FINAL REMEDIAL DESIGN REPORT

For:

Clifton Former Manufactured Gas Plant (MGP) Site

Operable Unit No. 1 (OU-1)
40 Willow Avenue Parcel
Site No. 2-43-023
Staten Island, Richmond County, New York

Prepared for:

KEYSPAN CORPORATION

One MetroTech Center
Brooklyn, New York 11210-3850

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Prepared by:

PAULUS, SOKOLOWSKI AND SARTOR ENGINEERING, PC
67A Mountain Boulevard Extension
Warren, New Jersey 07059

Date: 02/28/07

Joseph J. Lifrieri, P.E., P.P., CPG
N.Y.S. P.E. License No. 0555341

STATE OF NEW YORK · JOSEPH J. LIFRIERI · No. 055341 · LICENSED PROFESSIONAL ENGINEER

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EXECUTIVE SUMMARY

Paulus, Sokolowski and Sartor Engineering, PC (PS&SPC) has been retained by KeySpan Corporation (KeySpan) to prepare this Remedial Design Report (RDR) to document the design of the remedial actions for Operable Unit No. 1 (OU-1) of the Clifton Former Manufactured Gas Plant (MGP) Site located at 40 Willow Avenue in Staten Island, Richmond County, New York (Site No. 2-43-023). The New York State Department of Environmental Conservation (NYSDEC) technical and administrative guidance document, *Draft DER-10, Technical Guidance for Site Investigation and Remediation [NYSDEC, 2002]* (DER-10) was used as a guideline for the basis of the remedial design. This RDR has been prepared to be consistent with the NYSDEC DER-10 guidance document.

The 40 Willow Avenue Parcel encompasses an area of approximately 0.98 acres and is located at the southwestern corner of the intersection of Bay Street and Willow Avenue in the Clifton section of Staten Island, New York. The Site is bounded to the northwest by Willow Avenue; to the northeast and east by Bay Street; to the south by a residential section of Staten Island which fronts along Lynhurst Avenue, and to the west by a two-story commercial building and associated paved parking lot (66 Willow Avenue). Further to the northwest, beyond Willow Avenue, is the remainder of the Former Clifton MGP Site (i.e., the 25 Willow Avenue Parcel (OU-2)). The area surrounding the 40 Willow Avenue Parcel is characterized by a combination of urban residential and commercial uses.

The Clifton Former MGP Site was formerly owned and operated by Richmond County Gas Light Company from 1856 to 1901. The Site was sold in 1901 and owned and operated by the New York and Richmond Gas Company until 1957. At that time, Brooklyn Union (KeySpan) acquired the New York and Richmond Gas Company. Brooklyn Union/KeySpan never operated the former MGP site.

The remedial alternative to be implemented at OU-1 was selected in a document entitled "Record of Decision, Former Clifton MGP Site, Operable Unit No. 1, Staten Island Richmond County, New York" (ROD) prepared by the New York State Department of Environmental Conservation (NYSDEC) and dated March 31, 2004.

Subsequent to the issuance of the ROD, KeySpan has completed several studies to develop a remedial design. These studies have included topographic and obstruction surveys, borings, an initial test program for the jet grout columns and most recently, a full- scale Trial Field for the jet grout columns. KeySpan has also retained the services of a nationally recognized jet grouting consultant to guide the design of the jet grout column wall and has tried to secure access from adjacent residential properties to complete proposed monitoring and remedial activities.

A remedial design letter report was previously submitted to and approved by NYSDEC for the installation of steel sheet piling, as a component of the containment wall required by the ROD. The installation of the steel sheet piling was started in early January 2006. Work started without access agreements from the residential properties. Community complaints of noise and vibration at the Site were received from the residences during the sheet pile driving and pile driving work at the Site was suspended in February 2006 pending the NYSDEC approval of a Noise Mitigation Plan. A Noise Mitigation Plan was submitted by KeySpan and approved by NYSDEC in April 2006. This Plan requires the granting of access from the residences for the installation of noise and vibration monitoring equipment, and the use of an acoustical curtain during sheet pile driving. Access has not granted by the residences and efforts are being made to secure access in order to allow resumption of the sheet pile driving.

As a result of these studies and in compliance with the ROD, KeySpan's selected remedial design includes the construction of the following components in the sequence below:

- Installation of steel sheet piling to a maximum depth of approximately 35 feet below grade surface. Steel sheet piling installation will be completed under the terms of the detailed Noise and Vibration Mitigation Plan approved by NYSDEC. The depth of steel sheet piling may also be reduced if hard driving is experienced or if noise levels in excess of the approved Plan are observed. Steel sheet piling installation will commence when access to the adjacent residential properties has been obtained by KeySpan.

- Installation of a 12 inch thick reinforced concrete pad over the entire OU-1 area. The pad will prevent human exposure to any contaminated soil and will prevent the infiltration of precipitation.

- Installation of subsurface overlapping jet grout columns, constructed through special sleeves installed into the concrete pad. The jet grout columns will be joined to the steel sheet piling to form a continuous subsurface wall, keyed into a confining soil layer at a depth of approximately 125 feet below grade surface.

- The performance of a soil gas surveys at the Site and on adjacent properties prior to, during and after the installation of the jet grout column wall for the evaluation of soil vapor impacts due to construction of the jet grout column wall.

- Installation of recovery wells through the concrete pad for the purposes of passive DNAPL recovery and monitoring. Recovery wells will be installed after jet grouting has been completed to minimize potential interferences with jet grouting.

- Institutional controls consisting of an environmental easement which will include restrictions on groundwater usage or future use of the land, maintenance of site access restrictions through fencing and lockable gates and site management plan.

- Long term monitoring of groundwater and DNAPL in and outside the containment area and monitoring of the integrity of the concrete cap.

This RDR which details the design of KeySpan's selected remedial components is organized into the nine sections summarized below:

Section 1.0 – INTRODUCTION: This section describes the administrative history of the Site; describes the remedial design objectives and provides a project background.

Section 2.0 – OU-1 PRE-REMEDIAL DESIGN ACTIVITIES: This section summarizes the implementation of pre-remedial design activities to obtain supplemental information in support of the design of the proposed remedial actions.

Section 3.0 – OU-1 REMEDIAL DESIGN ACTIVITIES: This section provides the design basis and remedial objectives for the Site and describes the remedial systems that will be constructed during implementation of OU-1 remedial activities.

Section 4.0 – ENGINEERING COST ESTIMATE AND PROJECT SCHEDULE: This section provides a cost estimate for the remedial construction and provides a project schedule.

Section 5.0 - IDENTIFICATION OF PROPERTY ACCESS AND FEDERAL AND STATE PERMITS REQUIRED FOR OU-1 REMEDIATION: This section summarizes the property access and permits that will be necessary to implement the construction of the remedial actions described in this RDR.

Section 6.0 – CONSTRUCTION: This section provides a discussion of the implementation of remedial construction activities and the contractor selection method.

1.0 INTRODUCTION

1.1 Administrative History

Paulus, Sokolowski and Sartor Engineering, PC (PS&SPC) has been retained by KeySpan Corporation (KeySpan) to prepare this Remedial Design Report (RDR) to present the design of the remedial actions for Operable Unit No. 1 (OU-1) of the Clifton Former Manufactured Gas Plant (MGP) Site located at 40 Willow Avenue in Staten Island, Richmond County, New York (Site No. 2-43-023).

This RDR has been prepared in accordance with the Order on Consent, Index Number D2-0001-98-04 (the Order) executed by Brooklyn Union Gas Company (a predecessor to KeySpan) and the York State Department of Environmental Conservation (NYSDEC) on April 14, 1998. The Order obligates KeySpan to implement the remedial program at the Site

1.2 Remedial Design Objectives

In March 2004, the NYSDEC issued a Record of Decision (ROD) for the *Former Clifton MGP Site, Operable Unit No. 1, Staten Island, Richmond County, New York (Site Number 2-43-023).* This ROD requires that KeySpan remediate OU-1 in accordance with the selected remedy described in the ROD. As described in the March 2004 ROD, at a minimum, the selected remedy must eliminate or mitigate all significant threats to public health and/or the environment as a result of the presence of the hazardous waste disposed of at the Site.

The remediation goals for the Site are to eliminate or reduce, to the extent practicable:

- Exposures of persons at or around the Site to contaminants in surface and subsurface soils exceeding Standards, Criteria and Guideline (SCG) values;

- Exposures of persons to contaminants in groundwater that exceed groundwater quality standards;

- Migration of dense non-aqueous phase liquids (DNAPL) from subsurface soil into groundwater that may create exceedances of groundwater quality standards; and,

- Continued groundwater migration through subsurface soils that contain DNAPL.

The March 2004 ROD includes a selected remedy to achieve these objectives. The elements of this selected remedy, as stated in the March 2004 ROD, are as follows:

- A remedial design program to provide the details necessary for the construction, operation, maintenance and monitoring of the remedial program.

- Installation of vertical barrier walls around the area impacted by source materials to a depth of approximately 125 feet below grade surface (bgs) and keyed into the weathered bedrock layer. The wall will be approximately 460 linear feet and will isolate the source from contact with groundwater outside the walls and prevent migration of DNAPL. The wall will be constructed using jet grout technology to create continuous, overlapping adjacent columns. Alternate process options for the vertical barrier walls, such as vibrating beam panels, will be further evaluated during the design phase of the remedy.

- Installation of a low permeability cap over the entire OU-1 area. The cap will prevent human exposure to contaminated soil and inhibit infiltration of precipitation.

- Installation of wells screened in the DNAPL zone within the containment cell for the purposes of passive DNAPL recovery and monitoring. The wells will be screened at various depths where DNAPL has been found present. The number of wells and locations will be determined during the design phase of the project. When determined necessary, these wells will be pumped to maintain and inward groundwater gradient within the containment cell.

- Institutional controls consisting of an environmental easement which will include restrictions on groundwater usage or future use of the land for residential purposes, maintenance of site access restrictions through fencing and lockable gates and site management plan. The site management plan will be developed to: (a) address residual contaminated soils that may be excavated from the site during future redevelopment. The plan will require soil characterization and, where applicable, disposal/reuse in accordance with NYSDEC regulations; (b) evaluate the potential for vapor intrusion for any building developed on the site, including, provision for mitigation of any impacts identified; and, (c) identify any use restrictions. KeySpan will provide an annual certification, prepared and submitted by a professional engineer or environmental professional acceptable to the NYSDEC, which will certify that the institutional controls and engineering controls put in place, are unchanged from the previous certification and nothing has occurred that will impair the ability of the control to protect public health or the environment or constitute a violation or failure to comply with any operation and maintenance or site management plan.

- A soil gas survey performed at the Site prior to and after installation of the containment cell, to evaluate soil vapor quality; and,

- Long term monitoring of groundwater and DNAPL in and outside the containment area to: 1) determine the effectiveness of the selected remedy; 2.) assure that significant groundwater mounding is not occurring as a result of the construction of the containment cells, and 3.) assure that groundwater remains unimpacted and further migrations of contaminants from the containment cell into groundwater is not occurring. If the containment wall is found to be deficient based on monitoring results, additional remedial technology options will be performed to address any observed defects. The capping system will be monitored to ensure that the integrity of the system is maintained.

1.3 Project Background

1.3.1 Site Location

The 40 Willow Avenue Parcel encompasses an area of approximately 0.98 acres and is located at the southwestern corner of the intersection of Bay Street and Willow Avenue in the Clifton section of Staten Island, New York as shown on Figure 1. The Site is bounded to the northwest by Willow Avenue; to the northeast and east by Bay Street; to the south by a residential section of Staten Island which fronts Lynhurst Avenue, and to the west by a two-story commercial building and associated paved parking lot (66 Willow Avenue). Further to the northwest, beyond Willow Avenue, is the remainder of the Former Clifton MGP Site (i.e., the 25 Willow Avenue Parcel (OU-2)). The area surrounding the 40 Willow Avenue Parcel is characterized by a combination of urban residential and commercial uses.

The 40 Willow Avenue Parcel is currently improved by a paved parking lot that encompasses the northern and eastern portions of the parcel. Two (2) one-story brick buildings associated with the property's current usage as a natural gas regulator gate station are located on the northwestern portion of the property. The remainder of the property (southern portion) consists of an undeveloped, gravel surface lot. All above grade former MGP structures have been removed. The foundation structure associated with the single former relief gas holder located on the 40 Willow Avenue Parcel (Former Relief Holder No. 2) is depicted relative to the property on Figure 2. The entire perimeter of the 40 Willow Avenue Parcel is surrounded with fencing. The 40 Willow Avenue Parcel is relatively flat with a slight slope to the north.

The 66 Willow Avenue Parcel is currently occupied by a two (2)-story flex-office/warehouse building. Loading docks are located on the southern side of the building. The remainder of the parcel consists of paved loading/parking areas.

The Lynhurst Avenue properties are each occupied by a single residential dwelling. The residential dwellings are set back an average of 65 feet from the southern boundary of the 40 Willow Avenue parcel by the associated landscaped rear yards. Fencing surrounds the perimeter of the properties and also separates these sites from the adjacent 40 Willow Avenue Parcel.

The overall layout of OU-1 is depicted on Figure 2.

1.3.2 Site History

The Clifton MGP Site was formerly owned and operated by Richmond County Gas Light Company from 1856 to 1901. The Site was sold in 1901 and owned and operated by the New York and Richmond Gas Company until 1957. At that time, Brooklyn Union Gas Company (a predecessor to KeySpan) acquired the New York and Richmond Gas Company. Neither Brooklyn Union Gas Company nor KeySpan ever operated the former MGP.

The Site was undeveloped in 1783. Construction of the MGP site is reported to have begun in 1850. The plant at that time consisted of a 30 by 50 foot brick retort house, a 25 by 30 foot Purifying House (i.e., purifiers, condensers, scrubbers, etc.), a 20 by 30 foot building utilized as a combination Meter House/Office, lime and coal sheds, and a single 75-foot diameter holder having a brick tank 21 feet deep. The plant was owned and operated by the Richmond County Gas Light Company at that time. Production began in April 1857.

The Staten Island Gas Light Company merged with the Richmond County Gas Light Company in 1884. At that time, a new carbureted water gas plant was built. Available information indicates that the overall layout of the Site underwent several modifications during its history. Relief Holder No. 2 was constructed on the 40 Willow Avenue Parcel around 1917. This holder was an aboveground structure that stood approximately 150 feet tall. The structure was situated on a circular foundation measuring approximately 85 feet in diameter. The foundation extends approximately 18 feet below ground surface (bgs) and is constructed of brick. This holder was reported to have a storage capacity of approximately 1,000,000 cubic feet. Demolition of the gas plant occurred in the spring of 1959.

As reported in the March 2004 ROD, over the years, by-products, such as coal tar generated from the former MGP operations have leaked or been released from the former relief holder located on OU-1 and resulted in contamination of soil and groundwater.

In 1993, Brooklyn Union, currently KeySpan, excavated approximately 20 cubic yards of soil during which an eight (8)-inch diameter steel well, located just below the surface, was discovered. A mixture of water and free product was removed from the well for disposal. The 90 foot deep well was subsequently sealed with cement grout.

On June 15, 1994, 43 tons of contaminated soil was excavated in the area to the east of the former relief holder and disposed of in accordance with NYSDEC regulations.

In April 1998, KeySpan and the NYSDEC negotiated an Order on Consent (Index No. D2-0001-98-04) to investigate and remediate the Site. The Order on Consent required KeySpan to perform a Remedial Investigation (RI), a baseline Risk Assessment (RA) and a Focused Feasibility Study (FFS).

Additional remedial actions were performed at the Site in the form of two interim remedial measures (IRMs). The IRMs were performed to address the presence of surficial soils impacted by lead based paint residues on the Site as well as the adjacent Lynhurst Avenue and 990 Bay Street properties.

1.4 RD Report Organization

Section 1.0 – INTRODUCTION: This section describes the administrative history of the Site; describes the remedial design objectives and provides a project background.

Section 2.0 – OU-1 PRE-REMEDIAL DESIGN ACTIVITIES: This section summarizes the implementation of pre-remedial design activities to obtain supplemental information in support of the design of the proposed remedial actions.

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Section 6.0 – CONSTRUCTION: This section provides a discussion of the implementation of remedial construction activities and the contractor selection method.

2.0 PRE-REMEDIAL DESIGN ACTIVITIES

Pre-remedial design activities were performed to gather supplementary information in support of the design of the remedial alternative as well as to demonstrate the remedial technologies selected to implement the remedial actions. Two sets of pre-design activities were completed: one set associated with the Phase I jet grout demonstration project and a second set associated with a Revised Remedial Approach that was coordinated with NYSDEC after a review of the initial jet grout demonstration project. The implementation and results of the performance of the pre-remedial design activities are summarized in the following subsections.

2.1 Phase I Jet Grout Demonstration Project

2.1.1 Subsurface Obstruction Survey

A subsurface obstruction survey was performed at the Site to identify potential utilities and other impediments (i.e., former structures, foundations, etc.) at the Site including along and adjacent to the alignment of the vertical barrier containment wall. The identification of utilities/impediments was performed to allow for the preparation of contingencies to remove, relocate or incorporate the potential obstructions into the vertical barrier containment wall. Further, the performance of the subsurface obstruction survey was utilized to confirm the locations of potential subsurface structures, piping and utilities identified on existing site drawings. KeySpan contracted with Utility Survey Corporation (USC) of New Windsor, New York to conduct the Subsurface Obstruction Survey.

The survey by USC was conducted between September 21 and September 23, 2004 utilizing ground penetrating radar (GPR), electro-magnetic pipe, cable & box locators (EM) as well as a metal object detecting magnetometer instrument. The final survey drawing generated from the performance of the Subsurface Obstruction Survey activities is included as Appendix A to this RDR.

2.1.2 Baseline Land Survey

A baseline land site survey was completed to verify the existing topography of the Site and any physical features. Due to the relatively small size of the Site, conventional land surveying was utilized to establish one-half foot contours, with spot elevations to the tenth of a foot. Property corners were referenced to New York State plane coordinates. A copy of the completed land survey, signed and sealed by a professional land surveyor licensed in the State of New York, is included as Appendix B to this RDR.

2.1.3 Geotechnical Borings

In order to evaluate the subsurface conditions along the alignment of the proposed vertical barrier containment wall, three (3) soil borings (i.e., G-1, G-3 and G-4) were installed along the alignment of the proposed vertical barrier containment wall. The borings were located in areas to allow for evaluation of possible variations in the condition and the subsurface elevation of the underlying weathered bedrock (saprolite) as well as potential variations in the composition of the soils comprising the overburden soils. The approximate locations of the three soil borings are depicted on Figure 3.

The geotechnical soil borings were installed by Aquifer Drilling and Testing, Inc. (ADT) of New Hyde Park, New York between January 5 and January 31, 2005. The locations of the three soil borings are depicted on Figure 3.

The three soil borings were installed utilizing mud rotary drilling techniques to a depth corresponding with five to ten feet into the underlying weathered bedrock (saprolite) confining layer (i.e., approximately 130 feet bgs). Soil samples were collected from the soil borings in accordance with American Society of Testing and Materials (ASTM) Designation 1586 (Standard Penetration Testing (SPT)). Attention was given to obtaining representative soil samples from each type of geologic strata encountered including the interfaces between different geologic units. The borings confirmed the stratigraphy observed in earlier borings completed during earlier remedial investigations of OU-1. Copies of the boring logs are included in Appendix C.

2.1.4 Phase I Jet Grout Demonstration

After a review of available demonstrated remedial technologies for deep containment barriers (125 feet or deeper), KeySpan selected the use of a jet grout overlapping column wall, using the double fluid system (compressed air plus pressurized grout) as the containment system for the Site. A demonstration of the jet grout overlapping column installation technology at the Site was performed by KeySpan. The demonstration, herein referred to as the Phase I Demonstration Program, was conducted during the period of December 2004 through April 2005.

The demonstration activities were proposed as one of the pre-remedial design activities included in the RDWP. A Letter Work Plan, dated June 15, 2004, was prepared by KeySpan and submitted to the NYSDEC for review to document the methodology to be utilized to conduct the demonstration. An approval of the Letter Work Plan was provided by the NYSDEC on July 19, 2004.

Five jet grout columns were installed, not along the alignment of the proposed containment wall in the northwest portion of the Site, using the double fluid technology. A batch plant for the production of jet grout was installed in the paved parking area of OU-1, a clean zone. Wastes generated by the jet grout demonstration activities were also managed from this paved parking area. The jet grout columns were cored for quality control purposes.

Subsequent to the completion of the demonstration, KeySpan transmitted a letter, dated August 8, 2005, to the NYSDEC to provide a summary of the results of the Phase I Demonstration Program. The results of Phase I of the Demonstration Program indicated that there were some challenges that must be overcome to install jet grout overlapping columns at the Site, including the following:

- A high permeability, cobble zone was identified at a depth of approximately 50 to 70 feet bgs. This zone was previously unidentified from prior investigations. During the installation of geotechnical borings, this cobble zone caused a significant loss of a significant amount of drilling mud at this depth interval;

- The maintenance of verticality to ensure the overlap of adjacent jet grout columns using conventional drilling techniques was impeded by the presence of the cobble zone, but may have also been a result of the flexibility of the grouting equipment over deeper depths;

- The cobble zone impacted the use of the double fluid grouting technology (i.e., grout shrouded in high pressure compressed air). Unavoidable surfacings (i.e., surface breakthroughs) of grout were created when double fluid grouting was utilized in the upper 50 feet of the soil column. A field change apparently overcame this challenge: the construction of the upper portion of each the columns was modified to be constructed with the single fluid system. The use of the single fluid system , however, limited the achievable column diameters, elevating the verticality of the constructed columns to be a controlling factor in the success of the project to achieve column overlaps;

- The coring of the column overlaps was impeded by field and equipment conditions. First, conventional coring methods were unable to penetrate the column overlaps while maintaining verticality. Secondly, recovery of cores utilizing the triple barrel coring system was impacted by the presence of cobbles and large rock entrained in the soil/grout mixed columns;

- The inability of the grout to set up in-situ has become a factor of concern and may be the result of several factors including the presence of dense non-aqueous phase liquids (DNAPL), strong subsurface groundwater flow patterns and/or the existing artesian conditions and,

- Visual inspection of the core samples indicated that grout may have been washed out of the soil mix column, prior to solidification, by either strong groundwater flow patterns or the existing artesian condition in the lower portion of the aquifer.

2.2 Revised Remedial Design Approach

2.2.1 Overview

Subsequent to the issuance of KeySpan's findings with regard to the Phase I Jet Grout Demonstration, KeySpan retained a nationally recognized jet grouting consultant and formulated a new design approach for the installation of the subsurface barrier which addressed the challenges identified in Phase I Jet Grout Demonstration. At a meeting held in the NYSDEC offices in Albany, New York on September 22, 2005, KeySpan presented this design approach which included a combination of steel sheet piling and a jet grout wall to form the required vertical subsurface barrier. The steel sheeting would be driven to depth of approximately 35 feet bgs, below the existing fill layer to mitigate the previously observed grout releases into the fill layer during in Phase I. A jet grout column wall, using the super triple fluid technology (very high pressure compressed air, very high pressure water and very high pressure grout), would be installed five to ten feet above the tip of the steel sheeting and would continue into the saprolite layer at an approximate depth of 125 feet bgs.

As also discussed at this meeting, a proposed layout of the jet grout operations was presented. In this layout, the jet grout batch plant would be located in the 25 Willow Avenue portion of OU-2, rather than at its Phase I Demonstration location in the paved parking area of the 40 Willow Avenue portion of OU-1. To facilitate the completion of the jet grout columns, compressed air, high pressure water and jet grout materials from the batch plant would be pumped beneath Willow Avenue to the proposed vertical barrier containment area at 40 Willow Avenue. The paved parking area of the 40 Willow Avenue portion of OU-1 would be used solely as a waste management area since a large volume of waste materials from jet grouting was anticipated.

To implement this new design approach, the following construction sequence would be utilized:

1. Install steel sheeting around the entire perimeter of the Site.
2. Install concrete working pads and waste management sumps inboard of the sheet piling.
3. Perform a jet grout "dress rehearsal" in a clean support zone.
4. Initiate full construction of the jet grout wall. Begin jet grout wall construction as trial field located in the alignment of the permanent wall.

5. Install a test boring in a Trial Field zone. Obtain continuous samples in glacial outwash. Core drill a minimum of 10 feet into "competent" rock.
6. Perform instrumented drilling for the Trial Field columns with a Tricone bit and drilling additives.
7. Measure the deviation of the drill holes. Correlate the specific energy profile of the drill holes with the soil boring. Establish criteria for a sub-surface "key" into saprolite.
8. Perform jet grouting for the nine to twelve Trial Field columns using the super triple fluid technology.
9. Evaluate the Trial Field results. Complete coring of centers and overlaps of the Trial Field columns. Install a video camera in the core holes and complete pump down tests to determine the in-place permeabilities of the Trial Field columns.
10. Develop lift speeds versus column diameter for the Trial Field columns. Grout core holes. Repair Trial Field columns (as required).
11. During a three week hiatus in the jet grouting, prepare and submit a report to NYSDEC which specifies the design parameters for the production jet grouting.
12. Upon receipt of NYSDEC acceptance of the Trial Field report, commence production jet grouting in the alignment of the proposed containment wall.
13. For quality assurance/quality control purpose, complete coring, video camera observations and pump testing of the production jet columns to document the condition and in-place permeability of the columns.
14. Install a low permeability surface cap over the containment area, along with NAPL recovery wells.

At the September 22, 2006 meeting with NYSDEC, it was also agreed that in order to expedite the implementation of the remedy selected by NYSDEC for OU-1, two remedial design documents would be prepared and submitted to NYSDEC for approval. A remedial design letter report (RDLR) for the work associated with the construction of the steel sheeting with sealed interlocks (Waterloo Barrier®), a jet grout waste management system and a working mat for the jet grout installation equipment would be prepared and issued first. This RDLR would be followed by a remedial design report for jet grout column wall, passive NAPL recovery wells and the environmental cap after the remedial contractor was selected by KeySpan.

2.2.2 <u>Pre-Construction Activities</u>

Prior to the commencement of any construction, KeySpan identified the need to relocate an existing 12 inch gas main that was located in the pathway of the proposed containment barrier and they completed this relocation with their own forces. The relocated gas main was downsized to eight inches and was moved outside of the OU-1 containment area.

KeySpan continued its contacts with the Lynhurst Avenue residents to obtain access into their backyards during construction. A plan for rerouting drainage in their backyards, away from the proposed steel sheeting was prepared and presented to the residents.

As the jet grout batch plant would be located across on OU-2, KeySpan also completed the installation of three steel carrier pipes beneath Willow Avenue, with own forces. These carrier pipes would facilitate the movement of water, compressed air and jet grouting materials from the future jet grouting operations.

Lastly, KeySpan identified and removed, with its own forces, several relic pipes and structures (anomalies) that were identified from old drawings and that were located within the area to be contained by the proposed vertical barrier wall. Two additional relic pipes, not identified on record drawings, were confirmed by probing and their removal was held in abeyance due to their proximity to the KeySpan natural gas regulator station. Two cylindrical drip tanks related to the former MGP operations at the Site was located during removal operations. With the approval of NYSDEC, these tanks were filled with cement and abandoned in-place due to their proximity to the existing natural gas regulator station.

2.2.3 Contractor Procurements

Subsequent to the relocation of the gas main, installation of carrier pipes beneath Willow Avenue and anomaly removals at the Site in November 2005, KeySpan issued separate requests for proposal for the installation of the jet grout columns and for the transportation and disposal of waste materials from jet grouting/emergency response services (T&D/ER) during jet grouting. Pacchiosi Drill, North America (Pacchiosi) was selected as the jet grout contractor and Code Environmental (Code) was selected as the T&D/ER contractor. Both RFPs were intended to provide contractor services through the completion of the production containment barrier.

2.2.4 Sheeting RDLR

On October 31, 2005, KeySpan submitted an RDLR for the sheeting installation to NYSDEC for approval. This RDLR was revised on November 17, 2005 based upon NYSDEC comments (see Appendix H). NYSDEC approved the revised RDLR on November 22, 2005.

The purpose of the RDLR was to provide the NYSDEC with a design of the initial portions of a modified remedial action. The RDLR detailed the proposed design of the installation of the following components of the selected remedy for the Site:

- Installation of the sheet piling to form the upper portion of the vertical barrier containment wall which will also be used as a secondary containment measure as part of the jet grout waste management system;
- Installation of a concrete waste management sump system along the alignment of the proposed vertical barrier containment wall to be utilized to manage the spoils generated during the installation of the jet grout column containment wall; and,
- Installation of a working mat to provide a suitable and stable working platform for the support of the jet grout installation equipment.

The Waterloo Barrier® Sealed Sheet Pile System was proposed to form the upper portion of the modified vertical barrier containment wall. The Waterloo Barrier® system consists of flexible steel sheet piling with a modified interlock. A sealable cavity is incorporated into the interlock between adjacent sheet piles as the sheeting is manufactured. The interlocks are sealed with a proprietary grout. The barrier will be installed utilizing conventional pile driving technologies (i.e., vibratory or impact hammer). A foot-plate at the base of the cavity reduces the build-up of compacted soil and the entry of obstructions into the interlock during pile installation.

Subsequent to the NYSDEC approval of the RDLR, KeySpan issued a request for proposal for a steel sheeting contractor. In response to this RFP, C3 Environmental (C3), a licensed installer of the Waterloo Barrier®, was retained to install the steel sheeting and C3 mobilized to the Site. Simultaneous with the hiring of C3, KeySpan continued their on-going discussions with the Lynhurst Avenue residences, abutting the southerly boundary of the Site, regarding agreements for access onto their backyards.

The installation of the Waterloo Barrier® steel sheeting was started in early January 2006. Work started without access agreements from the residential properties. Sheeting installation commenced at the middle of the westerly Site border and was intended to be completed in a counter-clockwise pattern for the entire Site perimeter. The steel sheet piling was installed within about one to two feet of the fence/property line.

A vibratory hammer was used to drive the steel sheet piles. At the southerly boundary nearest to the Lynhurst Avenue residential properties, the sheets hit an unanticipated underground gravel/cobble layer at a depth of 30 to 35 feet below the ground surface. The typical sound level profile resulting from driving a sheet pile at approximately 80 feet from the active drive point included the following:

- During initial driving of a full sheet pile, the noise levels were approximately 90 dBA for a few minutes;

- The sound levels reduced to approximately 80 dBA for a few minutes after the sheet pile was advanced into the ground; and
- The sound levels returned to between 60 and 70 dBA, after active driving is complete, due to other general construction related activities at the site, along with background noise from traffic.

Community complaints of noise and vibration at the Site were received from the Lynhurst Avenue residences during the sheet pile driving and pile driving work at the Site was suspended in February 2006 pending the NYSDEC approval of a Noise Mitigation Plan. In this Plan, various noise/vibration mitigation options would be evaluated and an implementation plan for noise mitigation would be recommended for the Site. When the work was suspended by NYSDEC, sheet piles had been installed along approximately one half of the distance of the westerly site boundary and only about one third of the distance of the southerly site boundary, adjacent to the residential properties.

A Noise Mitigation Plan was approved by NYSDEC on April 27, 2006 (see Appendix I). This Plan required the granting of access from the residences for the installation of noise and vibration monitoring equipment, the use of an acoustical curtain during sheet pile driving. Access was not granted by the residences and the sheet pile driving could not be re-started. The residents also indicated that no construction should be completed during the summer of 2006 and the sheet pile driving continues to be suspended until access to the residential properties can be obtained.

2.2.5 Trial Field

2.2.5.1 Trial Field RDWP

During the period that sheet pile driving was suspended, KeySpan developed a plan to complete a revised jet grout Trial Field. This trial field would be located in the paved parking area of OU-1, outside of the alignment of the containment wall, in order to progress the Clifton OU-1 remedial construction while activities within the containment area were suspended. A remedial design work plan for this trial field (Trial Field RDWP) was issued on April 3, 2006 to NYSDEC. Comments were received from NYSDEC and responses provided by KeySpan on April 5, 2006 (see Appendix J). NYSDEC granted approval of the Trial Field RDWP on April 6, 2006.

2.2.5.2 Field Activities

On-site field work for the Trial Field began in late April 2006 with the installation of two new clustered monitoring wells and seven gas/pressure monitoring points and the installation of a deep geotechnical boring into the saprolite layer. Upon completion of this boring, a thermistor string was installed in this boring to obtain subsurface temperature readings, which would be used to detect any temperature impacts of the Trial Field jet grout columns. A 12 inch thick concrete pad was constructed by Pacchiosi, centered over the deep boring, and steel sleeves for up to four pairs of jet grout columns were cast into the pad.

KeySpan's jet grouting consultant had indicated that there was a potential for a subsurface temperature increase due to the use of 100% Portland Cement jet grout. Prior remedial investigations of the Site had documented the presence of benzene, a temperature sensitive pollutant and any potential temperature rises would need to be mitigated. In order to mitigate potential temperature effects of 100 % Portland cement grout, it was decided that a 50%/50% dry mix of Type I Portland Cement and granulated Grade 120 blast furnace slag, in a 0.7:1 water to solids ratio would be used. KeySpan's jet grouting consultant had also indicated this grout formulation would mitigate temperature rises while maintaining low permeabilities, good compressive strength and relatively short jet grout setting times.

Two automated jet grout batch plants were brought from Italy by Pacchiosi and were set up in the paved parking lot of OU-2. Special high pressure hoses were installed into the steel sleeves, previously installed beneath Willow Avenue and the three fluids required for super triple fluid jet grouting were conveyed to concrete pad in the paved parking area of OU-1.

The Trial Field included installation of three pairs of jet grout columns to illustrate how the site remediation would be performed in full production within the contaminated, exclusion zone. Each of the column pairs was composed of slag/cement jet grout and was constructed with three discrete sets of jet grouting parameters. The three pairs included columns numbered NYA101 and NYA102, NYA107 and NYA108, and NYA111 and NYA112.

Installation of the jet grout columns occurred from May 1 to May 18, 2006. General work performed during this first part of the trial field included creating the borehole, pressure-injecting the grout, collecting QA/QC samples, and disposing of generated waste.

- <u>Creating the borehole.</u> Each of the jet grout columns was installed through 12-inch steel collars, pre-installed in a concrete slab. The jet grout columns were first installed by drilling down from the ground surface to depths generally about 130 to 140 feet below existing grade. The drilling rods and accompanying equipment used for drilling the borehole were able to clear down to the bottom of the borehole, using methods similar to making a regular borehole.

The borehole was advanced using water and drilling polymer, used similarly to a mudded borehole, to keep the borehole open for the ensuing jet grouting. Polymer was pumped from the grout plant to the drill rig, using the same equipment which would be used for creating the jet grout columns.

- Pressure-injecting the grout. Once the borehole was cleared for a given jet grout column, the batch plant initially set up for mixing grout reverted back to this purpose (as it was being used to pump polymer during the boring process). The grout was batched and mixed according to the design specifications.

  When pressure injection was being performed, the grout was being injected under an approximate pressure of 500 bars. Water was also simultaneously injected, under an approximate pressure of between 200 and 250 bars. Originally, compressed air had been included in the contractor's "triple fluid" method, but early test results further precluded the use of compressed air in the treatment process.

  Each of the three pairs of columns was injected using a different lift speed, to see how the resulting treatment would vary. Depending on the lift speed and increment used, the installation of a column generally took between 3 and 5+ hours.

  As with the initial creation of the borehole, waste products were generated during the pressure grouting procedure. The waste was contained in the same closed system used to dispose of cuttings generated during the boring portion of the work.

- Collecting QA/QC samples. During the batching process, as well as the injection of grout during the installation of the columns, samples of the grout were taken for quality assurance and quality control measures.

  Samples were collected at the grout/batching plant, to verify the density of the grout being delivered. The contractor verified the density from the QC standpoint, and an independent testing lab, retained by KeySpan's Jet Grouting Consultant, checked grout density from the QA standpoint.

  In addition to field density testing, 2x2 grout cubes and 3x6 grout cylinders were collected, to check the increase in strength of the injected treatment over time. Samples were collected at both the mixing/batch plant, as well as the discharge end of the jet grouting equipment (prior to its disposal).

Disposal of generated waste. Wastes generated during the boring and jet grouting procedures were conveyed in a closed system of rods, hoses, pumps and fittings, to disposal receptacles (vactainers and covered/lined rolloffs).The collected wastes were transported offsite to disposal facilities authorized to receive the jet grout waste (and associated waste) generated during the trial field. Code coordinated all efforts for receiving waste, preparing the necessary waste manifests for proper waste disposal, and coordinating the removal of filled containers and receipt of empty containers. This coordination was necessary to prevent any extensive delays in performing the jet grouting trial field.

2.2.5.3 Quality Control

Quality control field testing was completed by Pacchiosi and KeySpan. This work included the work of coring the jet grout columns (to see how effective the injected grout treatment was), video inspection of the resulting coreholes (to provide visual documentation of the open corehole left after coring), and permeability and slug testing (to measure and quantify the order of magnitude of the treatments' permeability). These various tasks were performed after completion of the column installation, during the period from May 22 to June 27, 2006.

- Coring of the jet grout columns. To check how effective the jet grout treatment interacted with the surrounding, in-situ soil, cores were taken at selected column centers and at column overlaps in the column pairs installed.

  Coring of centers was done in one phase, going from the top of each column to a depth of about 120 feet below existing grade. The centers of Columns NYA101 and NYA107 were cored during the timeframe from May 23 to May 30.

  Coring of the overlaps was done in two phases, at the overlaps of column pairs NYA101/102, NYA107/108, and NYA111/112. The first phase of coring was performed from May 31 to June 5, and entailed coring down to a depth of about 80 feet below existing grade. After the slug and permeability testing was completed, the second phase of coring began. This second phase lasted from June 12 to June 21, and included coring from a depth of 80 feet to depths in excess of 110 feet below existing grade.

  During coring, each jet grout core was measured, photographed, and logged by PS&SPC, as well as by Pacchiosi. Logs also included the date when coring took place, the core length and recovery, and also a sketch of the core as it was retrieved and placed into the core box. After each phase of coring was completed, video inspection of the coreholes was then performed.

- Video Inspection. After cores were taken, an inspection of the newly cored hole was videoed by Pacchiosi using a special, down-the-hole camera. The video enabled KeySpan's consultants to see where the hole was cored, visually observe the depth to water in the corehole, and view any imperfections in the grout treatment.

- Permeability and Slug testing. After each phase of coring, the contractor performed an obligated slug test in each core hole. The slug test included drawing the corehole water level down to a certain depth. After drawdown was complete, the increase in water levels would be recorded to determine the permeability of the jet grout treatment. Additional permeability tests (step-draw down and constant head tests) were performed by PS&SPC and KeySpan's jet grouting consultant to better quantify and qualify the magnitude of the permeability being measured from the contractor's slug tests.

2.2.5.4 Report

A full report on the results of the Trial Field operations is being prepared by KeySpan's jet grouting consultant and will be issued in March 2007. This report will provide the detailed design parameters necessary for the installation of the production jet grout columns, when work in the containment area is allowed to proceed.

An interim report on the results of permeability/hydraulic conductivity analyses of the Trial Field jet grout columns was issued on September 20, 2006 and a copy of this report was provided to NYSDEC on that date. This report reviewed a total of 15 slug, pump and camera pump tests that were run on the different core holes. Well tests run on adjacent core holes in a column pair were used to assess the lateral variability in the grout treatment within the pair. By coring and testing incrementally to different depths, it was possible to assess soil cement formed in different natural soils (Till and Outwash).Three types of tests were run to examine the soil-cement under different hydraulic stresses: (1) slug test in which a 12-m height of water was removed and recovery monitored, (2) stepped rate pumping with monitored recovery, and (3) camera tests in which the well was emptied of water (about 25 meters) and a remote camera was inserted for visual inspection of the core hole walls and any seepage through the face of the core hole.

The data from the well tests were analyzed numerically to provide the hydraulic conductivity estimates reported here. The analyses were conducted using the well test data with iterative finite element modeling (FEM) of groundwater flow to back out the hydraulic conductivity of the soil cement. The models represent 2D time dependent flow through porous media into the well as well as the behavior of the water level within the well. Accounting for the water fluctuation in the well is key to assessing the hydraulic conductivity around wells installed in low permeability soil-cement. The results of the water test analyses were compiled to provide estimates of in-situ hydraulic conductivity for the soil-cement in general as well as the different column pairs and the spatial variability in the estimates.

The major findings in this report are as follows:

- In general, the in-situ hydraulic conductivity of all soil-cement examined is generally from one to three orders of magnitude lower than the NYSDEC requirement of 10^{-7} m s^{-1}(10^{-5} cm/sec).
- The compiled results from 6 water tests performed on Column Pair 107-108 supports the use of this column as having best barrier capability of the three trial field column pairs. The soil-cement in column pair 107-108 was concrete-like with an average hydraulic conductivity of approximately equal to 4×10^{-10} m s^{-1}(4×10^{-8} cm/sec).
- For Column Pair 107-108 the conductivity is on the same order-of-magnitude both laterally and vertically throughout. The Soil Cement was estimated for discrete depth increments, with values of 1.5×10^{-10} m s^{-1} (1.5×10^{-8} cm/sec) for soil-cement in the Outwash and 7×10^{-10} m s^{-1}(7.0×10^{-8} cm/sec) for soil-cement in the Till.
- The average (3 tests) hydraulic conductivity of the Column Pair 111-112 is approximately 5×10^{-9} m s^{-1}(5.0×10^{-7} cm/sec) for soil-cement in Till to 26 m (85.3 feet) bgs. Similar estimates from adjacent wells NYA124C (in the center of the overlap between two columns) and NYA125C (just beyond the overlap) the Soil-Cement is relatively uniform across the fuse zone between the two columns that form the pair.
- For jet grout column 101, the soil cement formed in till – outwash – and into the saprolite (approximate depth of 123 feet) produced in-situ soil-cement which had an average hydraulic conductivity of 1×10^{-8} m s^{-1}(1.0×10^{-6} cm/sec).

3.0 REMEDIAL DESIGN

3.1 Remedial Objectives

In accordance with the elements of the March 2004 ROD and the Revised Remedial Design Approach described in Section 2.2.1, the proposed remedial design for OU-1 will include a remedial design program to provide the details necessary for the construction, operation, maintenance and monitoring of the remedial program. Some aspects of the Remedial Design are currently generalized since the detailed report from the Trial Field has not yet been issued.

- Installation of vertical barrier walls around the area impacted by source materials to a depth of approximately 125 feet bgs and keyed into the saprolite. The wall will have a total length of approximately 460 linear feet and will be constructed as a combination of steel sheet piling joined to continuous, jet grout overlapping adjacent columns.

- Installation of a low permeability cap over the entire OU-1 area. The cap will prevent human exposure to contaminated soil and inhibit infiltration of precipitation.

- Installation of wells screened in the DNAPL zone within the containment cell for the purposes of passive DNAPL recovery and monitoring. The wells will be screened at various depths where DNAPL has been found present. The number of wells and locations are indicated on the Design Drawings. When determined necessary, these wells will be pumped to maintain an inward groundwater gradient within the containment cell.

- Institutional controls consisting of an environmental easement which will include restrictions on groundwater usage or future use of the land, maintenance of site access restrictions through fencing and lockable gates and site management plan. The site management plan will be developed to: (a) address residual contaminated soils that may be excavated from the site during future redevelopment. The plan will require soil characterization and, where applicable, disposal/reuse in accordance with NYSDEC regulations; (b) evaluate the potential for vapor intrusion for any building developed on the site, including, provision for mitigation of any impacts identified; and, (c) identify any use restrictions. KeySpan will provide an annual certification, prepared and submitted by a New York State licensed professional engineer who will certify that the institutional controls and engineering controls put in place, are unchanged from the previous certification and nothing has occurred that will impair the ability of the control to protect public health or the environment or constitute a violation or failure to comply with any operation and maintenance or site management plan.