterized by measures of compressive strength and penetration resistance at different times during the curing process.

Treatability tests have been completed by QUALTEC on sample soils from two TGPL compressor stations selected to represent the extremes in soil types found at TGPL stations; samples taken represented sandy soil types and clayey soil types. The results demonstrated the effectiveness of the process by forming an extremely low permeability material with sufficient compressive strength to support a cap or low-grade building. The TCLP was used to verify that no detectable PCBs leached from the solidified material. The test results indicate that solidification can be successfully applied to TGPL sites to meet the desired process specifications.

The treatment of soils by solidification is not a complex process and does not require specially designed or unique equipment. Common construction equipment such as cement mixers, conveyor belts, and sludge pumps can be modified to provide adequate mixing and proper proportioning of soil, water, and grout. Equipment can be sized to process various soil quantities efficiently. The equipment that would be chosen for this job should be able to process soils rapidly, relative to other on-site technologies. In addition, the processing of soils is typically insensitive to soil type and condition.

This remedial alternative would involve excavation/removal of soils and sediments that contain PCBs above the levels of potential concern and mixing in an aboveground reactor with appropriate chemical agents. The treated material would be placed in an excavated area on-site and, after curing until it meets the required specifications, covered with a soil layer. The placement area would be engineered to allow quality control measures to be implemented without the compromising of process throughput. The placement area would be designed so that each treated batch of material could be isolated and identified. Clean soils excavated to prepare the placement area may be used to backfill the voids resulting from the excavations of PCB-containing soils.

3.2 Quicklime Process

The USEPA has reported the use of quicklime as an additive at four sites, including the Cam-Or Superfund site in Westville, Indiana, to prepare PCB-containing materials for incineration. Subsequent testing of these PCB-containing materials showed a reduction of PCBs. Following these findings, the USEPA's Cincinnati-based research laboratory contracted with RMC Environmental and Analytical Laboratories (RMC) of West Plains, Missouri to analyze samples obtained from these sites in an attempt to discover the cause of the reduction in the levels of PCB concentrations.

RMC issued a draft report of its findings to the USEPA in October 1990 indicating that the addition of quicklime and a catalyst caused a reaction which triggered a molecular breakdown of the PCBs. USEPA is currently conducting an in-house peer review of RMC's initial findings.

Also, as part of an ongoing experimental program, the USEPA's Office of Research and Development in Cincinnati, Ohio designed and conducted an experimental program to reproduce and extend the work performed under the cooperative agreement with RMC Laboratories. The USEPA Risk Reduction Engineering Laboratory in Cincinnati, Ohio released the final report of this study, entitled "Fate of PCBs in Soil Following Stabilization with Quicklime" in September 1991 (USEPA Report Number EPA/600/2-91-052). The report states, "Significant PCB losses (60% to 85%) were evidenced after five hours of treatment. However, evaporation and steam stripping at elevated temperature conditions, rather than decomposition accounted for most of the losses observed. Low levels of partially dechlorinated PCB congeners were detected in lime-treated samples but quantities were stoichiometrically trivial." EPA further states that use of quicklime alone as an *in situ* treatment for removal of PCBs is not supported by these results. However, RMC has informed TGPL that it has identified the mechanisms causing PCB destruction and can reproduce them reliably. If additional information supports effective and efficient destruction of PCBs by quicklime or other modified techniques, TGPL will consider commissioning RMC to conduct treatability studies.

TGPL is also pursuing other potential avenues of quicklime application. For example, Groundwater Technology, Inc., an environmental consulting company headquartered in Pennsylvania, is working with a quicklime application called "Dispersion by Chemical Reaction (DCR) Technology." The DCR Technology was developed by Dr. Friedrich Bolsing, an organic chemist at the University of Hannover in Germany. It is designed to dehalogenate organic compounds, including PCBs, at ambient temperatures by means of nucleophilic aromatic substitution mechanisms.

Groundwater Technology, Inc. describes the DCR Technology in the following manner:

> "The DCR Technology uses hydrophobized quicklime (CaO) to disperse the soil particles, PCB's, and nucleophilic reagents thereby creating a highly mixed homogeneous medium. The degree of homogeneity is much greater than can be accomplished by mechanical means such as grinding.
>
> "The mechanism for the dispersion is the reaction of CaO with water to form calcium hydroxide $Ca(OH)_2$. The resulting calcium hydroxide has a surface area that is 20-30 times that of the CaO. This increase in surface area is not accompanied by a similar increase in volume.
>
> "To accomplish the dehalogenation of PCB's the hydrophobic quicklime is charged with potassium polyethylene glycolate (KPEG) and a solvent such as Dimethyl sulfoxide (DMSO) prior to the execution of the dispersing reactions. Nucleophilic substitutions other than KPEG can be utilized based on site specific conditions and requirements. The most useful nucleophilic reagent and the proper concentration of the reagent is established by performing laboratory bench scale studies."

TGPL is in the process of reviewing a proposal for bench-scale and pilot testing of the DCR technology process presented by Groundwater Technology. However, since the USEPA has commissioned RMC to conduct some of the Agency's own investigations, TGPL is currently concentrating its efforts with RMC.

3.3 Solvent Extraction

PCBs in soils and sediments can be extracted by using non-toxic and/or biodegradable solvents. Two processes that are available at commercial scale include Terra-Kleen and BEST processes. In Terra-Kleen process, mobile leaching units using a purportedly non-toxic, proprietary solvent are employed to extract PCBs from solids. The process is designed as a counter-current treatment unit with a continuous feed that uses recycled solvent. PCBs in the still bottom are concentrated by a distillation process prior to disposal. Technical feasibility of the Terra-Kleen process for PCB treatment was demonstrated under the EPA's Superfund Innovative Technology Evaluation program at a Superfund site in Tulsa, Oklahoma.

In the BEST process, the extraction agent used is triethylamine (TEA), which has a unique property of inverse miscibility at different temperature ranges. Below 65°F, TEA is miscible with water; above this temperature, it is immiscible. Treatment takes place in two stages known as cold and hot stages. During the "cold stage" (40°F), the feed material is mixed with the TEA. Sufficient residence time is provided to allow the water, oil, and solvent to form a single liquid phase. The solids are separated from the liquids via centrifugation or filtration. The solids are then dried for TEA recovery. (Any TEA remaining in the soil is reported to be gradually removed by biodegradation). The liquid phase now contains the PCBs, other organics and any oil originally present. During the "hot stage", the liquid (TEA/water/oil) fraction is heated to about 130°F where TEA and oil (containing all organics) separate from the water. Water is drawn off from the reactor and steam-stripped to recover any residual TEA. The TEA/oil fraction goes to an evaporator or distillation unit to recover TEA. The remaining oil phase contains the PCBs and requires final treatment or disposal.

The application of the BEST process was demonstrated at several sites including the General Refining site in Georgia and GM-Massena site in New York. Site remediation activities performed at the General Refining site included removal of PCBs in sludge by BEST solvent extraction; the PCBs levels were reduced from 10 ppm to below 0.1 ppm. During the pilot-scale demonstration performed at GM-Massena site in New York, the PCBs were reportedly reduced from 2000-ppm levels to below the detection limit of 1 ppm. The BEST process was successfully tested by the Resources Conservation Company for TGPL using representative PCB-bearing soils collected from TGPL stations. The initial PCB levels in the soil samples ranged from 430 to 1800 ppm, and were reduced to levels of 1.5 ppm or below as a result of the treatment.

These tests also indicate that the number of rinsing steps required to treat soil depends on the initial PCB levels in soils and the target remediation level.

3.4 Thermal Desorption

Thermal desorption uses heat to physically separates PCBs from soil and sediment. Typically, soils are screened to remove oversized material, then heated up to about 1,000°F, depending on the process. At these elevated temperatures, PCBs are volatilized from the solid phase. PCBs are subsequently condensed into a concentrated chemical waste stream, which is further treated or disposed of in an appropriate manner. The exact volume of the concentrated waste stream, although small, varies among the available thermal desorption processes, and dechlorination agents may be used to reduce or possibly eliminate the need for disposal of PCBs. The application of dechlorination as part of the remedial process depends on treatability testing results and cost-effectiveness. The process also generates a condensed water stream containing organic constituents originally present in the untreated soil. This water is generally treated on-site with an activated carbon system. Finally, air generated in the process is vented through activated carbon that is transported off-site for disposal or regeneration.

Three vendors are currently marketing thermal desorption for treatment of soils containing PCBs:

- Taciuk (Canonie Environmental [Canonie]);
- Desorption and Vaporization Extraction System (DAVE) (Recycling Sciences International [RSI]); and
- X-TRAX™ (Chemical Waste Management [CWM]).

The Taciuk process pilot tests have demonstrated that PCB levels in soils were reduced from 15,000 ppm to non-detect levels (<0.1 ppm). It was successfully used with dechlorination at the Wide Beach Superfund site in Brandt, New York, to treat silty and clayey PCB-containing soils to less than 2 ppm; the average PCB level in soils was 25 ppm. Canonie has also been contracted to remediate PCB-containing soils and sediments at the Outboard Marine Superfund site in Waukegan Harbor, Illinois (without dechlorination). While RSI has not yet constructed a full-scale treatment unit for the DAVE process, it has applied for a TSCA permit. In numerous tests on PCB-containing sediments from Waukegan Harbor, its pilot-scale unit reduced PCBs from more than 200 ppm to below 2 ppm. Finally, the X-TRAX™ unit is scheduled to treat PCB-containing soils at the Re-Solve Superfund site in North Dartmouth, Massachusetts. CWM also operates a TSCA-permitted, pilot-scale X-TRAX™ unit at its facility in Kettleman Hills, California.

3.5 Off-site Landfill

The remedial option considered here includes disposal of PCB-bearing soils and sediments in an off-site TSCA landfill. Disposal of soils and sediments with PCB levels less than 50 ppm into a non-TSCA landfill may also be considered. The selection of an appropriate landfill would be based on the quantity of materials that needs to be disposed and availability of landfill capacity. These issues will be discussed in details in the FS report where the soil and sediment quantities will be presented.

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ENVIRON

[illegible]

[illegible] North Fairfax Drive
Arlington, Virginia 22203
(703) 516-2300
(800) ENVIRON

[illegible]
[illegible]
(609) [illegible]
(800) 552-ECRA

[illegible]
[illegible]
[illegible] 94608
[illegible]

One Park Plaza, Suite 700
Irvine, California 92714
[illegible]
[illegible]