REMEDIAL ACTION WORK PLAN

FOR

UST AREA CHEMICAL OXIDATION

ESSEX JAMESTOWN SITE

129 HOPKINS AVENUE

JAMESTOWN, NY

NYDEC Site ID No. 9-07-015

Prepared for:

ESSEX SPECIALTY PRODUCTS INC.

(A FORMER SUBSIDIARY OF THE DOW CHEMICAL COMPANY)

Prepared by:

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PITTSBURGH, PA

URS Project No. 41568097

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1.0 BACKGROUND

This Remedial Action Work Plan (RAWP) has been prepared for the planned in-situ treatment of volatile organic compounds (VOCs) in soils and shallow groundwater in the former UST Area of the Essex Hope Site located in Jamestown, New York. The site was identified and entered into the New York State Department of Environmental Conservation (NYDEC) CERCLA program in 1990. A Record of Decision (ROD) was issued on March, 1994. The NYDEC Consent Order No. is B9-0354-94-05.

The general site location is shown on Figures 1-1 and 1-2.

1.1 Purpose

The purpose of this RAWP is to provide guidelines for remediation of VOC contamination in shallow soils and groundwater in the UST Area of the Site. In-situ chemical oxidation (ISCO) is the planned remedial technology.

This plan was developed with sufficient detail to serve as the basis for the Contractor's Field Operations Work Plan while satisfying the guidance provided in Section 5.3 of NYSDEC DER-10.

URS will serve as the lead engineer (Engineer) for this project. The Remedial Contractor has not been determined at this time.

1.2 Remedial Action Objectives

The primary objectives of the remedial actions are to:

- Reduce or eliminate volatile organic compounds (VOCs) present in soil and groundwater above the site remedial action objectives (RAOs) described in the Consent Order.

- Minimize Dow's long-term liabilities, O&M costs/efforts and constraints on potential future site use or reuse due to VOC-contaminated soils and groundwater on site.

The ROD Remedial Action Objectives (RAOs) for site cleanup as outlined in the NYDEC Consent Order are as follows:

Soils RAOs:

Total VOCs = 10 ppm

Individual VOCs = 1 ppm

Total Semi-VOCs = 500 ppm

Individual Semi-VOCs = 50 ppm

PCBs = 10 ppm

Groundwater RAOs:

Trans-1, 2- Dichloroethylene = 5 ppb

Trichloroethene = 5 ppb

Vinyl Chloride = 5 ppb

Ethylbenzene = 5 ppb

Toluene = 5 ppb

Xylene = 5 ppb

PCBs = 0.1 ppb

This RAWP was prepared to specifically address the UST Area of the overall Essex Jamestown Site which is primarily impacted by VOCs: cumene, toluene, ethylbenzene and xylenes.

For other compounds not listed groundwater RAOs default to compliance with NYDEC Ambient Groundwater Quality Standards. For Site VOCs these would be at 5 ppb.

2.0 SITE HISTORY AND DESCRIPTION

2.1 Site History

The Essex/Hope Site has been operated as a manufacturing facility for paints and industrial coatings since around 1900. Various companies owned the facility. Essex Specialty Products (ESP) occupied the site and produced paints and coatings from 1982 to 1989, at which time the facility was sold to Lily Industrial Coatings who operated the site until 1997. ESP was a subsidiary company of The Dow Chemical Company (Dow). Hope Windows Inc., currently Hope Architectural Products, Inc., also owned and occupied the Plant 5 building which was sold to ESP in the mid-1980. The entire property was purchased by Custom Production Manufacturing (CPM) in 2000. CPM operates a sheet metal fabrication business in the Plant 5 Building. CPM leases other site buildings to various small businesses. Currently Master Machine Inc. occupies the remaining site buildings on the south and southeast areas of the property. The general site plan is shown on Figure 2-1. Site photos are contained in Appendix A.

In the early 1990's, a Remedial Investigation and Feasibility Study (RI/FS) were conducted at the site by Obrien and Gere Engineering. In March 1994, NYDEC wrote a CERCLA Record of Decision (ROD) that outlined the scope of the proposed remedial actions. Three site areas were identified in the ROD for remediation:

- North Parking Lot Sump (NPLS) Area
- Former Aboveground Storage Tank/Underground Storage Tank (AST/UST) Area
- Previously Closed Underground Storage Tank (UST) Area

In October 1997 the Remedial Action Design and Construction was completed by Radian Engineering Inc. (Radian), on behalf of ESP. The implemented remedial actions included the following:

- Source area soils excavation in the NPLS Area and off-site disposal at a RCRA facility,

- Soil vapor extraction (SVE) and air sparge system installation in the NPLS, UST and AST/UST Areas, including modification of existing wells and construction of air treatment systems using activated carbon,

- Shallow groundwater recovery in the UST and AST/UST Areas and a combined shallow/deep groundwater recovery system in the NPLS Area,

- An on-site groundwater treatment system using activated carbon, for all site groundwater, including a 900 sf treatment plant building with office,

- ANPLS Area cap using asphalt and concrete paving,

Construction actions were documented in the Remedial Action Construction Close-Out Report, Radian Engineering, March 1998. Radian, now URS Corporation, has been operating the treatment system, performing necessary maintenance, and conducting performance monitoring since system start-up in 1998. Annual Performance Monitoring Reports containing all required monitoring data are submitted to NYDEC.

Subsequent to the initial actions conducted in 1997, numerous additional site investigations and supplemental remedial actions have been conducted at the site. The UST Area SVE System and groundwater extraction wells (RW-4 and RW-5) were determined to be ineffective and were shutdown in 2003. Subsequently, investigations conducted in the UST Area discovered five (5) buried tanks that contained hazardous wastes from previous paints and coatings manufacturing operations. These tanks and approximately 1100 tons of VOC-contaminated soils were removed from the site in 2003. Further investigations were conducted to delineate the residual soil and shallow groundwater contamination.

The UST Area is currently characterized as containing residual soil and shallow groundwater contaminants consisting of VOCs, primarily cumene, toluene, ethylbenzene and xylenes (CTEX).. A summary of the recent investigation results in the UST Area is contained in Section 3.0 and Appendix A of this RAWP.

2.2 Site Description

The Essex Hope Site occupies about 4.7 acres at 125 Blackstone Avenue in the City of Jamestown, NY. The site is located in a highly industrialized area that has contained various industrial manufacturing facilities since 1900.

The site area is currently active and contains metal fabrication operations for CPM, Inc. and Master Machine Inc. The general work area is flat, partially paved, and contains two large concrete containment pads and two small metal buildings. The remaining area is vegetated. The area of the former USTs has been backfilled with bank-run gravel. Underground public utilities are not present in the UST Area work area, however, an electrical conduit and water line for existing recovery well RW-6D cross the work area.

CPM Plant 5 building has a roof drainage system that conveys rainwater to three (3) drywell sumps located directly south of the building. These sumps were discovered during removal of the five USTs. Only one sump was opened and examined. The other two sumps appear to be similar. Sump No. 1(west) is an open joint masonry structure with a concrete top. The sump wall adjoins the building foundation wall and is about 3 ft. below ground surface (BGS). Dimensions are 8-ft diameter at the base, and 56-in. dia at the top. The sump had a concrete top with a 2-ft removable concrete lid. The sump is 8 ft. deep and was filled with water, which started to drain into the test pit and tank excavation area. There were two 4-in. inlet pipes in the sump. URS confirmed the roof connection by pouring water into the Building #5 roof drain inlet and observing flow into the sump. The source of any waters flowing into the sump from the other inlet pipe connection is unknown at this time.

General site conditions in the UST Area are presented on Drawing C-1.

2.3 Site Geology

The site is located within a glaciated region characterized by Pleistocene era outwash deposits. In general, the shallow soil consists of fine-grained silty-clay soils in the upper five (5) feet, below which is predominantly described as a sand and gravel zone, silty in some locations, and typically wet to saturated. The sand and gravel layer generally extends from about 6 feet

BGS, to the top of the gray clayey-silt upper confining layer. This shallow zone at the Site has been historically referred to as the upper water-bearing zone or “shallow zone”, where saturated.

The general site stratigraphy is as follows:

- Upper Zone (0 to 16-ft): Silty sand and gravel with clayey fine sand. Unconfined aquifer (shallow groundwater) starts at ~ 7-ft bgs with a saturated thickness ranging from 6 to 10-ft across site.
- Semi-Confining Layer (16 to 24-ft): Silt and /or Clay, varies in thickness from 1 to 20-ft. Absent offsite to the north; Eroded to east with gravel channel in place.
- Lower Zone (18 to 43-ft): Fine sand to sandy silt. Semi-confined aquifer (Lower Fine Sand WBZ).
- Lower Confining Unit (43 to 100-ft): Silt and interbedded clay
- Glacial Till (100-ft +) (not investigated)

The semi-confining layer depth varies with ground surface elevation and the sloped surface of the layer. The semi-confining layer was present throughout the UST Area, and generally exhibited an eroded surface feature that sloped to the east. A map of the elevation of top of the upper semi-confining clay in the UST Area is contained on Figure 2-2.

2.4 Hydrogeology

The subsurface geologic profile of interest in the UST Area ranges from approximately 0-20 ft. BGS. This interval consists of a shallow unconfined water-bearing zone and an upper semi-confining layer, generally described as clayey silt, which separates the shallow groundwater from a lower semi-confined zone. A thick clayey confining layer occurs at the base of the lower water-bearing semi-confined zone.

The geology of the upper water-bearing zone is composed of silty, sandy gravel with occasional clayey fine sand and has been found to range in total thickness between 11 and 16 feet.

The upper semi-confining layer ranges in thickness between approximately 2 to 9.5 feet across the site. The lower semi-confined water-bearing zone occurs within fine sandy silt to silty fine sand unit with a thickness ranging between approximately 17 and 28.5 feet. Drilling for the deep zone monitoring wells stopped at the top of the lower confining layer so additional data on this layer’s thickness has not been obtained.

Groundwater contours representing normal pumping conditions are contained in the Annual Reports and have been depicted in other site investigation reports. The most recent (June and September, 2010) potentiometric surface contour maps for the shallow groundwater zone are presented on Figures 2-3 and 2-4, respectively.

3.0 SUMMARY OF SITE CONTAMINATION

The nature and extent of contamination at the site were characterized through the completion of various site investigations conducted from 1992, beginning with the CERCLA Remedial Investigation, up to 2009 with the most recent UST Area investigations. The investigations of interest occurred after removal of the USTs and contaminated soil in 2003.

The results of these previous site investigations are summarized in this section. Soil and groundwater data are summarized on Tables 3-1 and 3-2, Figures 3-1 and 3-2, and Appendix A. UST Area investigation history is summarized in Appendix A. Test boring and monitoring well locations are shown on Drawing C-1. Geologic cross-sections are shown on Drawing C-7.

3.1 Soil Analytical Results

A total of 36 test borings were drilled to assess soils in the UST Area after removal of the tanks and contaminated soils. Twelve (12) borings were completed in 2003, designated TBUST-1 through TBUST-12. These borings focused on the vadose zone soils in the areas directly south and east of the former USTs. The remaining test borings TBUST-13 through TBUST-36 were completed in 2005-2006. These test borings were located beyond the previous investigations to determine the extent of VOCs. The test borings were advanced using direct-push drilling and sampling techniques. Continuous soil samples were collected from ground surface to the top of the upper semi-confining layer, located at approximately 12 to 16-feet in depth. All soil analyses from the UST Area are summarized on Table 3-1.

VOC‘s cumene, toluene, ethylbenzene and xylenes (CTEX) were most frequently detected in the UST Area soils. Chlorinated VOCs were not detected. The CTEX compounds were found at levels above the Remedial Action Objectives (RAOs primarily in the western end of the UST Area, around former Tank T1. The elevated CTEX soil areas generally correlate with the elevated CTEX in shallow groundwater. (See Section 3.2). These elevated CTEX areas are in the historic truck access aprons for chemical deliveries and loading for the former UST Area operations. The area is currently paved with concrete and is used as an access and parking area for the Master Machine Inc. plastic and metal working operations in the building directly west. See Figure 3-1 for a depiction of soil CTEX distribution.

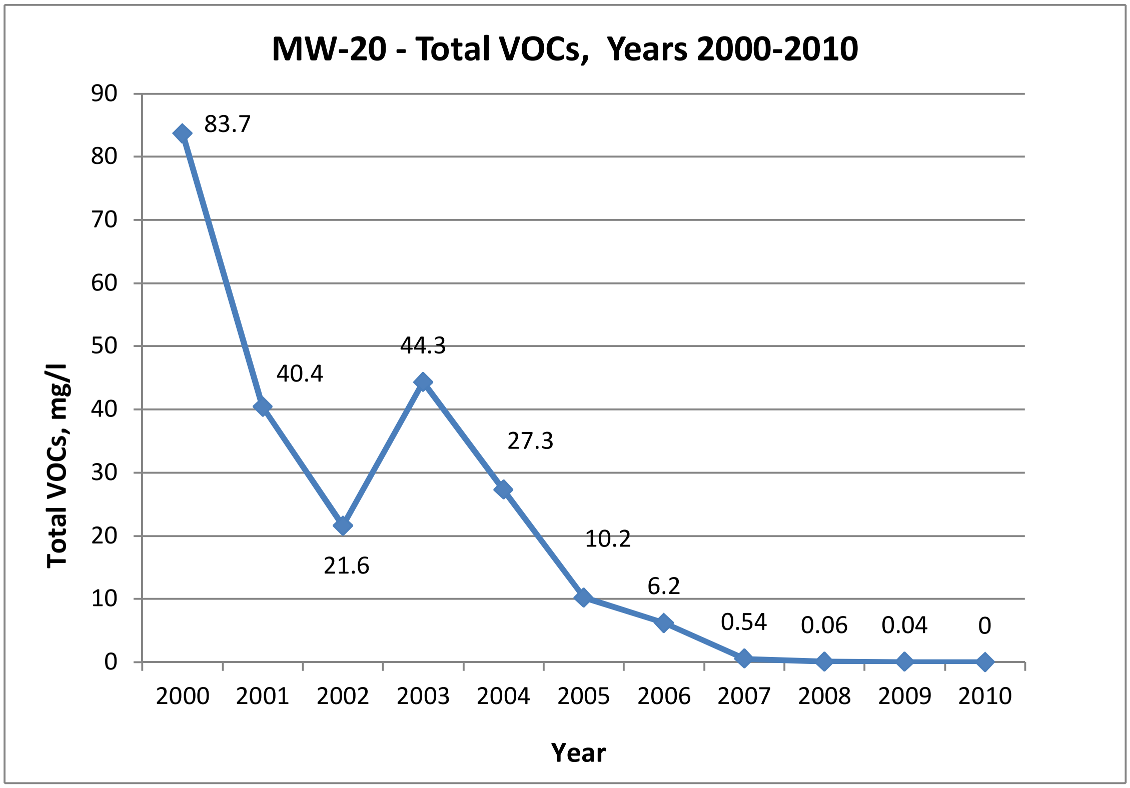
3.2 Groundwater Analytical Results

Shallow zone groundwater samples have been taken from two newer monitoring wells (MW-23S and MW-24S) and seven existing monitoring wells in the UST Area. In 2006, test borings were advanced in the UST Area and adjoining properties for retrieval of shallow groundwater samples by direct-push drilling methods. Groundwater samples were taken from a short screened interval (~ 4 ft. or less) either near the top of the semi-confining layer (average 16 ft. BGS) or the top of the saturated zone (approximately 10-12 ft. BGS). All shallow groundwater analyses for the UST Area are summarized on Table 3-2.

Consistent with the UST soils analyses, groundwater analyses indicates that the CTEX volatile organics (cumene, toluene, ethylbenzene and xylenes) were the dominant compounds detected in the UST Area. Chlorinated VOCs were found at relatively low levels.

The CTEX groundwater plume (1 ppm isocontour) extends across the entire UST Area to the former tank farm to the east, north to MW-20 (beneath Plant #5), and to the southwest, and has been delineated in the recent investigations. The extent of the plume to the southwest and eastern areas of the UST Area has been determined to be offsite onto adjoining properties. The mean CTEX concentrations in the western portion of the UST Area are 1 to 2 orders of magnitude greater than the mean CTEX concentrations in the eastern part of the UST Area. The shallow groundwater CTEX distribution is presented on Figure 3-2.

The only monitoring well in or near the UST Area that is routinely sampled is MW-20, beneath CPM Building No. 5. This well is within the shallow groundwater zone and it is hydraulically downgradient of the UST Area. The most recent data (2010) shows that CTEX levels have decreased to below detection limits (BDL). The total VOC levels in MW-20 have been decreasing continuously since a maximum recorded value of 83.7 ppm was found in 2000. MW-20 VOC data from years 2000 to 2010 is as follows:



The reason for the significant decline in VOCs in downgradient monitoring well MW-20 has not been determined. Pre-work baseline groundwater sampling in the UST area will establish the current CTEX distribution in the shallow groundwater zone. See Section 5.5.

4.0 PROPOSED REMEDIAL ACTION

4.1 General

The proposition of a supplemental remedial action at the UST Area was based on the limited performance of the original remedial measures (pumping shallow groundwater with soil vapor extraction) and the identification of more extensive site contamination. The discovery of the inadequately closed USTs and the residual VOC contamination surrounding the tanks after their removal prompted assessment of other remedial actions.

After removal of the USTs, URS conducted a series of subsurface investigations in the UST Area to define the extent of the contamination (See Section 3.0). Based on a preliminary evaluation of potential technologies, chemical oxidation was determined to be a feasible and cost-effective approach for treatment of the residual site VOCs. The predominant VOCs in the UST Area, CTEX, were amenable to chemical oxidation treatment based on review of remediation literature and URS experience with oxidation technologies. URS subcontracted VeruTek in 2010 to perform a bench-scale treatability study for chemical oxidation of UST Area soil and groundwater. The results of the study proved favorable for oxidation of the site contaminants with activated sodium persulfate, combined with a surfactant. Based on the site conditions and the results of the treatability studies, insitu chemical oxidation was selected as the preferred remedial action for the UST Area.

It is expected that multiple applications of oxidant would be required to achieve the site RAOs if insitu chemical oxidation alone is employed for remediation of the UST Area. Performance monitoring of the initial oxidant application will provide data on treatment effectiveness and residual VOCs, post-treatment. See Section 5.10. The results of the monitoring will be evaluated to determine the most feasible remedial actions to address residual VOCs. Additional chemical oxidation will be considered, and other approaches will also be assessed, including bio-enhancement and natural attenuation. A supplemental RAWP will be prepared, if necessary, to present proposed further remedial actions for the UST Area.

4.2 Chemical Oxidation Treatability Study

A laboratory treatability study was performed to evaluate the effectiveness of chemical oxidation for reducing VOCs present in the UST Area. VeruTEK Technologies, Inc. of Bloomfield, CT performed the study. URS collected representative soil samples for the study from across the UST Area and from a depth of approximately 4-12 ft. BGS. A summary of the treatability study samples, including field VOC headspace results are contained in Appendix B. The sample locations are shown on Drawing C-1.

Oxidants sodium persulfate and hydrogen peroxide, with and without surfactant augmentation, were used in the testing. The oxidants were blended with catalytic activators. The surfactant was a plant-based extract (citrus oil) that is naturally biodegradable: VeruSOL-3. Batch emulsion and soil column tests were performed. The treatability study report is contained in Appendix B. A summary of the treatability study is as follows:

4.2.1 Test Sample Baseline Characterization

Soil samples were composited and characterized prior to testing. The samples were primarily sand and gravel with clayey silts from interspersed lens throughout the site area. The clayey silt fraction was manually separated from the samples for characterization. A summary of the pre-treatment sample chemical analyses data is as follows:

Treatability Study Sample Characterization

Analyses	**S1- Sand/Gravel**	**S2- Sand/Gravel**	**S3- Clayey Silt**
VOCs, ug/kg			
Ethylbenzene	1,100	7,900	12,000
Benzene	2,700	BDL	6,200
n-Butylbenzene	180	480	1,000
n-Propylbenzene	110	410	870
Isopropylbenzene	500	610	3,800
tert-butylbenzene	BDL	BDL	10,000
Toluene	940	980	7,800
Xylenes	19,500	28,000	263,000
Total VOCs	28,640	41,960	328,670
Total TPH, mg/kg	149	310	3,030

4.2.2 Desorption Testing

Desorption and solubilization enhancement tests were performed to assess the effects of surfactant addition on VOC desorption. VeruSOL-3 was used as the surfactant. This is a plant-based surfactant developed by VeruTEK Technologies, Inc. Overall, results showed an increase in VOC/TPH solubility with increasing surfactant addition up to 10g/L. Solubilization enhancement factors of up to 9.4 times greater VOC concentrations and 218 times greater TPH concentrations were achieved in samples containing 10g/L VeruSOL-3 compared to the control sample containing deionized water only.

4.2.3 Stirred Reactor Batch Testing

VOC-laden supernatant from the desorption testing was blended in completely mixed reactor vessels with persulfate and peroxide oxidants. These tests do not simulate actual groundwater conditions since groundwater flow in porous media is dominantly laminar flow with chemical mixing by diffusion and solubilization, however the tests provide a reference point for ideal treatability of the VOCs by oxidation. Oxidants used were alkaline-activated persulfate, Fe-EDTA activated persulfate and Fe-TAML catalyzed hydrogen peroxide. Oxidant solutions were 100g/L persulfate and 4%, by weight, peroxide. The tests were run for 14 days in continuously stirred reactors. All three (3) oxidants achieved >99% VOC reduction and 52-92% TPH reduction compared to the control sample. The residual TPH presence in the treated samples is expected to be due in large part to the presence of VeruSOL-3 surfactant which contains plant oils known to cause false positive TPH readings. The VeruSOL-3 is expected to be further oxidized over time under in-situ field conditions.

The batch reactor tests were run in 500 ml flasks using 100g/L persulfate and 4% peroxide solutions. Based on the control sample VOCs and TPH concentrations, assuming minimal organic degradation, the oxygen/organic mass ratio was approximately 3:1 for the sodium persulfate reactors. Although natural organic matter was not measured in the test, its effects on the overall oxygen demand, and VOC treatability, were accounted for in the testing.

4.2.4 Soil Column Testing

Soil column tests were performed to simulate saturated soil treatment conditions in the field. The tests consisted of a control column, an Fe-EDTA activated persulfate treated column, an alkaline activated persulfate treated column, and an Fe-TAML catalyzed hydrogen peroxide treated column, each applied with and without VeruSOL-3. Oxidant solutions were 100g/l of sodium persulfate and 4% hydrogen peroxide. The persulfate columns were run for 28 days and the peroxide columns were run for 14 days. The difference was based on the expected reactivity of the two oxidants.

Soil samples were selected from sacrificed columns at the completion of the testing. Sampling and analyses of column effluent was performed after one pore volume was generated (Day 1) and on various days thereafter. Each column experienced a minimum 1 PV/day.

Overall, the treated columns exhibited decreased VOC levels compared to the control columns, with the exception of the Fe-TAML hydrogen peroxide column without surfactant. This exception is likely due to running the column for 14 days which is not expected to be sufficient time for VOC desorption. In all cases, the surfactant enhanced columns achieved significantly better VOC removals than the comparative oxidant-only columns. The Fe-EDTA persulfate and Fe-TAML hydrogen peroxide columns with VeruSOL-3 achieved VOC reductions to levels less than the NYDEC soil cleanup criteria for total VOCs of 10 ppm. A few selected VOCs remained above the individual VOC cleanup criteria (1 ppm),

The total VOC percent reduction relative to the control column for the sodium persulfate activated with Fe-EDTA was 97.7% and for the hydrogen peroxide activated with Fe-TAML was 96.3%. The treatability study column testing is summarized as follows:

Treatability Study Column Test Summary

Analyses	**Control**	**Sodium Persulfate**		**Hydrogen Peroxide**	
VOCs, ug/kg	28 days	28-days	% Reduction	14-days	% Reduction
Ethylbenzene	21,000	BDL	100	530	97.4
Trimethylbenzenes	15,700	BDL	100	1000	93.6
Isoproplylbenzene	4400	BDL	100	230	94.8
Isopropyltoluene	11,000	3600	67	460	95.8
Total Xylenes	230,000	800	98.8	7400	96.8
Total VOCs	***284,100***	***6400***	***97.7***	***10540***	***96.3***

4.2.5 Conclusion

The results indicate that in-situ treatment of the site VOC contaminants in soils with a surfactant-enhanced sodium persulfate activated with iron-EDTA should achieve reductions in soil VOCs to levels below or near NYDEC cleanup criteria when sufficiently and thoroughly applied to the zone of contamination.

4.3 Proposed Remedial Action

Based on the site conditions in the UST Area and the results of the chemical oxidation treatability study, **insitu chemical oxidation of shallow soils and groundwater** is the proposed treatment method. The general oxidant delivery methods proposed are injection and/or infiltration. Other alternative delivery techniques will be considered if proposed by Contactors.

The detailed scope of work for the UST Area ISCO is described in Section 5.0.

5.0 REMEDIAL ACTION SCOPE OF WORK

This section describes the scope of work for implementation of ISCO of the UST Area. The selected Contractor will be required to submit a Field Operations Work Plan (FOWP), including a Health and Safety Plan that outlines all of the field operations and requirements for implementation of the project. The scope of work outlined herein shall be followed at a minimum, and any modifications to this scope must be approved by URS/Dow and if necessary the NYDEC. Major changes to the scope of work as described in this section will be documented and submitted to NYDEC for approval prior to implementation in the field.

5.1 Stormwater Drainage System Modifications

The existing stormwater drainage system for CPM Building No. 5 in the UST Area will be modified to eliminate infiltration to local shallow groundwater in the UST Area. The three (3) drywell sumps will be closed in-place, and the Building 5 roof drainage waters will be conveyed to the City of Jamestown stormwater sewer on Blackstone Avenue. A new stormwater pipe system will be constructed that connects the three main roof drain pipes to a new storm sewer catch basin constructed adjacent to Blackstone Avenue. The existing drainage system is described in Section 2.3.

Preliminary design requirements have been provided by the City of Jamestown. The city is currently performing field surveys of their sewer and stormwater systems which will be provided to URS for preparation of final designs.

5.1.1 Drywell Closure

The drywells will be closed in-place by backfill with clean fill. Portions of the drywell walls may be demolished to allow routing and/or connections for the new stormwater pipe. Backfill material will be placed to the top of the drywell walls. The existing concrete lids shall be demolished.

5.1.2 New Stormwater Drainage System

The three (3) existing stormwater drainage pipes will be cut near the CPM Building 5 south foundation wall, upstream of their connection to the drywells. Individual inlet boxes will be constructed at each new connection. HDPE drainage pipe will be used for the new stormwater drains. All three inlet boxes will discharge to a new junction box inlet constructed onsite. The junction box will discharge to a new stormwater catch basin connected to the Blackstone Avenue storm sewer.

Engineering calculations and design details will be prepared and be submitted to the City of Jamestown for approval. A city construction permit will be obtained by the Contractor prior to starting the work.

Preliminary design of the stormwater system modifications is presented on Drawing C-3.

5.2 Permits

URS/Dow will obtain all necessary permits for the ISCO project, unless it proves to be more appropriate for the selected Contractor to obtain construction work and other local permits.

A USEPA Underground Injection Control (UIC) Permit will be required to perform the work. URS will prepare all necessary documentation for implementing the project, including this RAWP, and will submit that information to USEPA Region II for approval. A USEPA "authorization by rule" approval is anticipated.

The Contractor shall obtain all necessary local permits required for the performance of the remedial activities. These permits will include at least the following:

- City of Jamestown Construction Permits for stormwater drainage system and any other work in city right-of-ways,
- City of Jamestown permits for water line access and metering for onsite supply.

5.3 Construction Health and Safety Plan

The Contractor will be responsible for preparing a Construction Health and Safety Plan (CHASP) and implementing the CHASP. An existing Health and Safety Plan (HASP) has been prepared by URS for the Essex Jamestown Site that outlines all requirements necessary for compliance with OSHA 1910.120 HAZWOPER regulations and any other applicable general construction requirements. The HASP sets out personnel protection and action levels and establishes procedures and specifies H&S controls such as exclusion and decontamination zones. The URS HASP will be provided to the Contractor for reference purposes only. The CHASP will be reviewed and approved by URS prior to commencement of site work.

The Contractor will be responsible for conducting air monitoring within his work zones and taking appropriate action based on the results. Compliance with the CHASP will be maintained throughout the planned Remedial Action. It is expected that all intrusive Site work (i.e. soil excavation and injection) will be conducted under Level D, but PPE levels will be adjusted as per the HASP, based on air monitoring results.

Air monitoring will be conducted in accordance with the requirements of the CHASP. Dust control measures will be implemented by the Contractor as required to meet the requirements of the CHASP.

Based on the Site's size, location, and setting, no impact to nearby residents is expected as a result of the planned Remedial Action.

Notification of residents and all necessary site access will be obtained by URS/Essex.

Periodic air monitoring will be performed at perimeter and interior building locations for VOC's during intrusive (injection) work, and fugitive emissions control measures outlined in the CHASP will assure that there will be no impact to residents.

The basic elements of the plan are as follows:

- Project personnel and responsibilities

- Training requirements and documentation
- Medical surveillance requirements
- Activity hazards analyses
- Site work zones
- Personnel protective equipment
- Monitoring requirements
- Emergency response plan, including spills and fugitive emissions control measures
- Decontamination procedures

5.4 <u>Mobilization & Site Preparation</u>

The Contractor will be responsible for mobilization and site setup. General work zones and site preparation measures are shown on Drawing C-2. The Contractor will procure and transport the necessary resources to accommodate the project requirements (i.e. labor, materials, and equipment). Other requirements not specifically provided herein, but necessary for the successful conduct and completion of the work, will be provided by Dow or URS to the Contractor.

The UST Area is currently surrounded by a 6-ft high steel security fence with locking gates. Work and staging areas will be maintained inside of the perimeter fencing. All access to the site shall be via Blackstone Avenue and the two south perimeter gates.

Locating and marking underground utilities that may potentially be affected during site work will be required. Existing underground utilities/piping identified by URS to-date are shown on Drawing C-1.

Site preparation activities include the following operations:

- Clearing of debris (e.g. scrap equipment and materials, vegetation, etc.), as necessary to access the work areas. All materials are to be staged in areas identified by URS.

- Installation of five foot high, orange plastic construction safety fencing mounted on driven steel fence posts at 10 foot spacing around active work areas. Signs designating the work area and warning against trespass will be affixed to all sides of the fence during the construction period.

- Construction of temporary decontamination pad for personnel and equipment. The existing concrete pad on the east end of the site shall not be used for decontamination, however, it overlies the eastern injection area and it may be compromised if oxidant injections are conducted through the concrete pad.

- Mobilization of chemical injection and mixing equipment, reagent storage and application equipment, tanker trucks and necessary personnel.

5.4.1 Temporary Facilities

The proposed locations and extent of areas for Contractor temporary facilities, including any staging areas is shown on Drawing C-2. Limited water may be provided by URS for incidental uses, if necessary from the URS treatment building, as its supply is limited to a 5-10 gpm city water tap. The Contractor is responsible for locating and obtaining an adequate potable water supply for project needs.

Contractor shall provide a suitable small Site Office/Work Area to be used by Project Management and NYSDEC personnel during work onsite.

Contractor shall provide portable sanitary facility for site workers.

5.4.1.1 Employee Parking

Contractor employees shall park privately owned vehicles in area designated by URS.

5.4.1.2 Availability and Use of Utility Services

The Contractor is responsible for providing all temporary utility services required during construction.

5.4.1.3 Storage Areas

The Contractor shall designate a storage area in a portion of the Site, as approved by URS. Materials shall not be stockpiled outside the designated area in preparation for the next day's work. Mobile equipment, such as drilling rigs, mixers, and trucks, shall be parked within the designated area at the end of each work day, unless otherwise approved by URS.

The storage area will be kept in good repair. Should the Contractor elect to traverse, with construction equipment or other vehicles, grassed or unpaved areas that are not established roadways, such areas shall be protected as necessary to prevent rutting and the tracking of mud onto paved or established roadways.

5.4.2 Protection and Maintenance of Traffic

During construction the Contractor shall maintain and protect traffic on Blackstone Avenue when necessary. Measures for the protection and diversion of traffic, including the provision of watchmen and flagmen, erection of barricades, placing of lights around and in front of equipment and the work, and the erection and maintenance of adequate warning, danger, and directional signs, shall be in accordance with applicable State and local laws. The traveling public shall be protected from damage to person and property. The Contractor shall investigate the adequacy and allowable load limit on these roads. The Contractor shall be solely responsible for the repair of any damage to roads caused by construction operations.

5.4.3 Security Provisions

The Contractor shall be responsible for the security of its own equipment. If the Site is used for staging or storage of equipment and supplies, the Contractor shall be responsible for securing all vehicle gates and man gates at the end of each work day.

A daily visitor’s log will be maintained to document all visitors to the site.

5.4.4 Erosion and Sediment Control

In accordance with New York Guidelines for Urban Erosion and Sediment Control (New York 1997), an erosion and sediment control plan must be prepared for any construction activity that exceeds 1 acre in size.

During construction activities, erosion and sediment controls will be incorporated to minimize storm water contacting disturbed areas and to control runoff. Silt fences shall be installed around excavation areas and around the soil storage areas.

5.4.5 Equipment Decontamination

Vehicles and equipment that come into contact with affected media shall be decontaminated prior to leaving the site. The Contractor shall utilize procedures for decontamination of vehicles and equipment as outlined in the CHASP.

Injection rods and equipment in direct contact with oxidant solutions should be cleaned daily. This includes injection pumps, delivery hose/piping and batch mixing tanks.

Pressurized water with a detergent solution (Alconox or equivalent) is preferred. A temporary decontamination pad shall be established on-site that is of suitable size and provides containment of all decon liquids and solids. The decon wastes shall be collected and disposed offsite in accordance with NYDEC and City of Jamestown requirements. Some decon wastes may be returned to the site upon the approval of URS .

5.4.6 Spill and Discharge Control

The Contractor shall prepare a Spill and Discharge Control Plan. The Spill and Discharge Control Plan will be part of the CHASP and is to be implemented in the event of an accidental release of potentially hazardous materials and shall contain the following elements:

- Preventive Measures – the Contractor shall provide methods, means, and facilities required to prevent contamination of soil, water, atmosphere, uncontaminated structures, equipment, or material by the discharge of wastes from spills due to the Contractor's operations. Shovels, brooms, non-combustible sorbent materials, polyethylene sheeting, and PPE shall be maintained in accessible locations.

- Emergency Measures – the Contractor shall provide equipment and personnel to perform emergency measures required to contain any spillage and to remove spilled materials, soil, or liquids that become contaminated due to spillage. The collected spill materials shall be properly disposed of at the Contractor's expense.

- Decontamination Measures – the Contractor shall provide the equipment and personnel to perform decontamination measures that may be required to remove spillage from previously uncontaminated structures, equipment, or material. Disposal of decontamination residues and confirmation samples shall be performed at the Contractor's expense.

- Notification Procedure – the Contractor shall notify URS immediately after the release of potentially hazardous materials as well as the National Response Center and NYSDEC Hotline, as required (applicable phone numbers must be listed in the HASP).

5.4.7 Survey and Work Stake-out

The Contractor will be responsible for staking out the limits of work in the field as shown on the drawings. The exact locations of treatment areas and excavations will be staked from established control points. Survey crews utilizing traditional survey equipment and/or GPS equipment, as appropriate, will be employed. Each injection point will be numbered for identification purposes and the depth of injection clearly shown for each area of the site.

5.5 Baseline Groundwater Sampling

Existing monitoring wells and discrete groundwater sampling will be conducted by USR prior to initiating the project bidding and procurement process. The objective of the sampling will be to confirm the extent and nature of VOCs in the UST Area shallow groundwater zone and provide a baseline for ISCO performance. Any significant changes in the VOC characterization from current interpretations outlined in Section 3.0 may require a modification to the ISCO implementation plan. Major changes to the plan will be submitted to NYDEC for review. All data and revised ISCO plans and treatment zones, if prepared, will be provided to the Contractors prior to final project bidding.

5.6 Pre-Work Injection and Infiltration Field Tests

Prior to commencing full-scale treatment operations, field testing will be performed by the Contractor in representative treatment area locations to confirm injection and infiltration hydraulic design guidelines. These tests include injection and test pit infiltration tests using clean water. URS will monitor the testing and prepare a pre-work testing memorandum. The findings of the testing will be reviewed and modifications to the chemical oxidation treatment guidelines will be made if necessary.

5.6.1 Injection Test

An injection test shall be conducted in the shallow groundwater zone in the area directly east of the metal building (near well HW-9). The vertical test interval will be approximately 10-18 ft. BGS. Test criteria area as follows:

- Advance test injection point 5-ft from existing monitoring well HW-9, to the maximum test depth (18 ft. BGS).

- Injection clean water at a rate equivalent to 0.5, 1.0 and 2.0 times the calculated maximum injection pressures (Pm) as measured at the injection rod head. The estimated Pm’s for the site are 8-10 psi for depths of 10-15 ft.

- Inject a minimum 0.5 pore volumes (PV) of water per foot interval over the range of injection pressures. The estimated PV per foot for a 10-ft injection spacing is 224 gallons (at porosity = 0.3).

- Record the time, depth, injection pressure, water volume, flow rate and any other notable conditions observed during the tests. Measure the water levels in the adjacent monitoring well (HW-9) pre-test, and at intervals not to exceed 30 minutes during each test. Record a minimum three measurements per test.

- Adjustments to the injection test criteria may be made as a result of initial performance of the tests. All modifications will be communicated to and subsequently approved by URS prior to revising the testing criteria.

5.6.2 Infiltration Test

An infiltration test shall be conducted to assess area infiltration hydraulics prior to the full-scale infiltration of chemical oxidant. The test will in the vadose zone in the area directly west of the metal hut building, near monitoring well MW-23S. The vertical test interval will be the unsaturated zone above the water table, approximately 4-8 ft. BGS. Test criteria area as follows:

- Advance three (3) test pit excavations at a distance of 5 ft from existing monitoring well MW-23S. The test pits shall be approximately 2 ft. in width and a minimum 5 ft. in length at the bottom. The pits will be required to be excavated at depths of 2, 4 and 6 ft BGS. Orientations of the three pits will be north, west and south of the monitoring well. Seepage tests will be done at each 2 ft depth interval, starting at 2 ft. BGS. A minimum of 30 minute interval will be required between each test to allow water seepage from the excavation bottom.

- Fill the pit with clean water to achieve a 1-ft deep liquid depth.

- Record the time, water depth, total water volume, any other notable conditions observed during the tests over the period required to drain the initial water volume completely into the subsurface. Measure the water levels in the adjoining monitoring well (MW-23S) pre-test, and at intervals not to exceed 10 minutes during each test. Record a minimum three measurements per test.

- After all of the tests are completed, backfill the test pit to original grade.
- Adjustments to the infiltration test criteria may be made as a result of initial performance of the tests. All modifications will be communicated to and subsequently approved by URS prior to revising the testing criteria.

5.7 <u>Chemical Oxidation Implementation Plan</u>

The objective of the chemical oxidation of the UST Area is to achieve NYDEC cleanup objectives for site contaminants in soil and groundwater throughout the designated zones of treatment.

The UST Area presents some challenges for delivery of the oxidant to the zones of interest. These include the shallow distribution (4-8 ft. BGS) of the highest levels of contamination, the wide range of contaminant concentrations observed across the site (1-500 ppm), including minor groundwater VOC impacts of 1 ppm or less, and the shallow groundwater table (6-8 ft. BGS)..

The shallow depth of the vadose zone VOCs, and the overall site in general, limits the ability to inject oxidants at high pressures because of concerns with ground uplift, oxidant surface breakthrough, and groundwater mounding. The nearly three (3) orders of magnitude range of VOC concentrations increases the complexity of onsite preparation and delivery of optimum oxidant dosages. For example, the relatively low VOC levels require an equivalent low dosing of oxidant, however, the distribution of the oxidant by pore volume requires a site-wide fixed volume of solution, and thus a correspondingly very dilute (low % oxidant) solution for the low VOC areas. The high VOC areas conversely require a relatively concentrated solution (high % oxidant).

The RAWP proposes two (2) oxidant delivery methods as a performance specification with a preference for injection and shallow zone infiltration. Infiltration methods may be by trenches or open area (blanket). Alternative delivery methods will be considered by URS/Dow if proposed by the Contractor.

The proposed treatment areas are based on the existing investigation database. See Section 3.0. These areas may be modified based on the results of the pre-work confirmatory baseline sampling as described in Section 5.5.

Two (2) treatment zones have been designated and are identified as follows:

- West Area- High VOC area of soil and shallow groundwater
- East Area- Low VOC area of soil and shallow groundwater

These areas are shown on Drawing C-3. The extent of the groundwater treatment areas may be modified as a result of the pre-work baseline sampling.

5.7.1 InSitu Treatment Design Guidelines

General performance guidelines have been established for chemical oxidant formulation and delivery to the treatment zones of interest. These guidelines are intended as preliminary requirements for implementation of insitu chemical oxidation at the site. The pre-work water injection and infiltration tests and full-scale field performance will provide actual site-specific data that can be used to modify these guidelines as necessary. All major field modifications to the oxidant formulation and delivery system must be approved by URS/Dow.

Design calculations are contained in Appendix C.

5.7.1.1 Treatment Zone Pore Volume

The UST area soil pore volumes (PVs) were estimated to provide an indicator of the oxidant solution reference volume required to saturate the treatment zone. PVs were estimated based on a porosity of 0.3. Unit pore volumes (per/ft.) were estimated for a range of injection point spacings and for infiltration areas (per sq. ft.). A square injection area was assumed for the calculations to account for the entire surface area, although the radius of influence at injection may be typically more circular.

One (1) PV is the baseline volume for fully saturated distribution of the oxidant to the contaminants in the treatment zone. The total treatment zone, vadose plus saturated zones, has an estimated PV of 415,364 gallons at a porosity of 0.3. The average PV is 2.24 gallons per square foot/foot. For the site design injection spacing of 10 foot, the per point PV is estimated at 2693 to 3142 gallons, depending on the formation thickness (12-14 ft). This volume will vary throughout the site based on actual effective porosity and treatment zone thickness. The capacity of the formation to accept 1 PV in a reasonable time frame is critical to critical to achieving a cost-effective remedial action. The formation acceptance rate and time estimates are evaluated later in this section. See Table C-1 for the PV estimates.

5.7.1.2 Injection Pressure Guideline

Maximum in-situ injection pressures were estimated over the thickness of the treatment zone, approximately 6 to 16 feet BGS. A shallow zone average hydraulic conductivity of 2.69 ft./day used in the estimate was determined from a series of well slug tests performed in the UST Area. The mitigating effects of soil tensile strength resistance was neglected to allow a conservative estimate. Because the injection zone is relatively shallow, injection pressures will need to be monitored and controlled to prevent surface uplift and fluid return.

For the range of injection depths, maximum injection pressures (insitu) were estimated at 5.0 to 9 psi, with allowable pressure increasing with depth of the injection point. See Table C-2 for the injection pressure estimates.

The time to inject one pore volume of liquid was estimated over a range of injection pressures. The injection time is critical to deliver the oxidant in a reasonable time frame to reduce operations costs. A target delivery time per injection point of 0.5 to 2.0 hours per point, or less, is desirable.

Over the range of maximum injection pressures previously calculated, the injection times will likely range from about 90-175 minutes per point for 10 ft injection spacings and 5-10 psi injection pressures. The greater time frame is for the shallow zone (vadose) at the site. These estimates do not take into account the injection effects on groundwater mounding. See Table C-3 for the injection time estimates.

5.7.1.3 Hydraulic Acceptance Rate

The hydraulic acceptance rate of the formation was evaluated to estimate the operating limits to prevent groundwater mounding during injection. The shallow groundwater saturated zone was conservatively estimated at 6 ft. BGS, although the depth varies over the site and over the year and is typically deeper than 6 ft..

In general, the acceptance rate will decrease as the groundwater levels rise because of the back pressure caused by the groundwater mound. For injection, the acceptance rate also increases with depth because the allowable injection pressures also increases with depth.

The acceptance rates range from 6.7 to 13 gallons per minute (per injection point) at a groundwater mounding of 2 ft., and from 1.3 to 3.4 gpm at a mounding 6 ft., for injection depths ranging from 6 to 15 feet BGS, respectively. See Table C-4 for the injection acceptance rates.

For the minimum one (1) PV injection requirement of 224 gal/ft. injection (10 ft. spacing), the injection times would range from 17 to 172 minutes per injection point, depending on the depth and degree of mounding. The upper end of this range is within the injection time range estimated for the range of acceptable pressures. See Section 5.7.1.2.

For infiltration, assuming a mounding of 4 ft. (2-ft below ground surface), the infiltration rate can be estimated by Q = K * i * A, where the vertical gradient is the depth of the infiltration head. At a 1 ft. head, the nominal infiltration rate is 20 gpd/sf. This rate will increase with increasing the depth of the applied infiltration solution.

5.7.1.4 Oxidant Formulation

The oxidation treatability study evaluated three different oxidant-activator combinations, each applied with and without surfactant addition. Based on the results of the study, **sodium persulfate activated with iron-EDTA, in combination with the VeruSOL-3 surfactant,** is the proposed oxidant for site treatment. The oxidant formulation shall be as follows:

- Sodium persulfate ($Na_2S_2O_8$) – percent (%) solution varies with application area with higher concentrations of oxidant used in more highly contaminated areas.

- Fe-EDTA activator- 0.35% by weight, (350 mg/l as Fe at 10% oxidant solution-100g/L)- activator varies with oxidant percent solution

- VeruSOL-3 surfactant- 1.0% by weight, (10 g/L at 10% oxidant solution)-surfactant varies with a oxidant percent solution

The solubility of sodium persulfate has been reported to be 73g/ 100g water @ 25 deg C. The active oxygen content of commercially available sodium persulfate is reported at 6-7%.

The oxidant and EDTA activator are commercially available. The VeruSOL-3 surfactant is a proprietary product developed by VeruTEK Technologies, Inc., Bloomfield, CT. A spec sheet and MS/DS for the oxidant, VeruSOL-3 and Fe-EDTA are contained in Appendix D.

5.7.1.5 Oxidant Dosing

Oxidant dosing is defined as the mass of oxygen in solution delivered to the specific treatment zone. Dosing is based on the treatment zone VOC concentrations, the natural oxidant demand (NOD) and the acceptance capacity of the specific treatment zone.

VOC Stoichiometric Oxidant Demand

The stoichiometric oxygen equivalent for degradation of a volatile organic compound provides a baseline minimum oxygen requirement. Based on the highest molecular weight VOCs at the site- ethylbenzene and xylenes, the amount of oxygen needed is as follows:

$C_8H_{10} + 10.5\ O_2 = 8\ CO_2 + 5\ H_2O$

On a molecular weight basis, one mole of ethylbenzene/xylene (MW=106) would require 10.5 moles of oxygen (MW= 16 x 2), or, on a per weight basis, 3.2 lbs. of oxygen is required to degrade 1 pound of VOCs. Commercial sodium persulfate has approximately 6.5% available oxygen, by weight, for reaction with site VOCs. Therefore, approximately 49.2 lbs. (3.2/0.065) of bulk sodium persulfate is required to oxidize 1 lb. of VOC based on xylene oxidation stoichiometry. This is the minimum oxidant dose required for complete VOC destruction, based on xylene equivalent VOCs.

Other non-VOC contaminants present in the subsurface will also exert oxygen demand. TPH is the primary site non-VOC contaminant of interest from an oxidation standpoint.

Total Oxidant Demand

Naturally–occurring organic matter, petroleum hydrocarbons (TPH) and reduced subsurface materials can exert additional oxidant demand. TPH was measured in the treatability study. The treatability study did not assess specific natural oxygen demand (NOD) conditions, however, the effects of NOD were accounted for in the overall emulsion and column testing based on the use of site-specific soil samples used in the treatability testing.

The NOD/TPH demand was estimated as equivalent to 20% of the total VOCs in the west vadose zone and groundwater area, and equivalent to approximately 5 ppm in the remaining groundwater areas. Based on these estimates, a multiplier factor of 5.0 was used for the low VOC zones (groundwater) to increase the oxidant dosage, and a multiplier factor of 1.2 was applied to the vadose zones and high VOC (100 ppm) groundwater areas to account for NOD/TPH demand. The majority of the oxidant (90%) is needed for the vadose zone areas West 1 and West 2. The bulk oxidant required at the site is summarized on Table C-5. A total of 49,085 lbs. of bulk dry oxidant is estimated for the entire site. The bulk dry oxidant requirements based on these factors are as follows:

Treatment Area Bulk Dry Oxidant Estimate

Area	**Oxygen Equivalent, lbs**		**Bulk Oxidant Req't, lbs**	
	Vadose	Groundwater	Vadose	Groundwater
West 1	1371	122	21090	1880
West 2	1645	8	25309	125
West 3	0	16	0	247
Subtotal West	**3016**	**146**	**46399**	**2252**
East 1	8	1.6	129	24
East 2	0	18	0	280
Subtotal East	**8.4**	**20**	**129**	**304**
Total Site	**3024**	**166**	**46528**	**2557**
		Volume, cy:	***24.6***	***1.4***

Sodium persulfate is typically shipped dry, in bulk 1000 kg poly bags (~ one cubic yard), at approximately 70 pcf. Bulk oxidant will be pre-mixed on-site with water, activator and surfactant. In-line mixing is acceptable if suitably demonstrated by the Contractor. The bulk dry oxidant will be blended onsite in the required percent solution with water to allow delivery to the treatment areas. The oxidant solutions will vary by treatment area. More concentrated solutions (10-20%) will be used in high VOC zones while less concentrated solutions (1 %) will be used in low concentration zones.

Table C-6 summarizes the minimum oxidant volumes required across the site treatment zones for a range of percent solutions.

The primary criteria for designing the specific solution for the treatment zones is the bulk oxidant requirement and the reference pore volume saturation guideline. Essentially, the oxidant application should be optimized to deliver the required oxidant dosage throughout the entire treatment zone using the minimum amount of water. Other criteria to also consider include injection pressure and time limitations, and groundwater acceptance limitations.

Low VOC Zones

In the case where the VOC levels are relatively low (1 ppm), such as the East Area groundwater, the bulk oxidant dosages required are correspondingly low (304 lbs.). At a 10% oxidant solution, the delivery volume would equal 362 gallons, which is significantly less than the formation PV of approximately 148,000 gallons.

The equivalent % oxidant solution required in the East Areas to meet the PV design criteria of a minimum of 1 PV would be less than 0.1%. On a per injection basis, this would require about 200 gal oxidant solution/ft. for 10 ft. injection spacings.

High VOC Zones

In the case where the VOC levels are relatively high (> 100 ppm), such as the West Area vadose zone, the bulk oxidant dosages required are correspondingly high (55,679 lbs.). At a 10% oxidant solution, the delivery volume would equal 66,294 gallons, which is about 17% greater than the formation PV of approximately 41,963 gallons.

Table C-7 summarizes the oxidant volumes per unit area for a range of injection and infiltration oxidant delivery applications. Specific oxidant delivery plans for each treatment area zone are described in the following section.

5.7.1.6 Oxidant Delivery Plan

Two oxidant delivery methods are proposed for the UST Area: injection and surface infiltration. Injection is proposed for the groundwater zones with low VOCs: West 2 and West 3, and both East areas. Surface infiltration is proposed for the high VOC groundwater zone West 1, and the west and east high VOC vadose zones. These treatment zones are depicted on Drawing C-3.

To optimize the oxidant usage for each site area, and maintain the practicality of onsite oxidant mixing, specific oxidant dosages were designed for each treatment zone.. The oxidant doses were developed to deliver the minimal required oxidant and pore volumes (1) in consideration of the formation acceptance rate and a reasonable time for delivery of the oxidant solution.

In addition, injection of 1 PV of liquid at the site would require large volumes of water that may be impractical to manage. This is the case in the low VOC zones where oxidant requirements are relatively low and oxidant solutions would be approximately 0.1% to meet the unit PV goal.

Actual delivery of oxidant into the subsurface in these areas will be at volumes less than 1 PV since the effects of dispersion and diffusion of oxidants can also achieve oxidant distribution throughout the treatment zone. In the low VOC areas, the oxygen requirement was increased by a factor of 5.0 to overdose the zone with oxygen while injecting a PV < 1.0. This will increase the oxygen diffusion rate, significantly reduce the water volumes required for injection and reduce the potential negative effects of groundwater monitoring and contaminant migration. Although subsurface dispersion/diffusion of oxidants is site-specific and is not considered practical or useful to estimate, field monitoring of oxidant distribution at the selected delivery rates will confirm the effectiveness of the planned applications or indicate the need to modify the oxidant dosing.

The oxidant dosage plan is summarized below and on Table C-8.

Oxidant Mix per Injection Point (10 ft. spacings)

	Oxidant Solution		**Fe-EDTA, 0.35%**	**VeruSol 3, 1%**	**Oxidant Solution**	**PVs**
Area	**%**	**gal/ft.**	**Tot. lbs.**	**Total Gallons**		
West 1	5	88	1.5	11	1061	0.4
West 2	0.5	37	0.1	4	442	0.2
West 3	0.5	37	0.1	4	442	0.2
East 1	0.5	37	0.1	4	442	0.2
East 2	0.5	37	0.1	4	42	0.2

Oxidant Mix per Infiltration Area- Vadose Zone

	Oxidant Solution		**Fe-EDTA, 0.35%**	**VeruSol 3, 1%**	**Oxidant Solution**	**PVs**
Area	***%***	**gal/sq. ft./ft.**	**Tot. lbs.**	**Total Gallons**		
West 1	20	2.1	105	181	18063	0.95
West 2	20	2.1	126	217	21676	0.95
West 3	groundwater-injection only					
East 1	0.5	1.7	0.6	44	4420	0.76
East 2	groundwater-injection only					

5.7.1.7 Groundwater Injection

Injection is proposed for the shallow groundwater zones in the east and west treatment areas. Injections are proposed to be performed first, prior to infiltration (see Section 5.7.1.2). Depth of injection will range from approximately 4 to 14 feet below ground surface (BGS), depending on the depth of the clayey-silt confining layer. Nominal injection spacing is 10 foot centers. Injection by direct-push drilling equipment is preferred. Any changes to the oxidant injection plan as a result of field pre-injection testing or other field changes shall be as approved and directed by URS. Oxidant injection dosages are described in Section 5.6.1 6, and the planned injection areas are shown on Drawing C-3.

Some of the injections will require access to onsite building interiors (metal building on Blackstone Ave). URS will coordinate with the property owner and tenants to obtain access to the buildings and have manufacturing equipment and materials moved as needed to allow equipment access. Existing vehicle entry doors on the buildings have free-openings as follows:

General criteria for injections are as follows:

- Prior to injection, any surface/overhead utilities or obstructions and any underground utilities/piping shall be identified. Surface pavement shall be pre-cored prior to injections to achieve a clean hole for future repair, if the injection point is not within a planned infiltration zone.

- Each injection point shall be uniquely identified, and each injection point shall have an Injection Log form that contains the following information: injection number, date/time, oxidant dosage, oxidant flow rate and volume, injection pressure at injection drive-head pipe,

- The required oxidant dosages shall be pre-mixed in batches prior to injection. The activators should not be added to the injection mix until the oxidant solution is thoroughly mixed. A batch tank with a mixer is recommended for preparing the required volume of oxidant for each injection point. The nominal batch tank size required would be a minimum 1000 gallons based on the maximum oxidant solution volume estimated for any single injection point as outlined in the proposed injection plan (Table C-8, West Area 1). The batches may also be mixed in smaller proportions (500-1000 gal) if necessary to facilitate field operations. All oxidant batches shall be mixed for at least 5 minutes prior to injection to assure a homogeneous mixture. Mixed oxidant batches shall be used up on a daily basis.

- Injections shall be on nominal 10 foot centers spacing. The spacing may be modified based on the results of the pre-work injection testing (Section 5.6).

- Single or multiple injection points may be employed at one time. If multiple injection points are used, a manifold piping system may be used for oxidant delivery.

- Injections shall be performed from the bottom of the zone first, working towards the upper part of the zone of treatment. Injections may be delivered on 1-foot intervals or continuously to achieve a uniform oxidant dosage across the treatment zone vertical interval, depending on the injection rod configuration and the results of the pre-work injection testing.

- Injection activities shall be done prior to vadose zone infiltration delivery (Section 5.7.1.8). Treatment area perimeter injections shall be performed first. Injections shall be staggered so as not to inject next to a point that was injected immediately prior.

- Injection pressures shall be within the guidelines described in Section 5.6.1.2 and they shall not be excessive as to cause soil or pavement uplift, or excessive breakthrough of injected oxidant. Injection pressure shall be monitored continuously during injection operations. Uniform oxidant flow rate shall be maintained, if practicable without generating excessive back pressure in the injection pipe or formation.

- Existing monitoring wells and piezometers in and near the treatment zone shall be monitored daily for water levels. Wells or piezometers closest to the injection point shall be monitored more frequently during injection to check water levels. See Section 5.10 for specific monitoring requirements.

- Completed injection borings shall be backfilled and sealed immediately after injection of the specified volume of oxidant. The injection zone interval shall be backfilled with a clean sand, if possible.. Above the treatment zone the boring shall be grouted with a Portland cement-bentonite grout mixture to the ground surface.

5.7.1.8 Infiltration Beds

Infiltration is proposed for the vadose zones in the east and west treatment areas. Open infiltration beds or trenches will be used to deliver the higher concentration oxidants to the high VOC concentration vadose zones. Infiltration of oxidant solutions shall be by open shallow pits/trenches above the vadose zone VOC areas. No liners are planned. Removal of surface pavements will be necessary in the east treatment zone. Depth of the infiltration bed will range from approximately 2 feet BGS. The infiltration bed area may be the entire treatment zone, or subsections, depending on the Contractor's work strategy and management of onsite traffic and equipment. At a minimum, the West 2 Area should be implemented prior to the West 1 Area to allow access to the Master Machine Building by their employees during treatment of the West 2 Area. None of the proposed infiltration treatment areas will require access to building interiors. Any changes to the oxidant injection plan as a result of field pre-work infiltration testing or other field changes shall be as approved and directed by URS. Oxidant infiltration bed dosages are described in Section 5.6.1. 6 and planned infiltration areas are shown on Drawing C-3.

General criteria for infiltration are as follows:

- Prior to constructing the infiltration beds, any surface/overhead utilities or obstructions and any underground utilities/piping shall be identified. Surface pavement shall be removed from the infiltration area and removed from the site for offsite disposal in accordance with NYDEC and City of Jamestown requirements.

- The infiltration beds shall be excavated to a nominal depth of 2 feet BGS. The finished bed floors shall be level. Excavation spoils may be temporarily stored onsite for later backfill into the infiltration bed after treatment. The infiltration beds may be the entire treatment zone area, approximately 5000 sf in the west area, or they may be subareas of the treatment zones.

- The perimeter of the bed excavations shall be secured with temporary construction fencing to prevent onsite worker access or other visitor access.

- Surface runoff into the beds shall be minimized by ditches and/or barriers.

- Each infiltration bed shall be uniquely identified and have an Infiltration Bed Log that contains the following information: infiltration bed number, date/time, oxidant dosage, oxidant flow rate and volume, and bed liquid depths over time,

- The required oxidant dosages shall be pre-mixed in batches prior to placement in the infiltration bed. Multiple batches are anticipated for each infiltration area based on the total volume requirements of up to about 22,000 gallons of oxidant solution per area (Table C-8, West 2 Area). The activator should not be added to the mix until the oxidant solution is thoroughly mixed. A batch tank with a mixer is recommended for preparing the required volume of oxidant for each injection point. All oxidant batches shall be mixed for at least 5 minutes prior to bed placement to assure a homogeneous mixture. Mixed oxidant batches shall be used up on a daily basis.

- Mixed oxidant shall be placed uniformly over the entire infiltration bed by spraying or flooding, depending on the volume of oxidant solution, the bed area, and the infiltration rate. The maximum liquid level in any of the beds is expected to be 1 ft. or less based on the proposed oxidant delivery plan. The largest beds, West 1 & 2, have a total surface area of approximately 4700 sf, and a design oxidant solution volume of approximately 40,000 gallons. Maximum liquid depth at total volume would be approximately 13.5 inches.

- Existing monitoring wells and piezometers in and near the treatment zone shall be monitored daily for water levels. Wells or piezometers closest to the infiltration area shall be monitored frequently to check water levels. See Section 5.10 for specific performance monitoring requirements.

- After infiltration of the oxidant solution the beds shall be flushed with clean water. A minimum water volume of 20% of the oxidant volume shall be applied. Flush volumes are as follows:

	Oxidant Solution	*Clean Water Flush*
Area	**Gallons**	**Gallons**
West 1	18063	3600
West 2	21676	4300
East 1	4410	880

- Treated infiltration beds shall be backfilled immediately after the total required oxidant volume has infiltrated into the subsurface and the bed surface is relatively dry. Onsite clean spoil materials previously removed from the area or clean imported fill will be used for backfill of the beds.

In areas of previous pavement, a minimum of 8-inches of bituminous asphalt pavement shall be placed. The pavement subbase fill shall be placed in 1 ft. thick lifts and shall be compacted by a minimum 4 passes of a vibratory roller with a minimum 3500 lbs. dynamic force. In areas of previous vegetation (East), the backfilled area shall be vegetated with a suitable grass mixture. See Drawing C-4 Site Closure Plan. The schedule for backfill and paving of infiltration areas will be as directed by URS based on the results of post-treatment monitoring.

5.7.2 Process and Equipment Requirements

In general, the majority of the necessary project equipment needed will be associated with processing and injection of oxidants. Infiltration delivery of oxidants will require oxidant batch processing and delivery of the oxidant into excavated beds or trenches. In-line continuous mixing of oxidant solutions may be employed as an alternative approach, if these systems can be demonstrated by the Contractor to meet the design requirements for the project. The selected Contractor will propose specific equipment for the project which will be reviewed and approved by URS prior to commencement of the work.

5.7.2.1 Oxidant Processing Equipment

Oxidant processing will require multiple onsite storage tanks, mixing tanks, a bulk material handling system and pumping systems to prepare and deliver the oxidant solution to the treatment zone. All of the materials of construction shall be compatible with the oxidant and associated reagents.

- Storage- Dry reagents such as sodium persulfate, surfactants and iron-EDTA activators shall be stored in a secured dry condition, at a minimum on a dry pad/base with a waterproof covering.

- Water- ISCO processing will require significant volumes of water. For1 PV over the treatment zone, 415,000 gallons of water will be required. Less water will actually be needed since the current oxidant delivery plan proposes < 1 PV volume of oxidant solution. See Section 5.7.1.6. The water volume based on the current oxidant delivery plan is approximately 115,000 gallons. Additional water will be needed for infiltration bed flushing and other site uses. These other volumes are not estimated herein.

- Onsite storage of the total project water supply volume is not practical. Onsite storage of a minimum volume of water to supply 2 days of injection operations will be required. The source of water will be determined by the Contractor. City of Jamestown water lines are present on Blackstone Avenue. A fire water hydrant is located on the north side of the street, directly southeast of the metal hut building. The Contractor shall verify the availability of City of Jamestown water prior to commencing work.

- Mixing equipment will be needed to blend the dry oxidant and activator reagents with water. The mix tank shall be of sufficient volume to allow batching of a minimum volume needed for a single injection point. At a nominal 10-ft spacing, this volume is estimated to be up to 1061 gallons (Table C-8). The mixer shall be a high-shear unit capable of completely blending the dry oxidants and activators into a uniform, non-flocculated solution.

- The mix tank shall be placed within a secondary containment system capable of collecting and storing the mix tank volume in the event of a tank leak, spill or breach of piping.
- Materials Handling Methods- Preparation of oxidant solutions will require bulk feeding of dry products into mixing vessels. Mechanical or heavy equipment transfer of bulk oxidant to conveyance systems or directly to mixing vessels is anticipated. The mix proportions shall be accurately measured and controlled to achieve the desired oxidant solutions for delivery to each treatment zone. All oxidant and reagent mixing systems shall be placed within secondary containment structures. The Contractor will propose specific materials handling methods in the Contractor's Field Operations Work Plan submittal.
- Pumping Systems- A pumping system is required to transfer the mixed oxidant solution to the treatment areas. Since the areas include infiltration beds and injection points, the pumping requirements will vary. Injection pressures are limited by the shallow depth of the treatment zone and low pressure/high volume pump is more suitable for this application. Diaphragm and/or bladder pumps are acceptable for injection. Transfer of oxidants to the larger area and volume treatment beds may be accomplished by higher pressure pumping systems, such as positive displacement pumps. Delivery of oxidant to infiltration areas will be by open outfalls or spraying across the infiltration bed.
- Monitoring – Sufficient gauging equipment shall be installed to measure oxidant solution flow, transfer line and injection point pressures, injection and infiltration volume/time and oxidant solution temperatures. These data shall be measured and recorded on a Daily Log by the Contractor.

5.7.2.2 Injection Equipment

Injection by direct-push (DP) drilling equipment is preferred. These rigs provide greater flexibility for site access and mobility and they are capable of injecting the volumes of oxidant to the required depths of the site treatment zones. General requirements for the DP equipment are as follows:

- DP rigs shall be in good working condition and hydraulic lines shall be checked and replaced as needed prior to the start of work. Multiple rigs may be used on the project. Manifold systems shall each have multiple pressure gages and flow meters to allow measurement of injected solutions at each point.

- Drilling/injection rods shall be steel with threaded joints. All joints will have O-rings that are compatible with the injected fluids.

- Injection points may be slotted, retractable or pressure-activated, or a combination of these. The injection point shall be able to deliver oxidant in a 360 degree distribution within the borehole. Expendable tips with open ended rods are acceptable. The Contractor shall submit injection rod details for approval.

5.8 Cleanup and Site Restoration

Construction debris, waste materials, packaging material and miscellaneous solid wastes shall be removed from the work site on a daily basis. Any dirt or mud that is tracked onto paved or surfaced roadways shall be cleaned daily. Stored material shall be neatly stacked when stored.

Upon completion of the project and after removal of materials and equipment, the areas used by the Contractor for storage of equipment or materials, and transporting equipment and/or materials between work areas, shall be restored to original or better condition.

Any infiltration areas that had pavement removed shall be paved with bituminous concrete as described in Section 5.7.1.8. URS will direct the Contractor on the schedule for final paving based on the results of the performance monitoring. Disturbed vegetation areas shall be graded to a smooth condition and re-seeded. See Drawing C-5 Site Closure Plan.

5.9 Demobilization

Following completion of the remedial activities and acceptance of the work by the NYSDEC and Dow, the Contractor will remove all equipment, materials, supplies, debris/waste generated by Contractor's activities, temporary utilities and facilities, and manpower from the Site.

The areas of the Site utilized and/or disturbed by the Contractor during the project are to be left in a condition equal to, or better, than when the Contractor mobilized to the site.

5.10 Performance Monitoring

URS will conduct performance monitoring to monitor the site operations and evaluate the effectiveness of the insitu treatment. Monitoring will involve hydraulic and chemical measurements before, during and after the ISCO operations. The baseline pre-work sampling described in Section 5.5 is not included as part of the monitoring described herein. Performance monitoring is summarized on Table 5-1 and Drawing C-5 Site Monitoring Plan.

5.11 Field Modifications

Field modifications shall be managed in accordance with the construction quality assurance and control plan (CQACP) as prepared by the Contractor in accordance with this RAWP and as approved by URS.

Major changes to the scope of the ISCO operations as defined in the CQACP will require NYDEC review and approval. Minor changes to the operations will be approved by Essex/URS. All field changes will be documented per the CQACP. See Section 6.0.

6.0 QUALITY CONTROL AND ASSURANCE

The Contractor is responsible for quality control and shall establish and maintain an effective quality control system monitored by URS. The quality control system shall consist of plans, procedures, and organization necessary to produce an end product that complies with the contract requirements. The system shall cover all construction operations and shall be keyed to the proposed construct schedule. The work shall conform to the documents approved for construction including all work plans and drawings.

The Contractor and its subcontractors shall comply with the construction documents prepared by URS and the HASP prepared by the Contractor. The Contractor is responsible for providing quality control during all phases of work. URS is responsible for quality assurance.

Changes significantly affecting the approved construction documents or project schedule shall be brought to the prompt attention of URS. Work found to be out of compliance with approved construction documents will be reviewed and halted, if necessary, until satisfactory resolution acceptable to URS is achieved.

The Contractors construction quality assurance and control plan (CQACP) shall be described in their Field Operations Work Plan (FOWP) submittal.

6.1 Responsibilities

The principal organizations involved in implementing the remediation at the site include NYSDEC, ESP (Dow Chemical), URS, and the Contractor. Specific responsibilities and authorities are delineated below to establish the lines of communications required to produce an effective decision-making process during execution of the work.

6.1.1 Regulatory Agency

The lead regulatory agency involved with this project is the NYSDEC. In this capacity, the NYSDEC will review construction documents for conformance with applicable requirements.

The NYSDEC has the authority to review and accept design revisions or requests for variances that are submitted after the construction documents have been approved.

6.1.2 Essex Specialty Products Inc.

Essex Specialty Products Inc. (ESP), a former subsidiary of The Dow Chemical Company (Dow), as owner, will be responsible for the proper permitting, design, and construction of the project. ESP has retained URS as the project engineer and to confirm quality assurance. The Contractor will be placed under contract with URS following approval of the construction documents. ESP has the authority to dismiss all non-regulatory organizations involved in the design, quality control and assurance, and construction of the items and activities outlined in this RAWP.

6.1.3 URS

URS will function as Project Engineer and will provide construction quality assurance personnel. URS' responsibilities under these separate functions are defined below.

6.1.3.1 Project Engineer

As the Project Engineer, URS' primary responsibility will be to provide engineering technical support and QA oversight during ISCO implementation. In this capacity, URS will be responsible for the monitoring of construction work and providing the Contractor with feedback from questions regarding the RAWP. In addition, URS will be responsible for identifying, documenting and correcting any deviations, as necessary, and to request and receive NYSDEC approvals as may be required.

URS has the responsibility to review proposed design revisions associated with field changes that deviate from the RAWP, and the authority to approve the revisions, and submit the proposed revisions to Dow and the NYSDEC for approval. All field changes will be processed in accordance with established procedures outlined in Section 6.3.

6.1.3.2 Construction Quality Assurance Inspector

URS will provide Construction Quality Assurance (CQA) during implementation of the remediation activities. The CQA inspector has the responsibility and authority to halt work that is not in conformance with the NYDEC-approved RAWP. The CQA inspector's responsibilities include:

- Review Contractor Field Operations Work Plan (FOWP) for clarity and completeness so that the work can be implemented correctly in a timely fashion.
- Perform on-site inspections to ensure compliance with FOWP.
- Verify that air monitoring activities have been properly completed and documented.
- Document the results of all inspection, test, and monitoring activities.
- Report non-conforming conditions in accordance with the procedures explained in Section 6.4, as well as other deviations from the FOWP to the Owner and NYSDEC.
- Verify the implementation of any corrective action measures.

6.1.4 Contractor

The Contractor's responsibility is to perform the work in accordance with the FOWP. Construction personnel will coordinate their work with the URS CQA inspector.

6.2 Site Meetings

Periodic CQA meetings will be held during implementation and construction. It is anticipated that one meeting will be held each week for the duration of the project, unless otherwise approved by the Engineer. Additional meetings will be held, if warranted during the project. As availability allows, meeting attendees will include the URS Project Manager, the

CQA inspector, and the Contractor. Representatives of the NYSDEC and Dow may also attend, as necessary, and timely notice of any meetings shall be distributed by URS.

The initial CQA meeting will be conducted on-site prior to initiating work. Subjects proposed to be covered during this meeting include:

- Providing appropriate parties with the NYSDEC-approved RAWP and project FOWP and CHASP.
- Resolving identified conflicts within the FOWP.
- Reviewing the procedures and requirements for the tests and inspections to be performed.
- Reviewing methods for documenting and reporting inspection and monitoring data (e.g. appropriate field book entries).
- Reviewing procedures for identifying and correcting deviations.
- Reviewing the HASP as needed.
- Conducting a site walkover to review and discuss work issues.
- Discussing the overall project schedule.

6.3 Daily Construction Quality Assurance

On a daily basis the CQA inspector will communicate with the Project Engineer (URS) to discuss project activities. Discussion topics will include:

- Previous activities and progress.
- Planned activities.
- Anticipated or potential construction issues.

- Review of testing procedures, submittals, or inspection activities.

The CQA inspector will document the daily progress and activities. The documentation will be utilized in preparation of the Remedial Action Report at completion of the project.

Specific inspection items will be outlined in the Contractors CQACP and will include, but are not limited to, the following:

- General work zone and treatment area layouts
- Chemical manufacturer's spec sheets and submittal data
- Onsite chemical storage and security
- Site water source verification
- Oxidant solution preparation, mixing and delivery
- Oxidant solution sampling and testing
- Instrumentation calibration
- Groundwater hydraulic monitoring during oxidant application
- Offsite migration of dusts, particulates or vapors
- Waste and debris management
- Final site cleanup and restoration, including grading, pavement and vegetation replacement and final surface drainage.

6.4 Field Change Request Process

The purpose of this procedure is to describe the method for requesting acceptance for the implementation of field changes to the Work Plan and procedures applicable to the remedial action.

A Field Change Request (FCR) is a document used to request and acquire the necessary reviews and acceptance for implementing a field change involving design, process, or method. During the course of field activities, conditions may be encountered that necessitate a change in requirements affecting design, processes, or methods.

These changes may be necessary to correct or revise a design, institute use of additional requirement, or request approval for relief from an existing requirement with suitable justification. Field changes may also be requested to address and acquire guidance for unforeseen or unanticipated conditions, or to acquire acceptance for alternate methods or processes to be employed. A FCR form that includes a complete description of the requested change, seeks the necessary acceptance, and provides for disposition of the request and identifies affected documents is to be used for each proposed change.

6.5 Nonconformance Reporting

The purpose of this procedure is to establish and provide a system for identifying, reporting, evaluating nonconforming items to prevent their inadvertent use or installation. This procedure applies to permanent installations and items of hardware or materials, which are procured, constructed, installed, or used in conjunction with remedial activities. This procedure does not apply to expendable tools, supplies, or temporary equipment, items or materials. A nonconformance is a deficiency in characteristic, documentation, or procedure that renders the quality of an item or material unacceptable or indeterminate.

The CQA inspector initiating the Nonconformance Report will provide a detailed description of the nonconforming condition(s), including any reference(s) to drawings, work plans, specifications, or procedures which may provide acceptance criteria for the item or material being reported. The CQA inspector, will maintain a log of NCRs.

If the NCR prompts any change to the intent of the construction documents, NYDEC must approve of the change prior to implementation.

6.6 Project Closeout

Near the end of field activities work, URS will schedule a Site walk through with the Contractor, and ESP/Dow personnel. Any remaining work necessary to satisfy the intent of the RAWP will be identified and documented for follow-up action.

A draft Final Remedial Action Report will be prepared to include a description of activities conducted to comply with the requirements of this RAWP and the Contractors FOWP. Based on input from the NYDEC, the report will be finalized.

7.0 SCHEDULE

A general sequence of events is presented in this section. The Contractor will submit a detailed construction schedule that outlines project tasks, sequences and durations. The final project schedule will be approved by ESP/URS and be provided to NYDEC.

The general implementation schedule is as follows:

- Submittal of draft RAWP (URS)
- Baseline groundwater sampling (URS)
- NYDEC review and comment on RAWP
- RAWP revisions (URS) and final approval by NYDEC, as necessary
- Issuance of UIC Permit from USEPA
- Preparation of final project documents and bid package (URS)
- Notice of Award of project to selected Contractor (URS)
- Issuance of Subcontract/Work Order to perform project (URS)
- Submittal of project documents (Contractor)
- Approval of project documents and schedule (URS)
- Issuance of Notice to Proceed (URS)
- Pre-operations monitoring (URS)
- Mobilization of materials and equipment (Contractor)
- Site preparation activities (Contractor)
- New monitoring well (3) construction (URS)

- Groundwater ISCO Injection (Contractor)
- Vadose zone ISCO Infiltration (Contractor)
- CQA and operations monitoring (URS)
- Bituminous pavement replacement (Contractor)
- Final site grading and vegetation (Contractor)
- Site final walk-through (all parties)
- Demobilization and cleanup (Contractor)
- Project Completion Report (URS)
- Post-operations monitoring (URS)

TABLES

Essex Jamestown Site
UST Area ISCO
Soil VOC Data Summary

Soil VOC Summary

2003-2005 Data, mg/kg

Area	Sample Depth	Date	Total VOCs		Total CTEX		Cumene		Toluene		Ethylbenzene		Total Xylenes	
	Ft BGS		**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**
UST West	4 to 8	Nov, 2003	0.05-547	181.47	0.02-547	181.44	BDL-3.7	1.1	BDL-3.3	0.62	BDL-40	10.4	BDL-500	169
	4 to 8	2005	403-2436	1000	339-2436	999.2	3.4-5.9	4.5	2.3-660	116	10-250	94.8	373-1520	751
UST East	4 to 8	Nov, 2003	0.11-0.41	0.26	0.03-0.36	0.2	BDL	BDL	BDL-0.013	0.009	0.007-0.063	0.035	0.026-0.284	0.155
	4 to 8	2005	BDL-29.47	4.7	BDL-29.47	4.7	BDL-1.2	0.27	BDL-0.27	0.063	BDL-3.0	0.46	BDL-25	3.9
	8 to 12	Nov, 2003	0.53-93.8	28.7	0.53-93.8	28.7	BDL-6.1	1.32	BDL	BDL	BDL-15	4.8	0.53-72.7	22.4

Notes:
1. BDL values entered as 5 ug/kg in calculation for arithmetic mean

Table 3-2

Essex Jamestown Site
UST Area ISCO
Shallow Groundwater VOC Data Summary

Shallow Groundwater VOC Summary

2003-2006 Data, ug/l

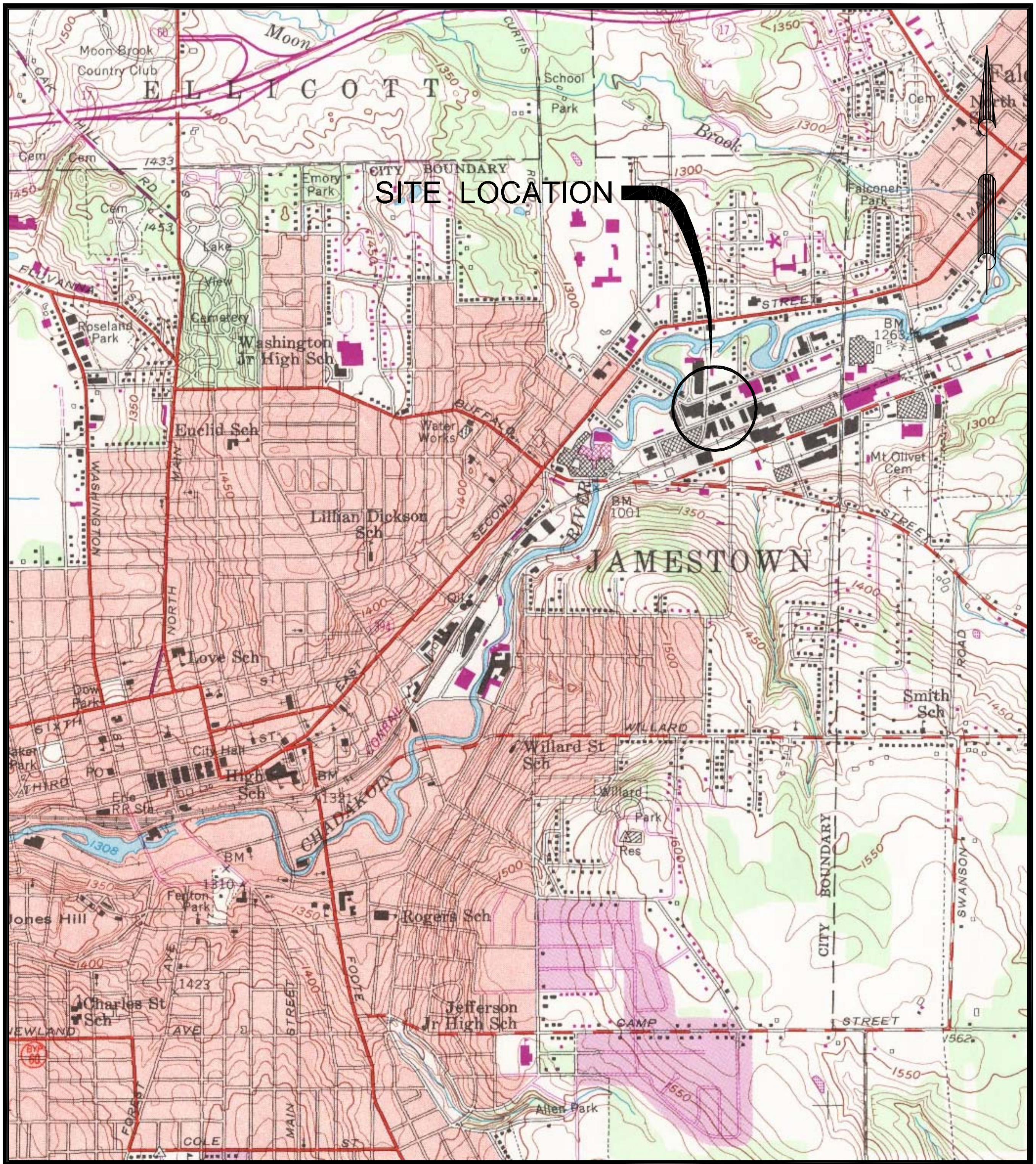
Area	Total VOCs		Cumene		Toluene		Ethylbenzene		Total Xylenes	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
UST West	BDL-1003K	120,895	BDL-6100	619	BDL-34,000	3884	BDL-160,000	12,676	BDL-810,000	102,800
UST East	BDL-93,805	10,225	BDL-6100	438	BDL-16	5.5	BDL-15,000	1798	BDL-72,700	7797

Notes:
1. BDL values entered as 5 ug/l in calculation for arithmetic mean
2. Data does not include MW-20 beneath CPM BL No. 5.

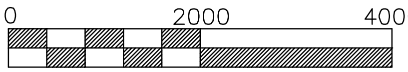
ISCO Performance Monitoring Summary

Work Phase	Objective	Monitoring Locations	Parameters	Frequency
Pre-Operations	Measure Groundwater Levels and Water Quality Indicators and VOCs to establish baseline conditions.	**Wells-** HW-9, MWs- 20, 23S, 24S, 26S, 27S and 28S, and PZ-5S	VOCs (EPA 8260), pH, cond, ORP, DO, sulfate, alkalinity, iron, and water levels	Within 2 weeks prior to the start of site oxidant applications
Operations	Measure Groundwater Levels, Water Quality Indicators and VOCs to assess ongoing operations and short-term effects of ISCO.	**Wells-** HW-9, MWs- 20, 23S, 24S, 26S, 27S and 28S, and PZ-5S (use selected monitoring wells closest to weekly ISCO activities)	VOCs (EPA 8260), pH, cond, ORP, DO, sulfate, alkalinity, iron, and water levels	Chemical Parameters- Weekly during oxidant application periods. Well water levels- daily and increased to 2x/day min. for wells < 50 ft from injection points.
Post-Operations	**Groundwater-** Measure Well Water Levels, Water Quality Indicators and VOCs to evaluate ISCO performance. **Soils-** Measure soil organic constituents to evaluate ISCO performance.	**Wells**- HW-9, MWs- 20, 23S, 24S, 26S, 27S and 28S, and PZ-5S. **Soils**- Continuous samples, 4 ft to water table. Select sample based on VOC headspace (HS) result. Sample vadose soils in west treatment area on 20 ft center grid and in east treatment area at centerline (E-W) on 10 ft centers.	**Groundwater-** VOCs (EPA 8260), pH, cond, ORP, DO, sulfate, alkalinity, iron and water levels. **Soils**- Field HS, VOCs and TPH.	**Wells**- Quarterly for 1-year after the end of site operations monitoring. **Soils-** 30 and 180 days after treatment

FIGURES



QUADRANGLE LOCATION



SCALE IN FEET

REFERENCE:

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PITTSBURGH, PENNSYLVANIA

REMEDIAL ACTION WORK PLAN
UST AREA CHEMICAL OXIDATION
SITE LOCATION MAP

ESSEX/HOPE SITE

JAMESTOWN, NY

CLIENT: ESSEX SPECIALTY PRODUCTS, INC.

JOB NUMBER: 41568097

SCALE: AS SHOWN

FIGURE NUMBER 1–1

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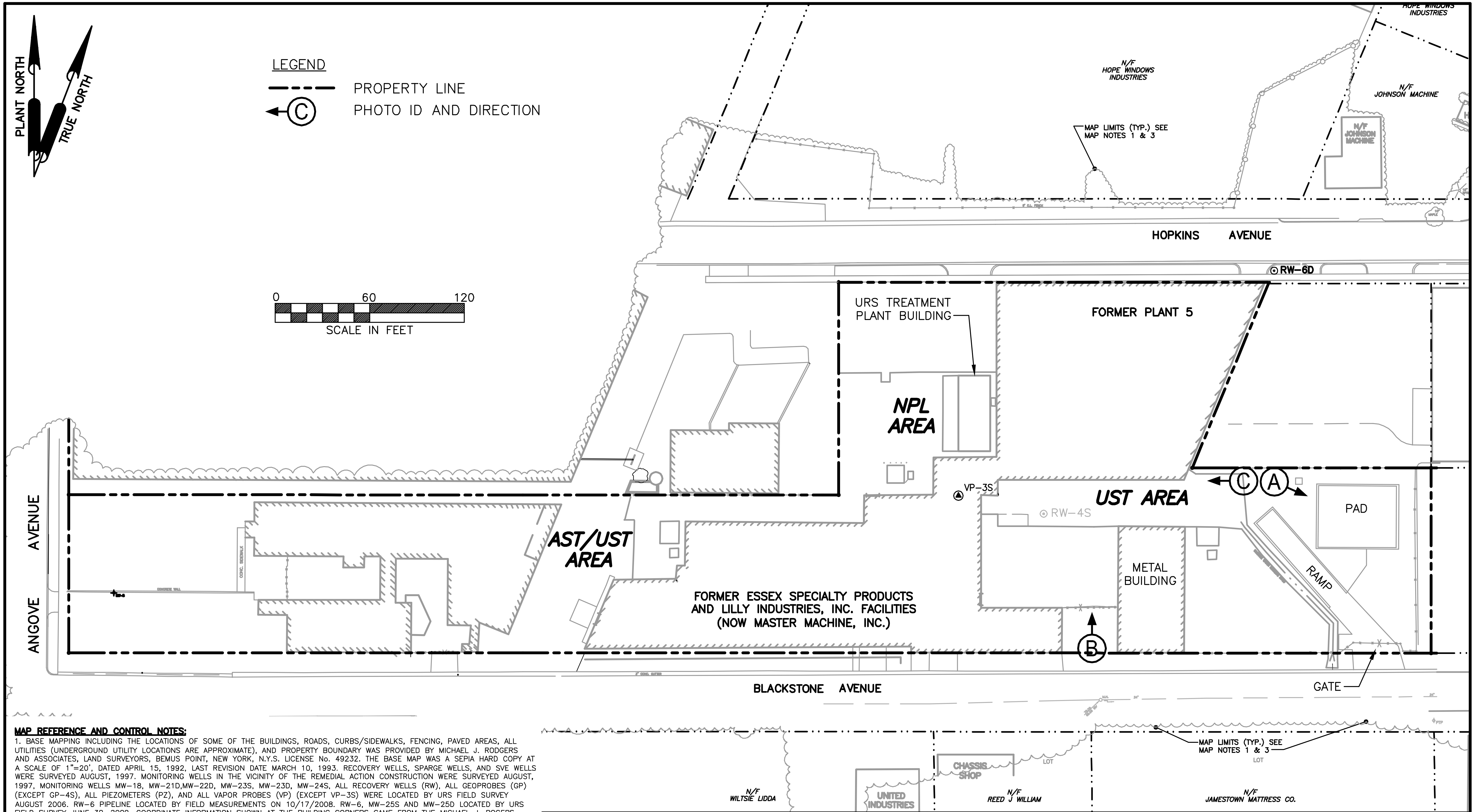

MAP REFERENCE AND CONTROL NOTES:

1. BASE MAPPING INCLUDING THE LOCATIONS OF SOME OF THE BUILDINGS, ROADS, CURBS/SIDEWALKS, FENCING, PAVED AREAS, ALL UTILITIES (UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE), AND PROPERTY BOUNDARY WAS PROVIDED BY MICHAEL J. RODGERS AND ASSOCIATES, LAND SURVEYORS, BEMUS POINT, NEW YORK, N.Y.S. LICENSE No. 49232. THE BASE MAP WAS A SEPIA HARD COPY AT A SCALE OF 1"=20', DATED APRIL 15, 1992, LAST REVISION DATE MARCH 10, 1993. RECOVERY WELLS, SPARGE WELLS, AND SVE WELLS WERE SURVEYED AUGUST, 1997. MONITORING WELLS IN THE VICINITY OF THE REMEDIAL ACTION CONSTRUCTION WERE SURVEYED AUGUST, 1997, MONITORING WELLS MW-18, MW-21D,MW-22D, MW-23S, MW-23D, MW-24S, ALL RECOVERY WELLS (RW), ALL GEOPROBES (GP) (EXCEPT GP-4S), ALL PIEZOMETERS (PZ), AND ALL VAPOR PROBES (VP) (EXCEPT VP-3S) WERE LOCATED BY URS FIELD SURVEY AUGUST 2006. RW-6 PIPELINE LOCATED BY FIELD MEASUREMENTS ON 10/17/2008. RW-6, MW-25S AND MW-25D LOCATED BY URS FIELD SURVEY JUNE 30, 2009. COORDINATE INFORMATION SHOWN AT THE BUILDING CORNERS CAME FROM THE MICHAEL J. ROGERS SURVEY DONE ON JANUARY 9, 1998. ALL OTHER BUILDING CORNERS ARE APPROXIMATE. THE SITE AREA BEYOND THE 1998 SURVEY WAS MAPPED BY URS CORPORATION IN AUGUST 2006. THIS MAPPING USED THE SAME VERTICAL AND HORIZONTAL REFERENCE DATA AS THE PREVIOUS SURVEY. THE MAPPING WAS MERGED WITH THE 1998 DATA TO PRODUCE A COMPOSITE SITE BASE MAP. THE LIMITS OF THE COMPOSITE SURVEY MAP ARE SHOWN ON THE DRAWING. SEE MAP REFERENCE 3.

2. VERTICAL BENCH MARK INFORMATION CAME FROM U.S.G.S. PLAQUE U-88-S.E. ABUTT. ERIE R.R. BRIDGE OVER BUFFALO ST., ELEV.=1296.034 (NATIONAL GEODETIC VERTICAL DATUM, 1929).
HORIZONTAL COORDINATES PROVIDED FOR THE MONITORING WELLS AND THE PROPERTY CORNERS ARE BASED ON A LOCAL GRID ESTABLISHED BY THE SURVEYOR. N10000, E10000 IS A PK NAIL SET IN THE CONCRETE CURB/GUTTER AND IS PART OF THE ORIGINAL TRAVERSE. IRON STAKES WERE SET AT THE PROPERTY CORNERS.

3. AREAS OUTSIDE OF CLOUD LINE: PROPERTY LINES AND MAPPING ADJACENT TO BIGELOW AVENUE, NORTH & SOUTH OF HOPKINS AVENUE & EAST OF BIGELOW AVENUE, AND SOUTH OF BLACKSTONE AVENUE WERE TAKEN FROM A VARIETY OF SOURCES INCLUDING SEPIA MYLAR SITE MAP (SEE REFERENCE 1), USGS 7.5 MINUTE TOPOGRAPHIC MAP – JAMESTOWN, NY, CITY OF JAMESTOWN TAX MAP RECORDS, AND URS FIELD RECONAISSANCE. LOCATIONS AND DIMENSIONS IN THESE AREAS ARE APPROXIMATE.

URS

PITTSBURGH, PENNSYLVANIA

REMEDIAL ACTION WORK PLAN – UST AREA CHEMICAL OXIDATION
GENERAL SITE PLAN

ESSEX/HOPE SITE
JAMESTOWN, NY

CLIENT: ESSEX SPECIALTY PRODUCTS, INC.
JOB NUMBER: 41568097

SCALE: AS SHOWN
FIGURE NUMBER 2-1
REV 0

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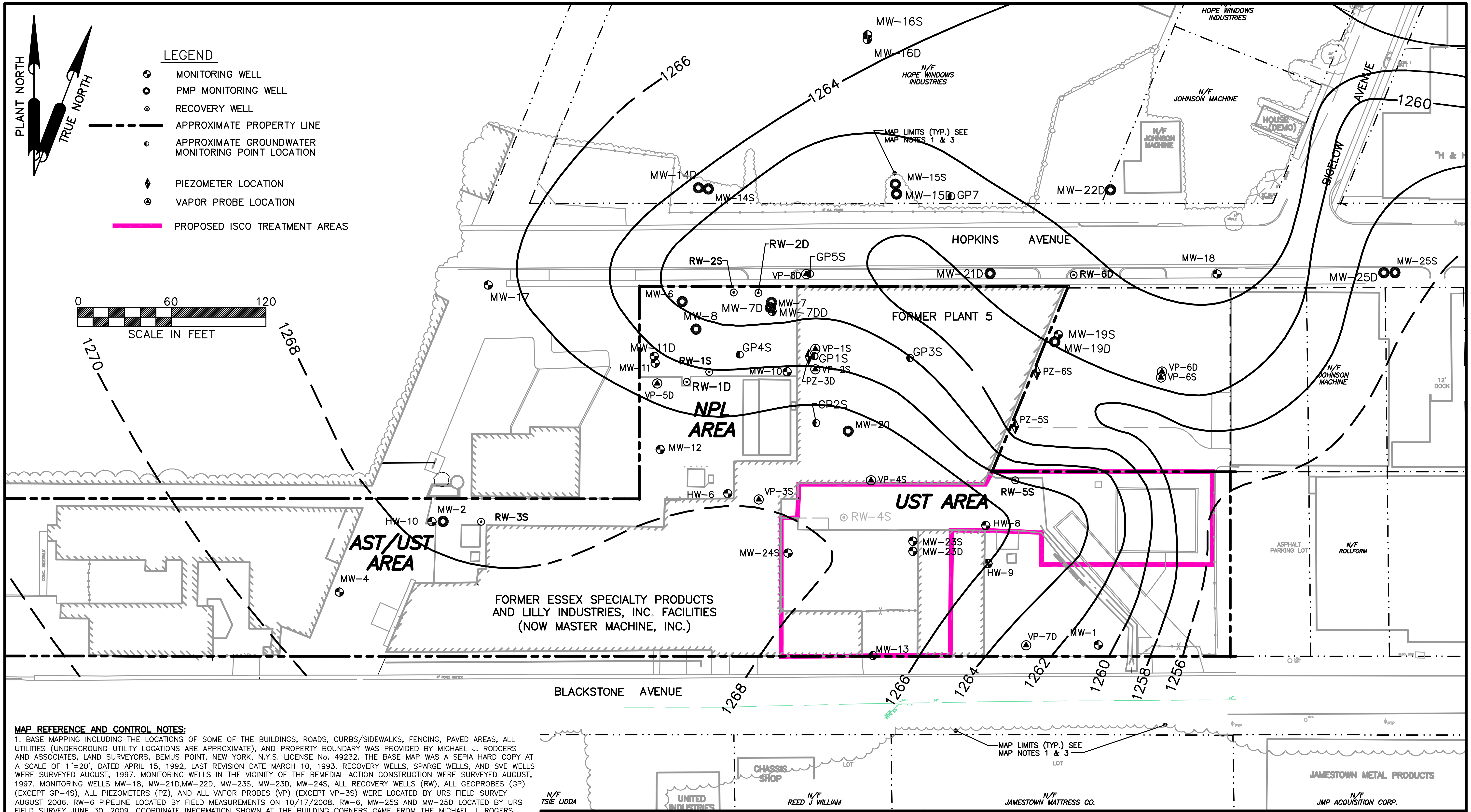
051311KG
051011KG

Photo A- UST Area East

Photo B- UST Area and Plant #5 Bldg from Blackstone Ave- Looking N

Photo C- UST Area at Bldg 5 and Metal Bldg-Looking West



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REMEDIAL ACTION WORK PLAN – UST AREA CHEMICAL OXIDATION
ELEVATION OF UPPER SEMI-CONFINING CLAY LAYER

ESSEX/HOPE SITE JAMESTOWN, NY

CLIENT: ESSEX SPECIALTY PRODUCTS, INC.
JOB NUMBER: 41568097
SCALE: AS SHOWN
FIGURE NUMBER 2-2
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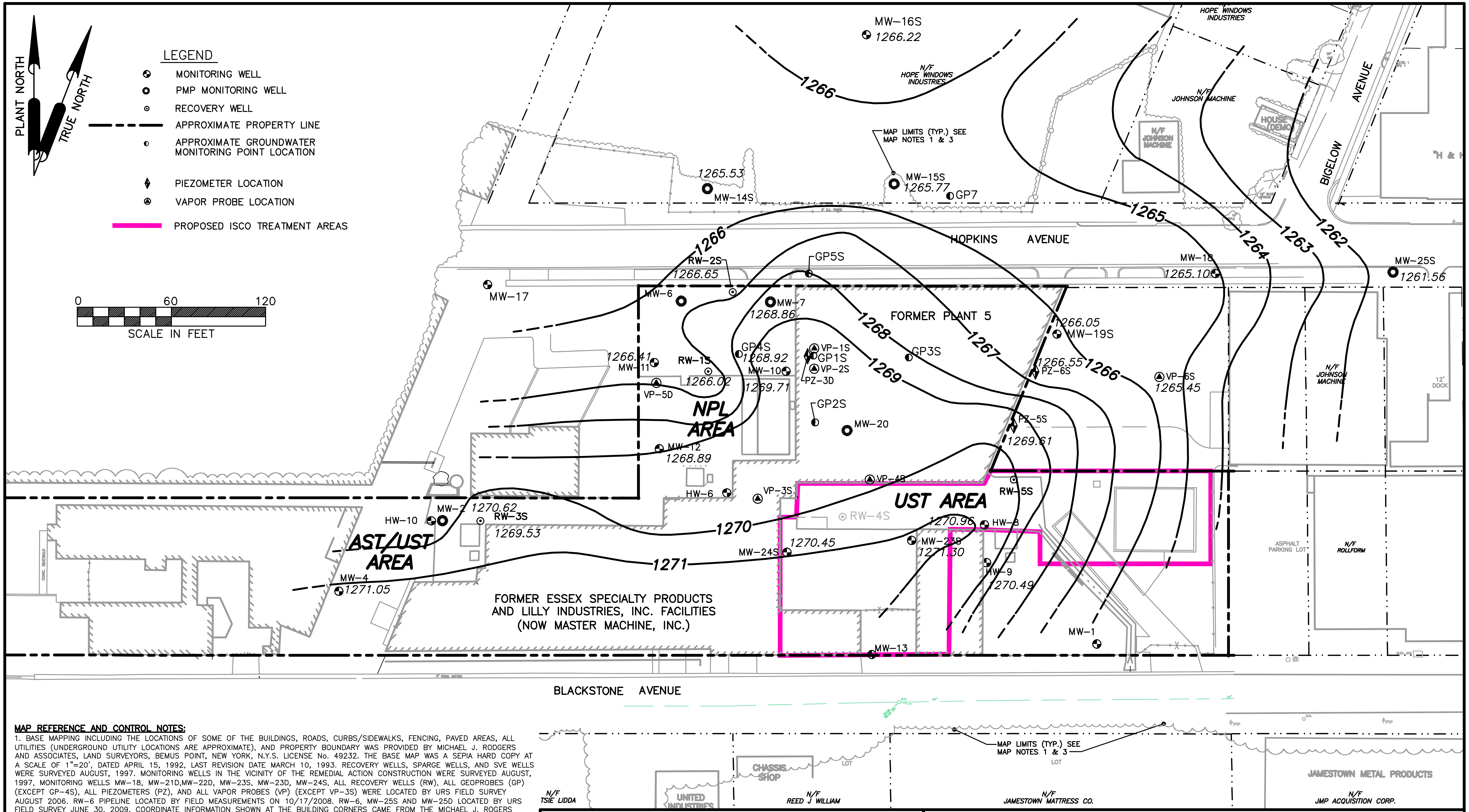

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FILE: \ESSEXHOP\2006-MAP\REM-ACT-WORK-PLAN\2010-A-JUL-2009-PMP-BASE-MAP-REV

URS

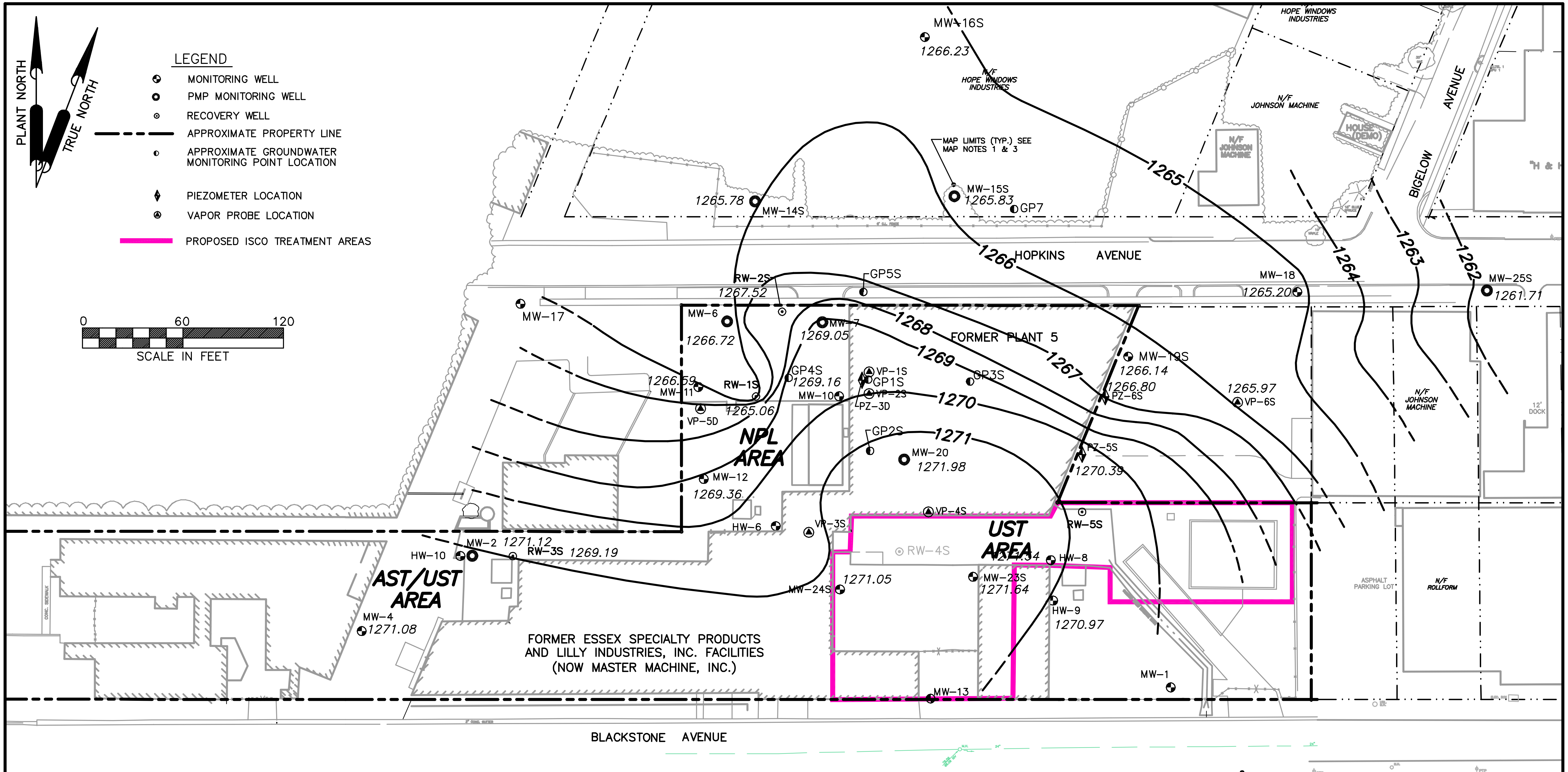
PITTSBURGH, PENNSYLVANIA

REMEDIAL ACTION WORK PLAN – UST AREA CHEMICAL OXIDATION
SHALLOW GROUNDWATER POTENTIOMETRIC SURFACE – JUNE 29, 2010

ESSEX/HOPE SITE
JAMESTOWN, NY

CLIENT: ESSEX SPECIALTY PRODUCTS, INC.
JOB NUMBER: 41568097

SCALE: AS SHOWN
FIGURE NUMBER 2-3
REV 0



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FILE: \ESSEXHOP\2006-MAP\REM-ACT-WORK-PLAN\2010-A-JUL-2009-PMP-BASE-MAP-REV

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PITTSBURGH, PENNSYLVANIA

REMEDIAL ACTION WORK PLAN – UST AREA CHEMICAL OXIDATION
SHALLOW GROUNDWATER POTENTIOMETRIC SURFACE – SEPT. 30, 2010

ESSEX/HOPE SITE
JAMESTOWN, NY

CLIENT: ESSEX SPECIALTY PRODUCTS, INC.
JOB NUMBER: 41568097
SCALE: AS SHOWN
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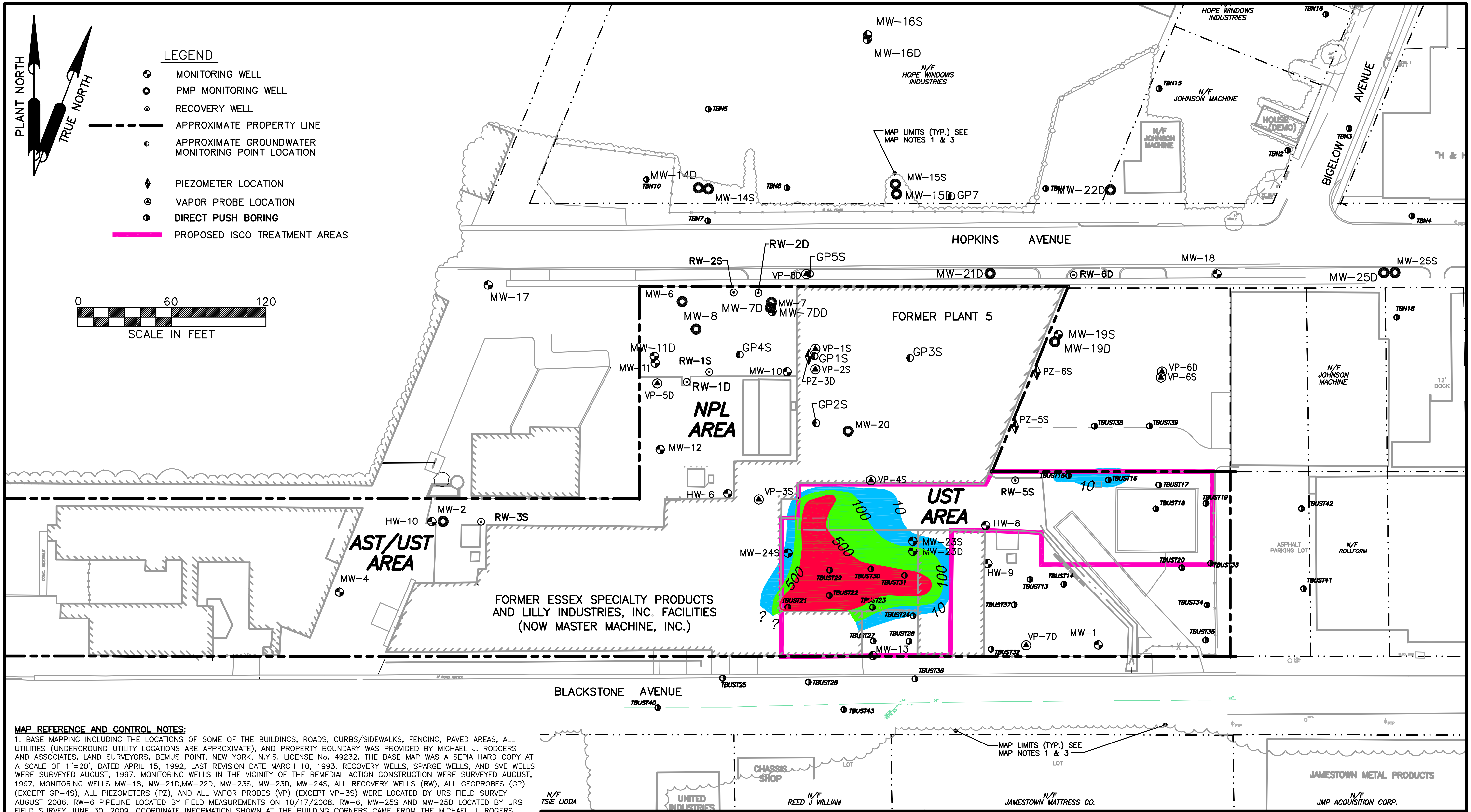
REV 0



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PITTSBURGH, PENNSYLVANIA

REMEDIAL ACTION WORK PLAN – UST AREA CHEMICAL OXIDATION
TOTAL CTEX ISOCONTOURS (PPM) UST AREA – SHALLOW SOILS

ESSEX/HOPE SITE JAMESTOWN, NY

CLIENT: ESSEX SPECIALTY PRODUCTS, INC. JOB NUMBER: 41568097

SCALE: AS SHOWN FIGURE NUMBER 3–1 REV 0

FILE: \ESSEXHOP\2006–MAP\REM–ACT–WORK–PLAN\2010–A–JUL–2009–PMP–BASE–MAP–REV

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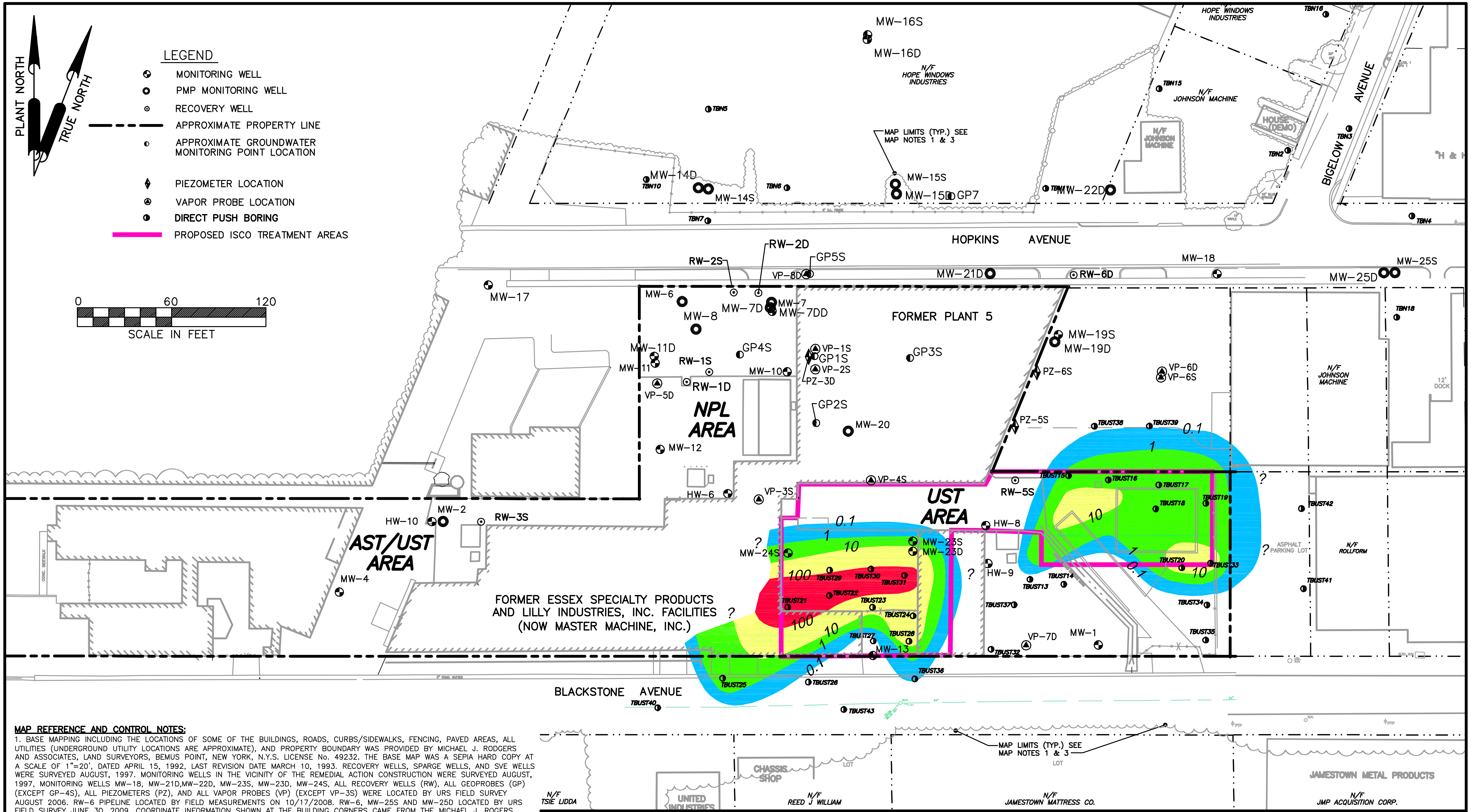

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PITTSBURGH, PENNSYLVANIA

REMEDIAL ACTION WORK PLAN – UST AREA CHEMICAL OXIDATION
TOTAL CTEX ISOCONTOURS (PPM) UST AREA – SHALLOW GROUNDWATER

ESSEX/HOPE SITE JAMESTOWN, NY

CLIENT: ESSEX SPECIALTY PRODUCTS, INC.
JOB NUMBER: 41568097
SCALE: AS SHOWN
FIGURE NUMBER 3–2
REV 0

APPENDIX A-

Site Investigations Summary

Site Investigations Summary of UST Area

Shallow Soil Chemical Analyses- - 2003

Chemical analyses indicates that VOC‘s cumene, toluene, ethylbenzene and xylenes (CTEX) were most frequently detected in the UST Area. Chlorinated VOCs were not detected in the UST Area soil samples. The CTEX compounds were found at levels above the Remedial Action Objectives (RAOs primarily in the western end of the UST Area, around former Tank T1. TBUST-9, approximately 20 feet south of former UST Tank 1, had CTEX levels of approximately 547 ppm, which were the highest levels found in the “unsaturated” test boring samples. The elevated CTEX soil areas generally correlate with the elevated CTEX in shallow groundwater. (See Section 3.2). These elevated CTEX areas are in the historic truck access aprons for chemical deliveries and loading for the former UST Area operations. The area is currently paved with concrete and is used as an access and parking area for the Master Machine Inc. plastic and metal working operations in the building directly west.

Elevated CTEX (>RAOs) was also found further south of the UST Area than had been previously known. TBUST-8 and TBUST-9, approximately 30 feet south of the former USTs, had CTEX levels of 226 and 547 ppm, respectively. It is noted that these samples were taken form a depth at or near the saturated zone and they may be affected by floating contaminants (LNAPL) and smear zone conditions associated with this interval. The southern and southwest extent of the CTEX in the UST Area was not completely determined in this investigation phase. The southwest direction from the UST Area includes the south plant CPM building which is currently leased to Master Machine Inc. These areas are upgradient of the former USTs and they are expected to be minimally affected, if at all. By historic UST Area operations.

Shallow Soil Chemical Analyses- 2005-2006

Continuous soil samples were taken at each UST Area boring, except for Phase II test borings TBUST-37 through TBUST 43. VOC headspace screening was done for all soil samples retrieved from the UST Area test borings. The headspace readings were used to screen samples for offsite lab analyses. Generally, unsaturated zone sample intervals in each boring with the highest readings were selected for confirmatory laboratory analyses.

Shallow soil headspace results indicates that a zone of high VOC's (>100 ppm, by PID) is present primarily in the area directly south of the former USTs T1 and T2, which were the westernmost tanks in the UST Area. In addition, high VOCs were found in test boring TBUST-5, directly south of the former UST T5, on the easternmost end of the UST Area.

Laboratory VOC analyses were performed on soil samples from UST Area test borings TBUST-13 through TBUST-23, TBUST-29, -30, -31 and -34. The samples were taken in the interval of approximately 4-7 ft. BGS. Samples below this depth are expected to be influenced by dissolved VOCs in groundwater and are not representative of unsaturated conditions.

Chemical analyses indicates that the VOC's detected were primarily cumene (isopropylbenzene), toluene, ethylbenzene and xylenes (CTEX). No chlorinated VOCs were detected in the UST Area soil samples. The CTEX compounds comprised 100% of the total VOCs detected in the UST Area soil samples, with the exception of benzene detected in TBUST-23 and acetone found in TBUST-18. CTEX compounds comprised 98.4% of the VOCs detected in these samples. The soils with detectable levels of VOCs all exceeded the Remedial Action Objectives (RAOs), set for individual and total VOCs in soil, 1 and 10 ppm, respectively.

The RAO exceedances are primarily in the western end of the UST Area, directly south of the former USTs. TBUST-21 through -23, and TBUST-29 through -31, approximately 40-60 feet south of the former USTs, had CTEX levels ranging from 403 to 2436 ppm. Soil samples taken in the eastern UST Area, in the vicinity of the former tank pad, had order of magnitude lower CTEX levels than the western UST Area, and most of the soil samples were below detection limits (BDL) for VOCs. The highest CTEX detections were found in TBUST15 and -16, along the north end of the tank pad area. CTEX levels in these samples were 10.1 and 29.4 ppm, respectively. All of the soil samples along the eastern end of the tank pad area were BDL for VOCs. Figure 3-1 depicts the UST Area soil VOC distribution as total CTEX concentrations.

The soil VOC data is generally consistent with previous investigations (2003 and prior) which found that the shallow soils in the UST Area had elevated VOC levels (> RAOs) only near Tanks T1 and T2, on the west end of the UST Area. Detected VOCs included xylenes, ethylbenzene, toluene and cumene. All other shallow soil VOCs taken from the eastern UST Area were below the RAOs for VOCs.

Groundwater Analytical Results

Shallow zone groundwater samples have been taken from the two newer monitoring wells (MW-23S and MW-24S) and seven existing monitoring wells in the UST Area. In 2006, test borings were advanced in the UST Area and adjoining properties for retrieval of shallow groundwater samples by direct-push drilling methods. Groundwater samples were taken from a short screened interval (~ 4 ft. or less) either near the top of the semi-confining layer (average 16 ft. BGS) or the top of the saturated zone (approximately 10-12 ft. BGS).

Consistent with the UST soils analyses, groundwater analyses indicates that the CTEX volatile organics (cumene, toluene, ethylbenzene and xylenes) were the dominant compounds detected in the UST Area. Chlorinated VOCs were found at relatively low levels.

Shallow Groundwater CTEX-2003

The 2003 investigations revealed that the CTEX plume (1 ppm isocontour) was found to extend across the entire UST Area to the former tank farm on the east, north to MW-20 (beneath Plant #5), and to the southwest, at least to new monitoring well MW-24S. The extent of the plume to the southwest and eastern areas of the UST Area was not fully delineated. The CTEX was concentrated in the western area of the UST Area and beneath Plant No. 5 towards monitoring well MW-20. This data is consistent with historical VOC data for the UST Area. Toluene, ethylbenzene, and xylene (TEX) have been found at elevated concentrations (RAOs->5 ppb) at the site only in and around the UST Area. Maximum TEX levels were historically found in the UST Area recovery wells RW-4S and RW-5S, which had toluene levels from 5400 to 6100 μg/l, ethylbenzene levels from 11,000 to 16,000 μg/l and xylene levels from 74,000 to 130,000 μg/l. These recovery wells were demolished as part of the UST removal work.

The CTEX plume was found to be migrating primarily to the north towards MW-20, beneath Plant #5, approximately 50 feet north of the UST Area. Total CTEX at MW-20 was 24,690 ppb, the highest level found in groundwater samples taken in these investigations. The CTEX plume has not migrated significantly to the northeast of the UST Area based on the low concentration of 8.3 ppb found at PZ-5S. The data does indicate that CTEX is present at elevated levels (>10 ppm) in saturated soil samples taken from test borings at the eastern UST Area, TBUST-6 and TBUST-7. Monitoring wells are not present in this area, and the extent of the CTEX directly east of the former tank farm has not been fully determined.

Elevated CTEX (>1 ppm) was also found south and southwest of the UST Area. Monitoring wells MW-23S and MW-24S had total CTEX levels of 2507 ppb and 7674 ppb, respectively. These wells are approximately 30 feet south of the UST Area. The extent of the migration in this direction has also not been determined, although MW-13, near Blackstone Avenue on the south end of the site, had a CTEX level of 7.3 ppb. This result suggests that CTEX has not migrated to the south end of the site near Blackstone Avenue, and it is also not migrating onto the site from the offsite area to the south. Southwest of the UST Area is generally upgradient and includes the CPM south plant building which is currently leased to a small business. Site investigations were not conducted in the south plant building area at that time.

Shallow Groundwater Chlorinated VOCs- 2003

Chlorinated VOCs were found at relatively low levels in the UST Area shallow groundwater compared to the historic levels found in the NPL Area to the north, where the primary source of the chlorinated VOCs was present. CVOCs above RAOs (5ppb) were found generally in the northwestern part of the UST Area (HW-6 and MW-20) and are expected to be associated with the historic NPL Area VOC source. TCE levels in the UST Area shallow groundwater were 110 ug/l or less.

TCE by-products cis-1, 2 DCE and vinyl chloride were found at 2900 ug/l and 1400 ug/l, respectively, at HW-6, which is located in the southern end of the NPL Area, approximately 40 feet from the west end of former UST T1. The only other UST Area well that had vinyl chloride levels above RAOs was MW-20, which had a concentration of 170 ug/l.

Vinyl chloride was not detected in any of the 2003 site investigations in the UST Area. TCE was detected above the RAO level of 5 ppb in only one shallow groundwater sample taken in the Plant #5 East and UST Area Investigations of 2001: RW-4S.

Shallow Groundwater CTEX-2006

Thirty-one (31) test borings were advanced in the onsite UST Area and adjoining properties for retrieval of shallow groundwater samples for VOC analyses.. Groundwater samples were taken from a short screened interval (~ 4 ft. or less) either near the top of the semi-confining layer (approximately 15-20 ft. BGS) or the top of the saturated zone (approximately 10-12 ft. BGS).

The CTEX groundwater plume (1 ppm isocontour) extends across the entire UST Area to the former tank farm to the east, north to MW-20 (beneath Plant #5), and to the southwest, and has been delineated in the recent investigations. The extent of the plume to the southwest and eastern areas of the UST Area has been determined to be offsite onto adjoining properties. The shallow groundwater CTEX distribution is presented on Figure 3-2.

In the western UST Area, the CTEX levels are the highest found at the site and are concentrated approximately 40-60 feet south of the former underground tank area. Total CTEX levels range from 110-167 mg/l in this area. The high concentration (> 100 mg/l) CTEX zone is estimated to be approximately 2500 sf. The extent of the plume to the west, beneath the Master Machine plant, has not been defined since drilling equipment could not access the inside of the building. The groundwater plume mapping suggests that the CTEX plume does extend beneath the Master Machine plant, however, it is not expected to extend much greater than 50 feet beneath the building based on projection of the isocontour lines from adjoining data points. This is further supported by the condition that the Master Machine plant is hydraulically upgradient of the UST Area under both natural shallow groundwater flow and pumping conditions.

To the south of the UST Area, towards Blackstone Avenue (City of Jamestown property), CTEX was found in the road right of way at one location, TBUST-25. Total CTEX at this location was 4.76 mg/l. CTEX was not found south of the road based on samples taken on the south end of the road which were non-detect. It is noted that a sanitary sewer line is present along the center line of Blackstone Avenue. The sewer construction has not been assessed and it is not known if the sewer may act as a drain for shallow groundwater flow in this area, thus affecting local groundwater flow directions. Because the shallow groundwater flow direction is dominantly to the north/northeast, significant migration of VOCs via groundwater to the south of the site is not expected.

To the east, CTEX in shallow groundwater appears offsite to the north and east of the tank pad area on property owned by Johnson Machine and Rollform, Inc. The extent of the CTEX is estimated at approximately 30 feet beyond the property line.

The 2006 data is consistent with historical VOC data for the UST Area. The VOCs detected are the same group as found previously at the site. Toluene, ethylbenzene, and xylene (TEX) have been historically found at elevated concentrations (RAOs->5 ug/l) at the site only in and around the UST Area. Maximum TEX levels detected were in former recovery wells RW-4S and RW-5S, which had toluenes from 5.4 to 6.1 mg/l, ethylbenzenes from 11 to 16 mg/l and xylenes from 74 to 130 mg/l.

APPENDIX B

Chemical Oxidation Treatability Study

Clean, Green, and Sustainable Solutions

S-ISCO® and ISCO
Laboratory Treatability & Dosage Study Report

DOW NY UST Site
155 Blackstone Avenue
Jamestown, NY

Submitted to:	**Submitted by:**
URS Corporation 501 Holiday Drive, Suite 300 Pittsburgh, PA 15220	VeruTEK Technologies, Inc. 65 West Dudley Town Road, Suite 100 Bloomfield, CT 06002

May 26, 2010

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Executive Summary

VeruTEK Technologies, Inc. (VeruTEK) was contracted by URS Corporation (URS) to complete a Surfactant-Enhanced In Situ Chemical Oxidation (S-ISCO®) and In Situ Chemical Oxidation (ISCO) Laboratory Treatability and Dosage Study for treatment of volatile organic compounds (VOCs), impacting the former Essex Specialty Products, Inc. facilities NY UST Site located at 155 Blackstone Avenue, Jamestown, NY. Contaminants of concern (COCs) specifically include (CTEX) cumene (isopropylbenzene), toluene, ethylbenzene, and xylenes. Soil column tests used to simulate field conditions indicate that the S-ISCO® processes tested preformed much better than the ISCO processes. The most effective S-SICO® processes in the soil column tests were S-ISCO® with Fe-EDTA activated persulfate, and S-ISCO® with Fe-TAML catalyzed peroxide resulting in a total of 98%, and 96% reduction of total VOCs, respectively, relative to the control column.

Laboratory tests were conducted to both compare and optimize ISCO and S-ISCO® treatment of VOCs present in Site soil to meet cleanup criteria (RAOs) established by the NYDEC Consent Order for the Site.[1] Treatability results revealed S-ISCO® outperformed ISCO for remedying VOC contamination at this Site, with up to 99% destruction of target compounds to levels below established NYDEC RAOs.

Based on the chemistry of the contaminated soils from the Site and a supplemental surfactant screening test, solubilization enhancement tests were conducted on homogenized Site soil using VeruSOL-3®, a proprietary mixture of USFDA Generally Recognized As Safe (GRAS) plant-based surfactants and co-solvents. Desorption/solubilization enhancement results revealed a controllable, incremental increase in COC solubility with increasing VeruSOL-3® concentrations up to 10 g/L. Solubilization enhancement factors (the ratio of contaminants solubilized from Site soil into the aqueous phase using VeruSOL-3® compared to a water-Site soil mixture alone) of up to 9.4 for total VOCs were achieved using VeruSOL-3® at a concentration of 10 g/L. Specific target compounds isopropylbenzene, toluene, ethylbenzene, m&p-Xylene, and o-Xylene achieved solubilization enhancement factors up to 14.6, 8.1, 26.8, 8.3, and 3.9, respectively, at 10 g/L VeruSOL-3®.

To evaluate the efficacy of the remedy, activated sodium persulfate and catalyzed hydrogen peroxide oxidation tests were carried out using supernatant generated from the solubilization enhancement tests. Oxidation tests verified that contaminants**,** once solubilized with VeruSOL-3®, could subsequently be destroyed in place using either activated persulfate or catalyzed peroxide. After a 14-day reaction period, Fe-TAML catalyzed hydrogen peroxide proved to be the most effective oxidation treatment, with up to 99% destruction of VOCs compared to the control in the emulsion previously generated using Verusol-3® at 10 g/L.

Soil column tests were conducted to more accurately simulate field implementation of the selected treatment processes, and to evaluate the efficiency of COC degradation in contaminated Site soil. Seven columns were packed wet with contaminated soil. One column acted as a control and was treated with only deionized water, while the six remaining columns were treated with three different activator-

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[1] Soil RAOs: Total VOCs = 10 ppm; Individual VOCs = 1 ppm; Total SVOCs = 500 ppm; Individual SVOCs = 50 ppm.

oxidant combinations (Fe-EDTA activated persulfate, alkaline activated persulfate, and Fe-TAML catalyzed peroxide), each applied using both ISCO and S-ISCO® processes. Surfactant and activator-oxidant combinations applied in the soil column tests were selected based on previous desorption/solubilization tests and oxidation tests. The surfactant selected for the S-ISCO® column tests was VeruSOL-3®. Subsequent results exhibited up to 99% destruction of target VOC compounds to levels below established NYDEC RAOs.

Based on the high levels of COC destruction achieved in the Laboratory Treatability and Dosage Study, S-ISCO® is recommended for effective treatment at this Site.

1.0 Introduction

S-ISCO® is a technology platform that incorporates different types of natural surfactants, catalysts, builders, and oxidants to destroy contaminants in place. Using the S-ISCO® technology platform, the chemistry of the coelution mixture is matched with the chemistry of the contaminants to optimize field implementation and lower costs. VeruTEK® has developed proprietary mixtures of USFDA Generally Recognized as Safe (GRAS) plant-based surfactants and cosolvents to increase the mass of target contaminants solubilized from the soil phase, making them significantly more available for oxidative destruction. The Laboratory Treatability and Dosage Study sequentially test the chemistry and the physics (transport properties) of S-ISCO® mixtures to determine the optimum strategy for removal of contaminants in field.

This study compares the efficacy of the ISCO and S-ISCO® processes, incorporating alkaline activated persulfate, Fe-EDTA activated persulfate, and Fe-TAML catalyzed peroxide. Plant-based surfactant mixtures were tested based on the generally non-polar chemistry of the contaminants. The laboratory tests were conducted with five specific objectives defined in the proposal:

1) Characterization of representative Site soil,
2) Evaluation of COC desorption/solubilization and treatment performance of target COCs,
3) Evaluation of the destruction of solubilized target COCs with alkaline activated persulfate, Fe-EDTA activated persulfate, and Fe-TAML catalyzed peroxide,
4) Evaluation of ISCO and S-ISCO® column tests to more accurately simulate the selected treatment processes under simulated field conditions and,
5) Preparation of report summarizing Laboratory Treatability and Dosage Study and results

To achieve the desired project goals, laboratory tests were conducted as follows:

- **Task 1:** Homogenization and partial characterization of Site soil

- **Task SS:** Supplemental solubilization screening tests to determine the most effective surfactant/cosolvent mixture(s) for COC desorption/solubilization.

- **Task 2:** Desorption/solubilization enhancement of target COCs in Site soil with the selected surfactant/cosolvent mixtures(s)

- **Task 3:** Destruction of desorbed/solubilized target COCs in the emulsion phase with S-ISCO®

- **Task 4:** Field simulated soil column tests using ISCO and S-ISCO®

2.0 Experimental Section

2.1 Receipt of Site Materials

On November 12, 2009, two 5-gallon buckets containing approximately 7-10 gallons of contaminated soil arrived at VeruTEK® via direct delivery by Mark Dowiak, P.E., of URS Corporation from the Essex Specialty Products, Inc. facilities NY UST Site located in Jamestown, NY. The buckets, which arrived in good condition with no visible damage, were carefully inspected upon arrival. Soil was contained in black garbage bags inside each bucket. After the inspection and log-in procedures were completed, both buckets were transferred to the laboratory hood and stored until further testing.

2.2 Homogenization and Characterization of Site Soil (Task 1)

Upon arrival, both buckets of soil were homogenized via manual mixing and designated as Soil-1 and Soil-2. Soil-1 contained sample that was gray in color with a very thick, clay-like consistency, and contained many pebbles and stones, both large and small. Core samples of this soil retained their cylindrical shape. Soil-2 was also gray and clay-like, but less thick and core-shaped than Soil-1. This soil also contained many large stones and small rock particles. The clay portion of each soil sample was separated, sampled for VOC analysis, and discarded to facilitate manageability of the soil. It is VeruTEK®'s experience that using clay samples in the column tests prove to be difficult and not representative of field implementation. The narrow columns cause the clay samples act as a block and prevent any effluent from ever passing through the matrix. Therefore, clay is separate from sand, to ensure only sand is used for the column tests. Sand and clay samples were taken in duplicate from each bucket to ensure homogeneity, and sent to Mitkem Laboratories of Warwick, RI (a NELAC accredited third-party analytical laboratory) for VOC and total petroleum hydrocarbon (TPH) analysis.

The analytical instruments and methods used throughout the Laboratory Treatability and Dosage Study are presented in Table 1.

2.3 Supplemental Solubilization Screening Tests (Task SS)

In order to determine the most effective surfactant/cosolvent mixture(s) to treat target contamination at this Site, a small-scale supplemental solubilization screening test was set up using soil from both Soil-1 and Soil-2, respectively. The test consisted of fourteen reactors, where S1-SS-1 through S1-SS-7, contained Soil 1, and S2-SS-1 through S2-SS-7 contained Soil 2. In both sets SS-1 acted as the aqueous control and SS-2 through SS-7 contained one of six different USFDA GRAS surfactant/cosolvent mixtures.

Each reactor consisted of 40 mL deionized (DI) water and 8 g of soil. SS-1 was then injected with 0.4 g DI water, while SS-2 through SS-7 were injected with 0.4 g of one of six USFDA GRAS surfactants. The reactions took place under isothermal conditions at 25°C and were shaken at 120 rpm for 72 hours. At the end of the 72 hour reaction period, samples were set upright on a bench and left to settle for 24

hours. At the end of the 24 hour setting period, process control parameters including interfacial tension (IFT) and TPH were measured in the VeruTEK® R&D laboratory.
Details of the experimental conditions for Task SS are presented in Table 2.

2.4 Solubilization Enhancement of **T**arget COCs from Site Soil with VeruSOL-3® **(Task 2)**

The objective of the desorption/solubilization enhancement tests was to determine the ability of VeruSOL-3®, the most effective surfactant system from the supplemental solubilization tests, to enhance availability of target contaminants in the aqueous phase, and to optimize the dose for field application. Task 2 consisted of five reactors (T2-A through T2-E), all of which had a total volume of 400 mL and contained 100 g of contaminated Site soil from Soil-1. Reactor 2-A acted as the control, containing only soil and DI water. Reactors 2-B, 2-C, 2-D, and 2-E were experimental vessels containing 2.5 g/L, 5 g/L, 10 g/L, and 25 g/L of VeruSOL-3®, respectively.

Solubilization experiments were conducted using a series of 500 mL glass jars, under isothermal conditions at 25°C and constant shaking speed of 120 rpm. The tests were run for 7 days and then left to settle for 24 hours. Photographs were then taken after the 7 day shaking period as well as after 24 hours of settling. At the end of the test, supernatant sample was collected from each reactor and sent to Mitkem Laboratories for VOC and TPH analysis. Other process control parameters, including pH, oxidation-reduction potential (ORP), IFT and turbidity were also measured in the VeruTEK® R&D laboratory.

Details of the experimental conditions for Task 2 are present in Table 3.

2.5 Destruction of Solubilized Target COCs in the Emulsion Phase with S-ISCO® (Task 3)

The goal of Task 3 was to monitor the degradation of desorbed/solubilized contaminants in order to determine the most efficient oxidant/activator system for the S-ISCO® process for application at this Site. Tests were conducted using supernatant samples generated from the preceding desorption/solubilization experiment. Supernatant of 2-D, which had been dosed with 10 g/L VeruSOL-3® and achieved the highest solubilization enhancement factor for VOCs, was used in the oxidation tests. The supernatant contained target COCs emulsified by the VeruSOL-3® and was treated with one of three potential oxidant/activator systems, including alkaline activated persulfate, Ferric Ethylene Diamine Tetra Acetate (Fe-EDTA) activated persulfate, and Fe-TAML catalyzed peroxide.

The oxidation tests were prepared using a series of 500 mL jar reactors under isothermal conditions at 25°C and a constant shaking speed of 120 rpm. Reactor 3-A served as the control and only contained supernatant of T2-D. Reactor 3-B was prepared containing 100 g/L sodium persulfate (SP) and was alkaline activated (pH kept above 12 with NaOH approximately 2.0M). Reactor 3-C contained 100 g/L SP and was activated with Fe-EDTA at 350 mg/L as Fe. Reactor 3-D contained 4% hydrogen peroxide and was activated with 0.1µM Fe-TAML.

After a period of 14 days, the test was terminated and samples were collected and sent to Mitkem Laboratories for analysis of VOCs and TPH. Parameters such as pH, ORP, conductivity, IFT, and turbidity were also measured in the VeruTEK® R&D laboratory on Day 14. VeruTEK® uses these measurements to assess the progress of the specific oxidation reactions for internal laboratory uses.

Details of the experimental conditions for Task 3 are presented in Table 4.

2.6 Field simulated soil column tests using ISCO and S-ISCO® (Task 4)

Soil column treatability tests were conducted in order to simulate field implementation on a laboratory scale, using homogenized Site soil. The oxidants selected for destruction of the solubilized compounds were alkaline activated persulfate, Fe-EDTA activated persulfate, and Fe-TAML catalyzed hydrogen peroxide, each applied using both ISCO and S-ISCO® processes. Based on the previous tests conducted by VeruTEK®, VeruSOL-3® was chosen as the optimal surfactant for contaminated Site soil in the S-ISCO® treated columns.

Seven identical columns were prepared using homogenized soil representative of all three components of soil characterized in Task 1 (mix of clay sample and Soil-1 and Soil-2). A layer of glass wool was placed in the bottom of each column, over the bottom screen, followed by a small layer of glass beads to retain the soil in the columns. Homogenized soil was then packed wet with deionized (DI) water into each column. Another layer of glass wool was placed on top of the full column, followed by a small layer of glass beads. The columns were then capped and tubing was attached. Column T4-A had one influent source and one effluent source, while the other six columns had two influent sources and one effluent source. The ISCO treated columns used one influent source to deliver the oxidant and one to deliver the activator; the S-ISCO® treated columns used one influent to deliver the oxidant and one to deliver the activator mixed with VeruSOL-3®.

Column T4-A acted as the control and had an influent of only DI water. Columns T4-B, T4-D and T4-F were ISCO treated, while columns T4-C, T4-E and T4-G were S-ISCO® treated with the same oxidant/activator combinations as the corresponding ISCO columns and an additional influent of 10 g/L VeruSOL-3®. Columns T4-B and T4-C were treated with 100 g/L sodium persulfate activated with Fe-EDTA at 350 mg/L as Fe. Columns T4-D and T4-E were treated with 100 g/L sodium persulfate, alkaline activated with sodium hydroxide (pH maintained above 12). Columns T4-F and T4-G were treated with 4% hydrogen peroxide activated with Fe-TAML at 0.1 µM.

The control column and columns treated with persulfate were treated for a period of twenty eight days, while the two columns treated with peroxide were run for fourteen days. For the columns treated with persulfate, Day 1 started after one pore volume (PV) was collected (12 hours). Column effluents were sampled after PV1, Day 14, and Day 28, and sent to Mitkem Laboratories for VOC and TPH analysis. Parameters including pH, ORP, conductivity, IFT, turbidity, sodium persulfate (SP) and TPH were measured on Day 1, Day 3, day 5, Day 7, Day 14, and Day 28 in the VeruTEK® R&D laboratory. After a period of 28 days, the columns were sacrificed. Soil from each column was homogenized and sent to

Mitkem Laboratories for COC analysis. For the columns treated with peroxide, Day 1 began after one pore volume (PV) was collected (12 hours). Column effluents were sampled after PV1 and Day 14 and sent to Mitkem Laboratories for VOC and TPH analysis. Parameters were not routinely measured in the soil columns containing peroxide due to complications with backpressure and effluent run time and volume, but the presence of peroxide and pH monitoring in the effluent was confirmed throughout the 14-day reaction period. After a period of 14 days, the columns were sacrificed. Soil from each column was homogenized and sent to Mitkem Laboratories for COC analysis.

Details of the experimental conditions for Task 4 are presented in Table 5.

3.0 Results and Discussion

3.1 Homogenization and Characterization of Site Soil (Task 1)

The homogenized composite soils (Soil-1 and Soil-2) and a clay sample were sent to Mitkem Laboratories for initial characterization analysis. Results indicate that contaminants of concern (COCs) consisted of several VOCs and VOC tentatively identified compounds (TICs), as well as TPH comprised of diesel range organics (DRO) and gasoline range organics (GRO).

Soil-1 had a total VOC concentration of 28.6 mg/kg and a total VOC TICs concentration of 21.7 mg/kg). Target VOC ethylbenzene had a concentration of 1.1 mg/kg; m&p-Xylene had a concentration of 15.0 mg/kg; o-Xylene had a concentration of 4.6 mg/kg; Isopropylbenzene had a concentration of 0.50 mg/kg; Toluene had a concentration of 0.94 mg/kg. The total TPH concentration in Soil-1 was 149 mg/kg (GRO = 8.7 mg/kg; DRO = 140 mg/kg).

Soil-2 had a total VOC concentration of 41.1 mg/kg and a total VOC TICs concentration of 17.5 mg/kg. Target VOC ethylbenzene had a concentration of 7.9 mg/kg; m&p-Xylene had a concentration of 18.0 mg/kg; o-Xylene had a concentration of 10.0 mg/kg; Isopropylbenzene had a concentration of 0.61 mg/kg; Toluene had a concentration of 0.98 mg/kg. The total TPH concentration in Soil-2 was 310 mg/kg (GRO = 80 mg/kg; DRO = 230 mg/kg).

The clay sample had a total VOC concentration of 328.7 mg/kg and a total VOC TICs concentration of 70.8 mg/kg. Target VOC ethylbenzene had a concentration of 12.0 mg/kg; m&p-Xylene had a concentration of 210 mg/kg; o-Xylene had a concentration of 53.0 mg/kg; Isopropylbenzene had a concentration of 3.8 mg/kg; Toluene had a concentration of 7.8 mg/kg. The total TPH concentration in the clay sample was 3,030 mg/kg (GRO = 930 mg/kg; DRO = 2,100 mg/kg).

Analytical results from Task 1 Initial Characterization are presented in Table 6.

3.2 Supplemental Solubilization Screening Tests (Task SS)

The goal of the supplemental solubilization screening tests was to determine the most effective surfactant for desorption/solubilization of target contaminants at this Site. Seven reactors were set up for both Soil-1 and Soil-2, which consisted of one aqueous control and six experimental reactors, each containing one of six different USFDA GRAS surfactants. The IFT and TPH was measured in-house at the VeruTEK® R&D Laboratory after a 72 hour shaking period and subsequent 24 hour settling period for each reactor. TPH measurements were all detected below the reporting limit (BRL) for both GRO (<25 mg/L) and DRO (<5.0 mg/L). Surfactant/cosolvent blends were selected based upon IFT values and visual inspection of a complete emulsion. VeruSOL-3® was selected based on visual examination of the emulsion and its low IFT value of 33.3 mN/m and 36.7 mN/m for Soil-1 and Soil-2, respectively. Previous successful laboratory studies and field work performed by VeruTEK® using VeruSOL-3® for treatment of VOC contaminants also supported its use for subsequent tests in this Study.

Results from Task SS supplemental solubilization are presented in Table 7.

3.3 Solubilization Enhancement of **T**arget COCs from Site Soil with VeruSOL-3® **(Task 2)**

Task 2 was conducted to optimize the surfactant/cosolvent dose for desportion/solubilization enhancement of contaminants from the Site soils. As described previously, reactors 2-B, 2-C, 2-D, and 2-E contained VeruSOL-3® at concentrations of 2.5 g/L, 5 g/L, 10 g/L, and 25 g/L, respectively. The control reactor 2-A did not contain VeruSOL-3® and had a total VOC concentration of 14.6 mg/L and a total TPH concentration of 16.2 mg/L. Reactors 2-B, 2-C, 2-D, and 2-E had total VOC concentrations of 20.0 mg/L, 11.8 mg/L, 137 mg/L, and 84.7 mg/L, respectively and TPH concentrations of 170 mg/L, 706 mg/L, 3,480 mg/L, and 13,100 mg/L, respectively. VOC TICs were measured in only reactors 2-C, 2-D, and 2-E and had concentrations of 70.0 mg/L, 1,136 mg/L, and 2,327 mg/L, respectively. Target VOCs also exhibited increasing desorption/solubilization with increasing VeruSOL-3® concentrations up to 10 g/L.

Process control parameters were monitored as standard VeruTEK® protocol. Results demonstrated that VeruSOL-3® has minimal, or no effect on pH, ORP, or conductivity. However, as expected the interfacial tension (IFT) was lower in the presence of VeruSOL-3® than in the aqueous control.

Overall, results revealed a controllable, incremental increase in COC solubility with increasing VeruSOL-3® concentrations up to 10 g/L, and successfully demonstrated the ability of VeruSOL-3® to enhance solubilization of residual contamination in the homogenized soil. Solubilization enhancement factors of up to 9.4 for total VOCs and 218 for TPH were achieved using VeruSOL-3® at a concentration of 10 g/L. In other words, there were 9.4 times greater VOC concentrations and 218 times greater TPH concentrations present in the samples containing 10 g/L VeruSOL-3® than in the control sample containing deionized water only. At the same concentration of 10 g/L, specific target compounds isopropylbenzene, toluene, ethylbenzene, m&p-Xylene, and o-Xylene achieved incremental increases in solubilization enhancement factors up to 14.6, 8.1, 26.8, 8.3, and 3.9, respectively.

Analytical results from Task 2 Solubilization Enhancement are presented in Table 8, and Figures 1a, 1b, and 1c.

3.4 Destruction of Solubilized Target COCs in the Emulsion Phase with S-ISCO® (Task 3)

Three oxidants were compared in Task 3 for the oxidative destruction of solubilized target VOCs and TPH including: alkaline activated persulfate, Fe-EDTA activated persulfate, and Fe-TAML catalyzed peroxide. The oxidation tests were carried out on the supernatant from Task 2D, which contained contaminants solubilized by VeruSOL-3® at 10 g/L.

The results of the Task 3 oxidation tests indicate that S-ISCO® treatment is highly effective in destroying the desorbed/solubilized target VOCs and TPH originally present in the soils. At the end of the 14-day reaction period, the control reactor (3-A) which contained only supernatant from 2-D, had a total VOC concentration of 12.9 mg/L and a total TPH concentration of 2153 mg/L. Target VOCs: m&p-Xylene had a concentration of 9.2 mg/L and o-Xylene had a concentration of 2.6 mg/L. Target VOCs ethylbenzene, isopropylbenzene, and toluene were all detected below the reporting limit (<1,000 µg/L).

Reactor 3-B, treated with alkaline activated sodium persulfate, had a total VOC concentration of 0.18 mg/L and a total TPH concentration of 1,033 mg/L, exhibiting a 99% decrease in VOCs compared to the control and a 52% decrease in TPH contamination compared to the control. Target VOC m&p-Xylene had a concentration of 0.182 mg/L; target VOCs ethylbenzene, o-Xylene, isopropylbenzene, and toluene were all detected below the reporting limit (<50 µg/L).

Reactor 3-C, treated with Fe-EDTA activated sodium persulfate, had a final VOC concentration of BRL (<0.1) mg/L and a final TPH concentration of 171 ppm, exhibiting a >99% decrease in VOCs relative to the control, and a 92% decrease in TPH contamination compared to the control. All target VOCs were detected BRL (<100 µg/L), and the only source of VOC contamination came from acetone, a common laboratory contaminant.

Reactor 3-D, treated with Fe-TAML activated hydrogen peroxide, had a total VOC concentration BRL (<0.01) mg/L and a final TPH concentration of 453 mg/L, resulting in a >99% decrease in VOCs compared to the control and a 79% decrease in TPH contamination compared to the control, following the oxidation treatment. All target VOCs were detected BRL (<10 µg/L).

The high concentrations (>100 mg/L) of TPH present in the Task 3 samples is likely due to the residual presence of VeruSOL-3® in the reactors. VeruSOL® is made up of plant oils which are known to cause a false positive measurement in TPH DRO and GRO readings. Although VeruSOL-3® is oxidized over time along with target contaminants, its residual presence has been previously observed to disrupt TPH measurements in bench-scale tests.

Analytical results from Task 3 are presented in Table 9 and Figure 2a, 2b, and 2c.

3.5 Field simulated soil column tests using ISCO and S-ISCO® (Task 4)

The column experiments consisted of a control column (4-A), an Fe-EDTA activated persulfate treated column, an alkaline activated persulfate treated column, and an Fe-TAML catalyzed hydrogen peroxide treated column, each applied both in the absence and presence of VeruSOL-3®. Water quality parameters for the effluents were measured throughout the reaction period in the laboratory as standard VeruTEK® protocol. Parameters including pH, SP and hydrogen peroxide were monitored in the column effluents to ensure the chemicals were flowing through the entire column.

After a period of 28 days, the control soil column and each of the four soil columns treated with persulfate were sacrificed, homogenized separately, and samples were sent to Mitkem Laboratories for analysis. After a period of 14 days, the two columns treated with peroxide were sacrificed, homogenized separately, and samples were sent to Mitkem Laboratories for analysis.

The control column (4-A) had a final VOC concentration of 284 mg/kg and a final TPH concentration of 1,640 ppm. Target VOC ethylbenzene had a final concentration of 21.0 mg/kg; m&p-Xylene had a concentration of 190 mg/kg; o-Xylene had a concentration of 42 mg/kg; isopropylbenzene had a concentration of 4.4 mg/kg; and toluene was detected BRL (<9,700 µg/kg).

The final VOC concentration in the soil after treatment with ISCO Fe-EDTA activated persulfate was 66.2 mg/kg in the ISCO column (4-B) and 6.4 mg/kg in the S-ISCO® column (4-C). For the ISCO column (4-B), target VOC ethylbenzene had a concentration of 2.7 mg/kg; m&p-Xylene had a concentration of 33.0 mg/kg; o-Xylene had a concentration of 6.4 mg/kg; isopropylbenzene had a concentration of 1.9 mg/kg; and toluene had a concentration of 1.4 mg/kg. Comparatively, the S-ISCO® column, with Fe-EDTA activated persulfate, (4-C), target VOC m&p-Xylene had a concentration of 2.8 mg/kg. The other target VOCs were detected BRL (<3,900 µg/kg). The final TPH concentration in the ISCO treated column was 700 mg/L, and the final TPH concentration in the S-ISCO® treated column was 9,300 mg/L. In comparison to the final concentration in the control column, there was a 77% decrease of VOCs in the ISCO column and a 98% decrease of VOCs and in the S-ISCO® column. Although a 57% decrease in TPH was observed in the ISCO column, the S-ISCO® column showed a significant increase in TPH compared to the control. This discrepancy, however, was most likely due to the interference of VeruSOL-3® in the TPH analysis. Previous experience with Mitkem Laboratories analysis has proven that components of VeruSOL-3® are detected by GC Method 8015B. Since these columns were not flushed with water at the end of the reaction period, it is likely that VeruSOL-3® was still present in the soil upon analysis.

The final VOC concentration in the soil after treatment with ISCO alkaline activated sodium persulfate was 228 mg/kg in the ISCO column (4-D) and 147 mg/kg in the S-ISCO® column with alkaline activated persulfate (4-E). For the ISCO column (4-B), target VOC ethylbenzene had a concentration of 14.0 mg/kg; m&p-Xylene had a concentration of 150 mg/kg; o-Xylene had a concentration of 35.0 mg/kg; isopropylbenzene had a concentration of 3.9 mg/kg; and toluene was detected BRL (<9,400 µg/kg). Comparatively, the S-ISCO® column (4-C), target VOC ethylbenzene had a concentration of 9.6 mg/kg; m&p-Xylene had a concentration of 94.0 mg/kg; o-Xylene had a concentration of 23.0 mg/kg; isopropyltoluene had a concentration of 2.3 mg/kg, and toluene had a concentration of 1.3 mg/kg. The final TPH concentration in the ISCO column was 700 mg/L, and the final TPH concentration in the S-ISCO® treated column was 1,670 mg/L. In comparison to the final concentration of the control column, there was and 20% decrease of VOCs in the ISCO column and a 48% decrease of VOCs in the S-ISCO® column. Similar to the previous set of columns, a 57% decrease in TPH was observed in the ISCO column, but the S-ISCO® column showed a slight increase in TPH. This again was most likely due to interference of VeruSOL-3® in the TPH analysis.

The final VOC concentration in the soil after treatment with ISCO Fe-TAML catalyzed hydrogen peroxide was 430.1 mg/kg in the ISCO column (4-D) and 10.5 mg/kg in the S-ISCO® column with Fe-TAML catalyzed peroxide (4-E). For the ISCO column (4-B), target VOC ethylbenzene had a concentration of 12.0 mg/kg; m&p-Xylene had a concentration of 270 mg/kg; o-Xylene had a concentration of 70.0 mg/kg; isopropylbenzene had a concentration of 13.0 mg/kg; and toluene had a concentration of 3.6 mg/kg. Comparatively, the S-ISCO® column (4-C), target VOC ethylbenzene had a concentration of 0.53

mg/kg; m&p-Xylene had a concentration of 5.8 mg/kg; o-Xylene had a concentration of 1.5 mg/kg; isopropyltoluene had a concentration of 0.23 mg/kg, and toluene had a concentration of 0.17 mg/kg. The final TPH concentration in the columns was not measured by Mitkem Laboratories due to accidental loss of sample. In comparison to the final concentration of the control column, there was no decrease of VOCs in the ISCO column and a 96% decrease of VOCs in the S-ISCO® column.

Overall, soil columns treated with ISCO and S-ISCO® exhibited decreased levels of VOCs than the control column, with the exception of the ISCO column treated with Fe-TAML catalyzed hydrogen peroxide. This exception is likely due to the fact that this column was run for 14 days only—without the aid of a surfactant/cosolvent like VeruSOL-3® to increase VOC destruction efficiency, 14 days is not enough time to see any significant decrease in VOC concentration. In every ISCO and S-ISCO® column, S-ISCO® outperformed ISCO in total VOC destruction. Two soil columns, S-ISCO® with Fe-EDTA activated persulfate and S-ISCO® with Fe-TAML catalyzed peroxide, were able to achieve VOC concentrations that met cleanup criteria for total VOCs (>10 mg/L). A few select individual VOCs remained above the cleanup criteria (<1.0 ppm), but based on the short-term reaction period (14 or 28 days) for these columns, these results suggest that further destruction of VOCs can be achieved in the field to meet cleanup criteria standards for soil and groundwater.

Analytical results from Task 4 are presented in Table 10 and Figure 2a, 2b, and 2c.

4.0 Conclusion

The purpose of the Laboratory Treatability and Dosage Study was to compare and optimize ISCO and S-ISCO® treatment of VOCs present in Site soil in order to meet cleanup criteria (RAOs) established by the NYDEC Consent Order. Soil column tests used to simulate field conditions indicate that the S-ISCO® processes tested preformed much better than the ISCO processes. The most effective S-SICO® processes in the soil column tests were S-ISCO® with Fe-EDTA activated persulfate, and S-ISCO® with Fe-TAML catalyzed peroxide resulting in a total of 98%, and 96% reduction of total VOCs, respectively, relative to the control column.

To achieve this goal, desorption/solubilization enhancement tests were conducted using VeruSOL-3®, a proprietary mixture of USFDA GRAS plant-based surfactants and cosolvents, to facilitate desorption and dissolution of target contamination in the Site soils. Oxidation tests were subsequently conducted using activator/oxidant systems including: Fe-EDTA activated persulfate, alkaline activated persulfate, and Fe-TAML activated hydrogen peroxide to destroy solubilized contamination in the soil. Finally, soil column tests treated with ISCO and S-ISCO® were run in order to simulate treatment effectiveness expected during field implementation of this technology. Results from the study illustrated the advantage of S-ISCO® technology, and demonstrated its effectiveness in reducing COCs below RAO levels in the Site soil. Conclusions based on the results obtained from this study are as follows:

- Homogenization and characterization of the composite Site soil indicate the presence of several volatile organic compounds (VOCs), as well as total petroleum hydrocarbons made up of diesel range organics (DRO) and gasoline range organics (GRO).

- Desorption/Solubilization enhancement test results indicate that VeruSOL-3® was the most efficient for desorption of contaminants present in the Site soils. Solubilization enhancement factors indicate that the solubility of VOCs is up to 9.4 times greater at a VeruSOL-3® concentration of 10 g/L than with water alone. The results confirm that VeruSOL-3® at 10 g/L is an optimal choice for the S-ISCO® process for successful implementation at this Site.

- Activated persulfate and peroxide oxidation tests indicate that contamination can be efficiently oxidized in the emulsion phase. Compared to the control reactor, the S-ISCO® process reduced VOC contamination by 99% using alkaline activated persulfate, >99% using Fe-EDTA activated persulfate, and >99% using Fe-TAML activated hydrogen peroxide. TPH contamination was decreased by 52% using alkaline activated persulfate, 92% using Fe-EDTA activate persulfate, and 79% using Fe-TAML activated hydrogen peroxide. Overall, the oxidation test results indicate that S-ISCO® can achieve the highest degree of contamination destruction.

- Soil column tests demonstrated the effectiveness of using the S-ISCO® process for the efficient treatment of contamination at this site. Based on the results, the most effective method was determined to be Fe-EDTA activated sodium persulfate, which resulted in a 98% decrease of VOCs over a period of 14 days, relative to the control. These results indicate that the S-ISCO® process is effective and is recommended for treating contamination at this Site.

Tables

Table 1 – Analytical Instruments and Methods

Testing Procedures			
Parameters	**Instruments**	**Analysis methods**	**Conducted By**
pH, Conductivity	Accumet Model 25 pH/ORP meter and Denver Instrument AP 50 pH/Ion/Conductivity Meter	Solution pH (4500-H+in Standard Methods for the Examination of Water and Wastewater (1995); Soil pH (SW 846 Method 9045C)	VeruTEK®
Oxidation Reduction Potential (ORP)	Orion Model 810 ORP meter/platinum combination electrode	Standard methods for water and soil	VeruTEK®
Interfacial Tension (IFT)	SITA Dynotester/bubble pressure tensiometer	Standard methods for water and soil	VeruTEK®
Sodium Persulfate	Spectronic Genesys 5 Spectrophotometer	Colorimetric method	VeruTEK®
VOCs and SVOCs	Gas Chromatography/Mass Spectrometry	SW-846 Method 8260B and Method 8270C/8270Sim for soil; Methods 624 and 625 for liquid	Mitkem Laboratories
TPH	Sitelab Spectrophotometer	Sitelab colormetric method / GC Extractable Products Method 8100	VeruTEK®/ Mitkem Laboratories

Table 2 – Supplemental Solubilization Protocol (Task SS)

TASK SS: URS-DOW - S1 (Bucket 1 of 2)

Task SS: Supplemental Solubilization										
Task	**Test Conditions**	**Surfactant**	**Total Volume (mL)**	**Soil Added (g)**	**Water : Soil ratio**	**Reaction Media**	**Surfactant Added (g)**	**Surfactant (g/L)**	**Water Quality Parameters**	**Contaminants of Concern (COC)**
S1-SS-1	Aqueous Control	None	40	8.0	5 to 1	Deionized water	0	10	IFT	TPH
S1-SS-2	Solubilization	VeruSOL-3	40	8.0	5 to 1	Surfactant dosed water	0.4	10	IFT	TPH
S1-SS-3	Solubilization	VeruSOL-10	40	8.0	5 to 1	Surfactant dosed water	0.4	10	IFT	TPH
S1-SS-4	Solubilization	VeruSOL-11	40	8.0	5 to 1	Surfactant dosed water	0.4	10	IFT	TPH
S1-SS-5	Solubilization	VeruSOL-12	40	8.0	5 to 1	Surfactant dosed water	0.4	10	IFT	TPH
S1-SS-6	Solubilization	X1	40	8.0	5 to 1	Surfactant dosed water	0.4	10	IFT	TPH
S1-SS-7	Solubilization	X2	40	8.0	5 to 1	Surfactant dosed water	0.4	10	IFT	TPH

TASK SS: URS-DOW - S2 (Bucket 2 of 2)

Task SS: Supplemental Solubilization										
Task	**Test Conditions**	**Surfactant**	**Total Volume (mL)**	**Soil Added (g)**	**Water : Soil ratio**	**Reaction Media**	**Surfactant Added (g)**	**Surfactant (g/L)**	**Water Quality Parameters**	**Contaminants of Concern (COC)**
S2-SS-1	Aqueous Control	None	40	8.0	5 to 1	Deionized water	0.4	10	IFT	TPH
S2-SS-2	Solubilization	VeruSOL-3	40	8.0	5 to 1	Surfactant dosed water	0.4	10	IFT	TPH
S2-SS-3	Solubilization	VeruSOL-10	40	8.0	5 to 1	Surfactant dosed water	0.4	10	IFT	TPH
S2-SS-4	Solubilization	VeruSOL-11	40	8.0	5 to 1	Surfactant dosed water	0.4	10	IFT	TPH
S2-SS-5	Solubilization	VeruSOL-12	40	8.0	5 to 1	Surfactant dosed water	0.4	10	IFT	TPH
S2-SS-6	Solubilization	X1	40	8.0	5 to 1	Surfactant dosed water	0.4	10	IFT	TPH
S2-SS-7	Solubilization	X2	40	8.0	5 to 1	Surfactant dosed water	0.4	10	IFT	TPH

Table 3 – Solubilization Enhancement Protocol (Task 2)

Task 2: Soil Desorption/Solubilization Enhancement with VeruSOL-3 Protocol								
Task	**Test Conditions**	**Cosolvent/ Surfactant**	**Volume DI Water Added (mL)**	**Mass Soil Added (g)**	**Cosolvent/ Surfactant (g/L)**	**Contaminants of Concern (COCs)**	**Cosolvent/ Surfactant Parameters (CSP)[3]**	**Water Quality Parameters (WQPs)**
2-A	Aqueous Control	None	400	100	0	VOCs, SVOCs, TPH	IFT	pH, ORP, IFT, Temp, Turb
2-B	Solubilization	VeruSOL-3®	400	100	2.5	VOCs, SVOCs, TPH	IFT	pH, ORP, IFT, Temp, Turb
2-C	Solubilization	VeruSOL-3®	400	100	5	VOCs, SVOCs, TPH	IFT	pH, ORP, IFT, Temp, Turb
2-D	Solubilization	VeruSOL-3®	400	100	10	VOCs, SVOCs, TPH	IFT	pH, ORP, IFT, Temp, Turb
2-E	Solubilization	VeruSOL-3®	400	100	25	VOCs, SVOCs, TPH	IFT	pH, ORP, IFT, Temp, Turb

Notes:

1. Experiments will be run at 120 rpm at 25 °C for 7 days. Following this will be a 24 hour settling period.
2. Photographs taken immediately after7 day shaking and also after 24 hour settling.
3. After 24 hour settling, supernatant samples sent to Mitkem Laboratories and also analyzed by VeruTEK.
4. Mitkem laboratories does TPH, VOC and SVOC. VeruTEK additionally performs GRO/DRO TPH.
5. Plots will be made of COCs versus VeruSOL dose.

Table 4 – Destruction of Solubilized Target COCs in the Emulsion Phase (Task 3)

Task 3: Dissolution/Oxidation of Desorbed COCs using S-ISCO®										
Task ID	**Test Conditions**	**Total Solution Volume (mL)**	**Reaction Media**	**Oxidant**	**Oxidant/Activator Concentrations**	**COCs**	**Monitored Parameters**	**Cosolvent/ Surfactant Parameters (CSP)**	**COCs Sampling Frequency**	**Monitored Parameters Sampling Frequency**
3-A	Control	500	Supernatant from Task 2D with VeruSOL-3	None	None	TPH, VOCs, SVOCs	pH, Conductivity	IFT	Day 14	Daily
3-B	Oxidation	500	Supernatant from Task 2D with VeruSOL-3	Alkaline activated Sodium Persulfate	Persulfate = 100 g/L pH > 12	TPH, VOCs, SVOCs	Persulfate, pH, Conductivity	IFT	Day 14	Daily
3-C	Oxidation	500	Supernatant from Task 2D with VeruSOL-3	Fe-EDTA activated Sodium Persulfate	Fe-EDTA = 350 mg/L as Fe Persulfate = 100 g/L	TPH, VOCs, SVOCs	Persulfate, Fe-EDTA, Conductivity	IFT	Day 14	Daily
3-D	Oxidation	500	Supernatant from Task 2D with VeruSOL-3	Fe-TAML activated Hydrogen Peroxide	Fe-TAML = 0.1 uM as Fe Peroxide = 4%	TPH, VOCs, SVOCs	Peroxide, pH, Conductivity	IFT	Day 14	Daily

Table 5 – Soil Column Experiments (Task 4)

Task 4: Soil Column Tests: URS - Essex, Jamestown									
Task	**Test Conditions**	**Reaction Media**	**Surfactant/ Cosolvent**	**Oxidant/ Activator**	**Oxidant/Activator Concentrations**	**COCs**	**Water Quality Parameters (WQPs)**	**Sampling Frequencies (days)**	**Soil Analyses**
4-A	Control	Contaminated Homogenized Soil	None	None	None	VOC, SVOCs, TPH	TPH(Site Lab), pH, Temp, Conductivity, IFT, Turbidity	COCs (aq),Time = D14, D28 WQPs,Time = D1, D3, D5, D7, D14, D28	Composite after 28 days for VOCs, SVOCs, TPH
4-B	ISCO	Contaminated Homogenized Soil	None	Fe-EDTA activated Persulfate	Fe-EDTA = 350 mg/L as Fe Persulfate = 100 g/L	VOC, SVOCs, TPH	TPH(Site Lab), SP, pH, Temp, Conductivity, IFT, Turbidity	COCs (aq),Time = D14, D28 WQPs,Time = D1, D3, D5, D7, D14, D28	Composite after 28 days for VOCs, SVOCs, TPH
4-C	S-ISCO	Contaminated Homogenized Soil	VeruSOL-3 (10 g/L)	Fe-EDTA activated Persulfate	Fe-EDTA = 350 mg/L as Fe Persulfate = 100 g/L	VOC, SVOCs, TPH	TPH(Site Lab), SP, pH, Temp, Conductivity, IFT, Turbidity	COCs (aq),Time = D14, D28 WQPs,Time = D1, D3, D5, D7, D14, D28	Composite after 28 days for VOCs, SVOCs, TPH
4-D	ISCO	Contaminated Homogenized Soil	None	Alkaline activated Persulfate	Persulfate = 100 g/L pH > 11	VOC, SVOCs, TPH	TPH(Site Lab), SP, pH, Temp, Conductivity, IFT, Turbidity	COCs (aq),Time = D14, D28 WQPs,Time = D1, D3, D5, D7, D14, D28	Composite after 28 days for VOCs, SVOCs, TPH
4-E	S-ISCO	Contaminated Homogenized Soil	VeruSOL-3 (10 g/L)	Alkaline activated Persulfate	Persulfate = 100 g/L pH > 11	VOC, SVOCs, TPH	TPH(Site Lab), SP, pH, Temp, Conductivity, IFT, Turbidity	COCs (aq),Time = D14, D28 WQPs,Time = D1, D3, D5, D7, D14, D28	Composite after 28 days for VOCs, SVOCs, TPH
4-F	ISCO	Contaminated Homogenized Soil	None	Catalyzed Hydrogen Peroxide	HP - 4% Fe-TAML (0.1uM) pH ~ 8	VOC, SVOCs, TPH	TPH(Site Lab), HP, pH, Temp, Conductivity, IFT, Turbidity	COCs (aq),Time = D14, WQPs,Time = D1, D3, D5, D7, D14	Composite after 14 days for VOCs, SVOCs, TPH
4-G	S-ISCO	Contaminated Homogenized Soil	VeruSOL-3 (10 g/L)	Catalyzed Hydrogen Peroxide	HP - 4% Fe-TAML (0.1uM) pH ~ 8	VOC, SVOCs, TPH	TPH(Site Lab), HP, pH, Temp, Conductivity, IFT, Turbidity	COCs (aq),Time = D14, WQPs,Time = D1, D3, D5, D7, D14	Composite after 14 days for VOCs, SVOCs, TPH

Table 6 – Initial Characterization Results

Task 1 - Initial Characterization:URS-DOW Essex, Jamestown			
Sample Type	**Soil**	**Soil**	**Clay**
MitKem ID	H2342-01	H2342-02	H2423-01
VeruTEK ID	UDEJ-S1	UDEJ-S2	UDEJ-Clay
VOCs (SW846 8260B)	**ug/kg**	**ug/kg**	**ug/kg**
1,2,4-Trimethylbenzene	**1,100**	**1,600**	BRL (<3,100)
1,3,5-Trimethylbenzene	**670**	**680**	**5,400**
1,2,4-Trichlorobenzene	BRL (<150)	BRL (<130)	BRL (<3,100)
2-Butanone	BRL (<150)	BRL (<130)	BRL (<3,100)
2-Chlorotoluene	BRL (<150)	BRL (<130)	BRL (<3,100)
4-Isopropyltoluene	**880**	**130**	BRL (<3,100)
cis-1,2-Dichloroethene	BRL (<150)	BRL (<130)	BRL (<3,100)
trans-1,2-Dichloroethene	BRL (<150)	BRL (<130)	BRL (<3,100)
Ethylbenzene	**1,100**	**7,900**	**12,000**
Benzene	**2,700**	BRL (<130)	**6,200**
Methylene chloride	BRL (<150)	BRL (<150)	**17,000**
m&p-Xylene	**15,000**	**18,000**	**210,000**
o-Xylene	**4,600**	**10,000**	**53,000**
n-Butylbenzene	**180**	**480**	**1,000**
n-Propylbenzene	**110**	**410**	**870**
Naphthalene	**670**	**880**	**1,600**
Isopropylbenzene	**500**	**610**	**3,800**
sec-Butylbenzene	**190**	**290**	BRL (<3,100)
p-Isopropyltoluene	BRL (<150)	BRL (<130)	BRL (<3,100)
tert-Butylbenzene	BRL (<150)	BRL (<130)	**10,000**
Styrene	BRL (<150)	BRL (<130)	BRL (<3,100)
Toluene	**940**	**980**	**7,800**
Total Xylenes	**20,000**	**28,000**	**260,000**
Trichloroethene	BRL (<150)	BRL (<130)	BRL (<3,100)
Tetrachloroethene	BRL (<150)	BRL (<130)	BRL (<3,100)
Total VOCs	**28,640**	**41,960**	**328,670**
Total VOC TICs	**21,700**	**17,540**	**70,800**
TPH by GC-FID (8015) (GRO)	**mg/kg**	**mg/kg**	**mg/kg**
Gasoline Range Organics	**8.7**	**80**	**930**
TPH by GC-FID (8015B) (DRO)	**mg/kg**	**mg/kg**	**mg/kg**
Extractable Total Petroleum Hydrocarbons	**140**	**230**	**2,100**
Total TPH (mg/kg)	**149**	**310**	**3,030**

Table 7 – Supplemental Solubilization Tests

Task SS - Supplemental Solubilization (Bucket 1 of 2)

Sample ID	Surfactant	IFT (mN/m)	Temp. (°C)	TPH-GRO* (ppm)	TPH-DRO* (ppm)	Total TPH
S1-SS-1	Control	69.0	21.6	6.5	3.6	10
S1-SS-2	VeruSOL-3	33.3	21.6	8.5	0.30	8.8
S1-SS-3	VeruSOL-10	39.2	21.6	12	1.2	13
S1-SS-4	VeruSOL-11	44.7	21.5	8.0	1.2	9.2
S1-SS-5	VeruSOL-12	32.7	21.5	12	3.0	14
S1-SS-6	X1	39.7	21.7	7.5	0.90	8.4
S1-SS-7	X2	42.1	21.6	7.0	0.80	7.8

Task SS - Supplemental Solubilization (Bucket 2 of 2)

Sample ID	Surfactant	IFT (mN/m)	Temp. (°C)	TPH-GRO* (ppm)	TPH-DRO* (ppm)	Total TPH
S2-SS-1	Control	68.7	21.6	7.5	0.05	7.6
S2-SS-2	VeruSOL-3	37.2	21.7	18	0.55	18
S2-SS-3	VeruSOL-10	36.7	21.8	18	0.60	18
S2-SS-4	VeruSOL-11	44.6	21.8	18	0.85	18
S2-SS-5	VeruSOL-12	32.8	21.8	14	0.35	14
S2-SS-6	X1	44.9	21.8	19	0.70	20
S2-SS-7	X2	41.2	21.8	8.0	0.10	8.1

***Note**: values below detection limits:
TPH-GRO detection limit = 25 ppm
TPH-DRO detection limit = 5 ppm

Table 8 – Desorption/Solubilization Enhancement Tests (Task 2)

Task 2: Solubilization - URS-DOW Essex, Jamestown					
Sample Type	**Emulsion**	**Emulsion**	**Emulsion**	**Emulsion**	**Emulsion**
MitKem ID	H2545-01	H2545-02	H2545-03	H2545-04	H2545-05
VeruTEK ID	121009-UDEJ-T2A	121009-UDEJ-T2B	121009-UDEJ-T2C	121009-UDEJ-T2D	121009-UDEJ-T2E
Test Conditions	Control	VeruSOL-3 2.5 g/L	VeruSOL-3 5.0 g/L	VeruSOL-3 10 g/L	VeruSOL-3 25 g/L
VOCs (SW846 8260B)	**ug/L**	**ug/L**	**ug/L**	**ug/L**	**ug/L**
1,2,4-Trimethylbenzene	**150**	**220**	BRL (<1,000)	**3,200**	BRL (<500)
1,3,5-Trimethylbenzene	**150**	**124**	BRL (<1,000)	**1,960**	**1,020**
1,2,4-Trichlorobenzene	BRL (<100)	BRL (<100)	BRL (<1,000)	BRL (<1000)	BRL (<500)
2-Butanone	BRL (<100)	BRL (<100)	BRL (<1,000)	BRL (<1000)	BRL (<500)
2-Chlorotoluene	BRL (<100)	BRL (<100)	BRL (<1,000)	BRL (<1000)	BRL (<500)
4-Isopropyltoluene	BRL (<100)	**200**	**3,000**	**36,000**	**26,000**
cis-1,2-Dichloroethene	BRL (<100)	BRL (<100)	BRL (<1,000)	BRL (<1000)	BRL (<500)
trans-1,2-Dichloroethene	BRL (<100)	BRL (<100)	BRL (<1,000)	BRL (<1000)	BRL (<500)
Ethylbenzene	**142**	**580**	BRL (<1,000)	**3,800**	**2,400**
Benzene	**920**	**2,200**	BRL (<1,000)	**2,800**	**1,160**
m&p-Xylene	**8,000**	**11,600**	**6,400**	**66,000**	**38,000**
o-Xylene	**5,000**	**4,000**	**2,400**	**19,600**	**12,200**
n-Butylbenzene	BRL (<100)	BRL (<100)	BRL (<1,000)	BRL (<1000)	BRL (<500)
n-Propylbenzene	BRL (<100)	BRL (<100)	BRL (<1,000)	BRL (<1000)	BRL (<500)
Methylene chloride	BRL (<100)	BRL (<100)	BRL (<1,000)	BRL (<1000)	**660**
Naphthalene	BRL (<100)	BRL (<100)	BRL (<1,000)	BRL (<1000)	BRL (<500)
Isopropylbenzene	BRL (<100)	BRL (<100)	BRL (<1,000)	**1,460**	**1,420**
sec-Butylbenzene	BRL (<100)	BRL (<100)	BRL (<1,000)	BRL (<1000)	**920**
p-Isopropyltoluene	BRL (<100)	BRL (<100)	BRL (<1,000)	BRL (<1000)	BRL (<500)
tert-Butylbenzene	BRL (<100)	BRL (<100)	BRL (<1,000)	BRL (<1000)	BRL (<500)
Styrene	BRL (<100)	BRL (<100)	BRL (<1,000)	BRL (<1000)	BRL (<500)
Toluene	**240**	**960**	BRL (<1,000)	**1,940**	**900**
Total Xylenes	**13,000**	**15,400**	**8,800**	**86,000**	**50,000**
Trichloroethene	BRL (<100)	BRL (<100)	BRL (<1,000)	BRL (<1000)	BRL (<500)
Tetrachloroethene	BRL (<100)	BRL (<100)	BRL (<1,000)	BRL (<1000)	BRL (<500)
Total VOCs	**14,602**	**19,884**	**11,800**	**136,760**	**84,680**
TPH by GC-FID (8015) (GRO)	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Gasoline Range Organics	**16**	**42**	**186**	**1,780**	**5,600**
TPH by GC-FID (8015B) (DRO)	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Extractable Total Petroleum Hydrocarbons	**BRL (<1.8)**	**128**	**520**	**1,700**	**7,500**
Total TPH (mg/kg)	**16**	**170**	**706**	**3,480**	**13,100**

Table 8 – Destruction of Solubilized COCs in Emulsion Phase (Task 3)

Task 3: Oxidation - URS-DOW Essex, Jamestown				
Sample Type	**Liquid**	**Liquid**	**Liquid**	**Liquid**
MitKem ID	J0157-01	J0157-02	J0157-03	J0157-04
VeruTEK ID	102610-UDEJ-T3-A	102610-UDEJ-T3-B	102610-UDEJ-T3-C	102610-UDEJ-T3-D
Test Conditions	Control	Alkaline activated Sodium Persulfate	Fe-EDTA activated Sodium Persulfate	Fe-TAML activated Hydrogen Peroxide
VOCs (SW846 8260B)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
1,2,4-Trimethylbenzene	BRL (<1,000)	BRL (<50)	BRL (<100)	BRL (<10)
1,3,5-Trimethylbenzene	BRL (<1,000)	BRL (<50)	BRL (<100)	BRL (<10)
1,2,4-Trichlorobenzene	BRL (<1,000)	BRL (<50)	BRL (<100)	BRL (<10)
2-Butanone	BRL (<1,000)	BRL (<50)	BRL (<100)	BRL (<10)
2-Chlorotoluene	BRL (<1,000)	BRL (<50)	BRL (<100)	BRL (<10)
4-Isopropyltoluene	BRL (<1,000)	BRL (<50)	BRL (<100)	BRL (<10)
Acetone	BRL (<1,000)	**580**	**8,400**	BRL (<10)
cis-1,2-Dichloroethene	BRL (<1,000)	BRL (<50)	BRL (<100)	BRL (<10)
trans-1,2-Dichloroethene	BRL (<1,000)	BRL (<50)	BRL (<100)	BRL (<10)
Ethylbenzene	BRL (<1,000)	BRL (<50)	BRL (<100)	BRL (<10)
Benzene	BRL (<1,000)	BRL (<50)	BRL (<100)	BRL (<10)
Chlorobenzene	**1,120**	BRL (<50)	BRL (<100)	BRL (<10)
m&p-Xylene	**9,200**	**182**	BRL (<100)	BRL (<10)
o-Xylene	**2,600**	BRL (<50)	BRL (<100)	BRL (<10)
n-Butylbenzene	BRL (<1,000)	BRL (<50)	BRL (<100)	BRL (<10)
n-Propylbenzene	BRL (<1,000)	BRL (<50)	BRL (<100)	BRL (<10)
Methylene chloride	BRL (<1,000)	BRL (<50)	BRL (<100)	BRL (<10)
Naphthalene	BRL (<1,000)	BRL (<50)	BRL (<100)	BRL (<10)
Isopropylbenzene	BRL (<1,000)	BRL (<50)	BRL (<100)	BRL (<10)
sec-Butylbenzene	BRL (<1,000)	BRL (<50)	BRL (<100)	BRL (<10)
p-Isopropyltoluene	BRL (<1,000)	BRL (<50)	BRL (<100)	BRL (<10)
tert-Butylbenzene	BRL (<1,000)	BRL (<50)	BRL (<100)	BRL (<10)
Styrene	BRL (<1,000)	BRL (<50)	BRL (<100)	BRL (<10)
Toluene	BRL (<1,000)	BRL (<50)	BRL (<100)	BRL (<10)
Total Xylenes	**11,800**	**182**	BRL (<100)	BRL (<10)
Trichloroethene	BRL (<1,000)	BRL (<50)	BRL (<100)	BRL (<10)
Tetrachloroethene	BRL (<1,000)	BRL (<50)	BRL (<100)	BRL (<10)
Total VOCs	**12,920**	**182**	**0**	**0**
SVOCs (SW846 8270C)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
1,2,4-Trichlorobenzene	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
1,2-Dichlorobenzene	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
1,4-Dichlorobenzene	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
2,4-Dimethylphenol	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
2-Methylnaphthalene	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
2-Methylphenol	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
4-Methylphenol	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)

Test Conditions	Control	Alkaline activated Sodium Persulfate	Fe-EDTA activated Sodium Persulfate	Fe-TAML activated Hydrogen Peroxide
SVOCs cont. (8270B)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
4-Chlorophenyl-phenylether	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
Acenaphthene	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
Acenaphthylene	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
Acetophenone	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
Anthracene	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
Benz(a)anthracene	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
Benzo(a)pyrene	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
Benzo(b)fluoranthene	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
Benzo(ghi)perylene	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
Benzo(k)fluoranthene	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
Bis(2-ethylhexyl)phthalate	**200**	**349**	BRL (<50)	**100**
Butylbenzylphthalate	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
Carbazole	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
Chrysene	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
Dibenzofuran	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
Di-n-butylphthalate	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
Di-n-octylphthalate	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
Fluoranthene	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
Fluorene	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
Hexachlorobenzene	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
Hexachlorobutadiene	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
Indeno(1,2,3-ed)pyrene	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
Naphthalene	**73**	BRL (<100)	BRL (<50)	BRL (<40)
Phenanthrene	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
Phenol	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
Pyrene	BRL (<50)	BRL (<100)	BRL (<50)	BRL (<40)
TPH by GC-FID (8015) (GRO)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
Gasoline Range Organics	**220,000**	**4,600**	**5,400**	**6,000**
TPH by GC-FID (8015B) (DRO)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
Extractable Total Petroleum Hydrocarbons	**1,933,333**	**1,028,571**	**165,517**	**446,667**
Total TPH (mg/kg)	**2,153,333**	**1,033,171**	**170,917**	**452,667**

Table 9 – Soil Column Tests (Task 4)

Task 4: Soil Column Experiments Day 28							
Sample Type	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
MitKem ID	J0222-06	J0222-07	J0222-08	J0222-09	J0222-10	J0828-03	J0828-04
VeruTEK ID	UDEJ-T4A-S-D28	UDEJ-T4B-S-D28	UDEJ-T4C-S-D28	UDEJ-T4D-S-D28	UDEJ-T4E-S-D28	UDEJ-T4F-S-D28	UDEJ-T4G-S-D28
Test Conditions	Day 28 Column Soil Control	Day 28 Column Soil ISCO Fe-EDTA activated SP	Day 28 Column Soil S-ISCO Fe-EDTA activated SP + VS-3	Day 28 Column Soil ISCO Alkaline activated SP	Day 28 Column Soil S-ISCO Alkaline activated SP + VS-3	Day 28 Column Soil ISCO FeTAML activated HP	Day 28 Column Soil S-ISCO FeTAML activated HP + VS-3
VOCs (SW846 8260B)	(ug/Kg)	(ug/Kg)	(ug/Kg)	(ug/Kg)	(ug/Kg)	(ug/Kg)	(ug/Kg)
1,2,4-Trimethylbenzene	**9,900**	**4,700**	BRL (<3,900)	**8,900**	**5,900**	**21,000**	**530**
1,3,5-Trimethylbenzene	**5,800**	**2,800**	BRL (<3,900)	**5,300**	**3,200**	**15,000**	**470**
1,2,4-Trichlorobenzene	BRL (<9,700)	BRL (<4,600)	BRL (<3,900)	BRL (<9,400)	BRL (<4,500)	BRL (<3,700)	BRL (<360)
2-Butanone	BRL (<9,700)	BRL (<4,600)	BRL (<3,900)	BRL (<9,400)	BRL (<4,500)	BRL (<3,700)	BRL (<360)
2-Chlorotoluene	BRL (<9,700)	BRL (<4,600)	BRL (<3,900)	BRL (<9,400)	BRL (<4,500)	BRL (<3,700)	BRL (<360)
4-Isopropyltoluene	**11,000**	**6,100**	**3,600**	**11,000**	**5,000**	**14,000**	**460**
Acetone	BRL (<9,700)	BRL (<4,600)	BRL (<3,900)	BRL (<9,400)	BRL (<4,500)	BRL (<3,700)	**310**
cis-1,2-Dichloroethene	BRL (<9,700)	BRL (<4,600)	BRL (<3,900)	BRL (<9,400)	BRL (<4,500)	BRL (<3,700)	BRL (<360)
trans-1,2-Dichloroethene	BRL (<9,700)	BRL (<4,600)	BRL (<3,900)	BRL (<9,400)	BRL (<4,500)	BRL (<3,700)	BRL (<360)
Ethylbenzene	**21,000**	**2,700**	BRL (<3,900)	**14,000**	**9,600**	**12,000**	**530**
Benzene	BRL (<9,700)	**1,300**	BRL (<3,900)	BRL (<9,400)	BRL (<4,500)	BRL (<3,700)	**280**
Chlorobenzene	BRL (<9,700)	BRL (<4,600)	BRL (<3,900)	BRL (<9,400)	BRL (<4,500)	BRL (<3,700)	BRL (<360)
Chloroethane	BRL (<9,700)	BRL (<4,600)	BRL (<3,900)	BRL (<9,400)	BRL (<4,500)	BRL (<3,700)	BRL (<360)
Chloroform	BRL (<9,700)	BRL (<4,600)	BRL (<3,900)	BRL (<9,400)	BRL (<4,500)	BRL (<3,700)	BRL (<360)
Chloromethane	BRL (<9,700)	BRL (<4,600)	BRL (<3,900)	BRL (<9,400)	BRL (<4,500)	BRL (<3,700)	BRL (<360)
m&p-Xylene	**190,000**	**33,000**	**2,800**	**150,000**	**94,000**	**270,000**	**5,800**
o-Xylene	**42,000**	**6,400**	BRL (<3,900)	**35,000**	**23,000**	**70,000**	**1,500**
n-Butylbenzene	BRL (<9,700)	**1,400**	BRL (<3,900)	BRL (<9,400)	**970**	**2,500**	**170**
n-Propylbenzene	BRL (<9,700)	BRL (<4,600)	BRL (<3,900)	BRL (<9,400)	BRL (<4,500)	**1,500**	BRL (<360)
Methylene chloride	BRL (<9,700)	BRL (<4,600)	BRL (<3,900)	BRL (<9,400)	BRL (<4,500)	BRL (<3,700)	BRL (<360)

VeruTEK ID	UDEJ-T4A-S-D28	UDEJ-T4B-S-D28	UDEJ-T4C-S-D28	UDEJ-T4D-S-D28	UDEJ-T4E-S-D28	UDEJ-T4F-S-D28	UDEJ-T4G-S-D28
Test Conditions	Day 28 Column Soil Control	Day 28 Column Soil ISCO Fe-EDTA activated SP	Day 28 Column Soil S-ISCO Fe-EDTA activated SP + VS-3	Day 28 Column Soil ISCO Alkaline activated SP	Day 28 Column Soil S-ISCO Alkaline activated SP + VS-3	Day 28 Column Soil ISCO FeTAML activated HP	Day 28 Column Soil S-ISCO FeTAML activated HP + VS-3
VOCs cont. (8260B)	(ug/Kg)	(ug/Kg)	(ug/Kg)	(ug/Kg)	(ug/Kg)	(ug/Kg)	(ug/Kg)
Naphthalene	BRL (<9,700)	**3,000**	BRL (<3,900)	BRL (<9,400)	**1,700**	**3,100**	**260**
Isopropylbenzene	**4,400**	**1,900**	BRL (<3,900)	**3,900**	**2,300**	**13,000**	**230**
sec-Butylbenzene	BRL (<9,700)	**1,500**	BRL (<3,900)	BRL (<9,400)	BRL (<4,500)	**5,100**	**140**
p-Isopropyltoluene	BRL (<9,700)	BRL (<4,600)	BRL (<3,900)	BRL (<9,400)	BRL (<4,500)	BRL (<3,700)	BRL (<360)
tert-Butylbenzene	BRL (<9,700)	BRL (<4,600)	BRL (<3,900)	BRL (<9,400)	BRL (<4,500)	BRL (<3,700)	BRL (<360)
Styrene	BRL (<9,700)	BRL (<4,600)	BRL (<3,900)	BRL (<9,400)	BRL (<4,500)	BRL (<3,700)	BRL (<360)
Toluene	BRL (<9,700)	**1,400**	BRL (<3,900)	BRL (<9,400)	**1,300**	**3,600**	**170**
Total Xylenes	**230,000**	**40,000**	**2,800**	**180,000**	**120,000**	**340,000**	**7,400**
Trichloroethene	BRL (<9,700)	BRL (<4,600)	BRL (<3,900)	BRL (<9,400)	BRL (<4,500)	BRL (<3,700)	BRL (<360)
Tetrachloroethene	BRL (<9,700)	BRL (<4,600)	BRL (<3,900)	BRL (<9,400)	BRL (<4,500)	BRL (<3,700)	BRL (<360)
Total VOCs	**284,100**	**66,200**	**6,400**	**228,100**	**146,970**	**430,800**	**10,540**
TPH by GC-FID (8015) (GRO)	(ug/Kg)	(ug/Kg)	(ug/Kg)	(ug/Kg)	(ug/Kg)	(ug/Kg)	(ug/Kg)
Gasoline Range Organics	**640,000**	**110,000**	**2,300,000**	**260,000**	**270,000**	**--**	**--**
TPH by GC-FID (8015B) (DRO)	(ug/Kg)	(ug/Kg)	(ug/Kg)	(ug/Kg)	(ug/Kg)	(ug/Kg)	(ug/Kg)
Extractable Total Petroleum Hydrocarbons	**1,000,000**	**590,000**	**7,000,000**	**440,000**	**1,400,000**	**--**	**--**
Total TPH	**1,640,000**	**700,000**	**9,300,000**	**700,000**	**1,670,000**	**--**	**--**

Figures

Figure 1a – Soil Desorption/Solubilization Enhancement Tests

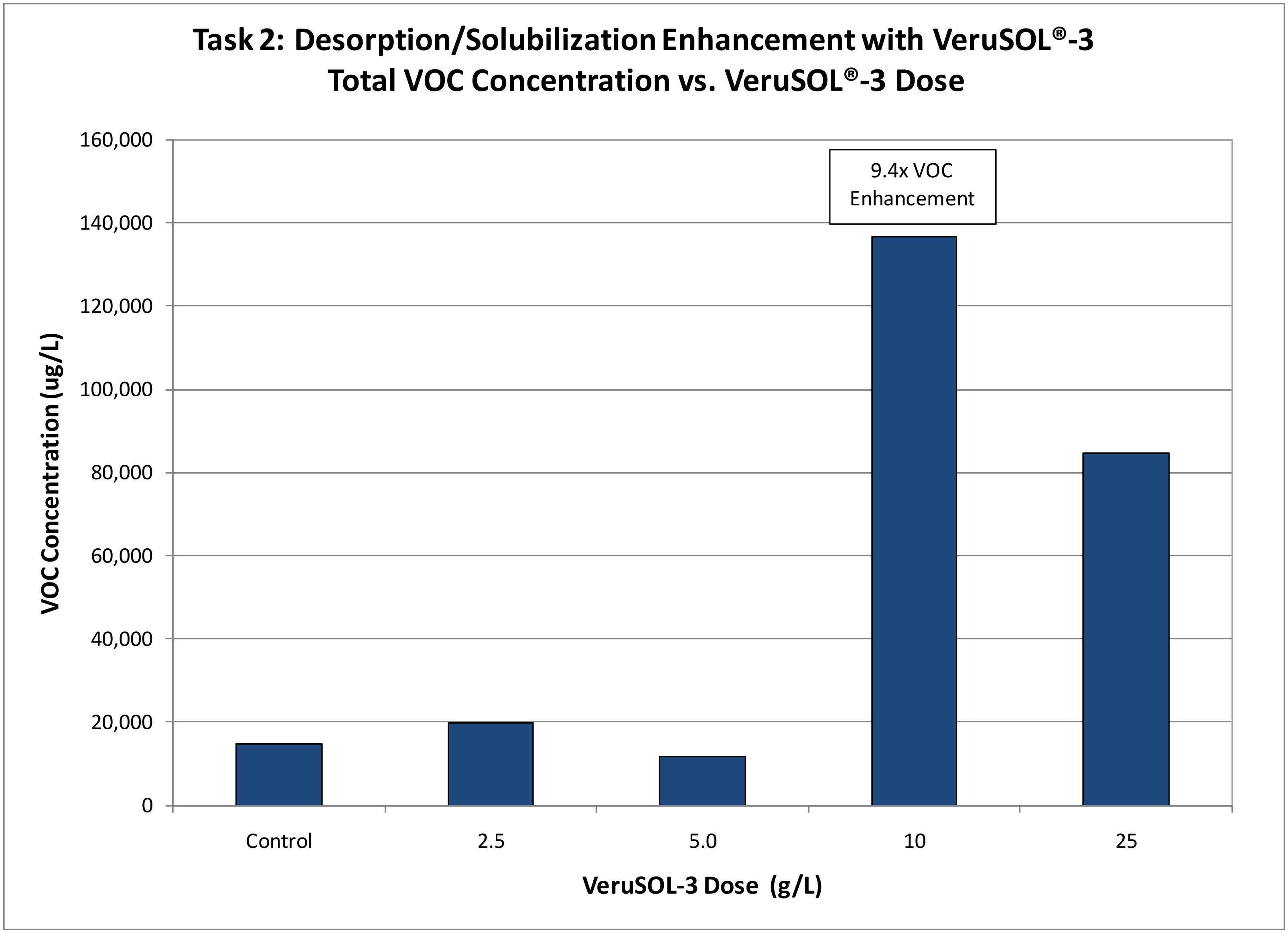


Figure 1b – Soil Desorption/Solubilization Enhancement Tests

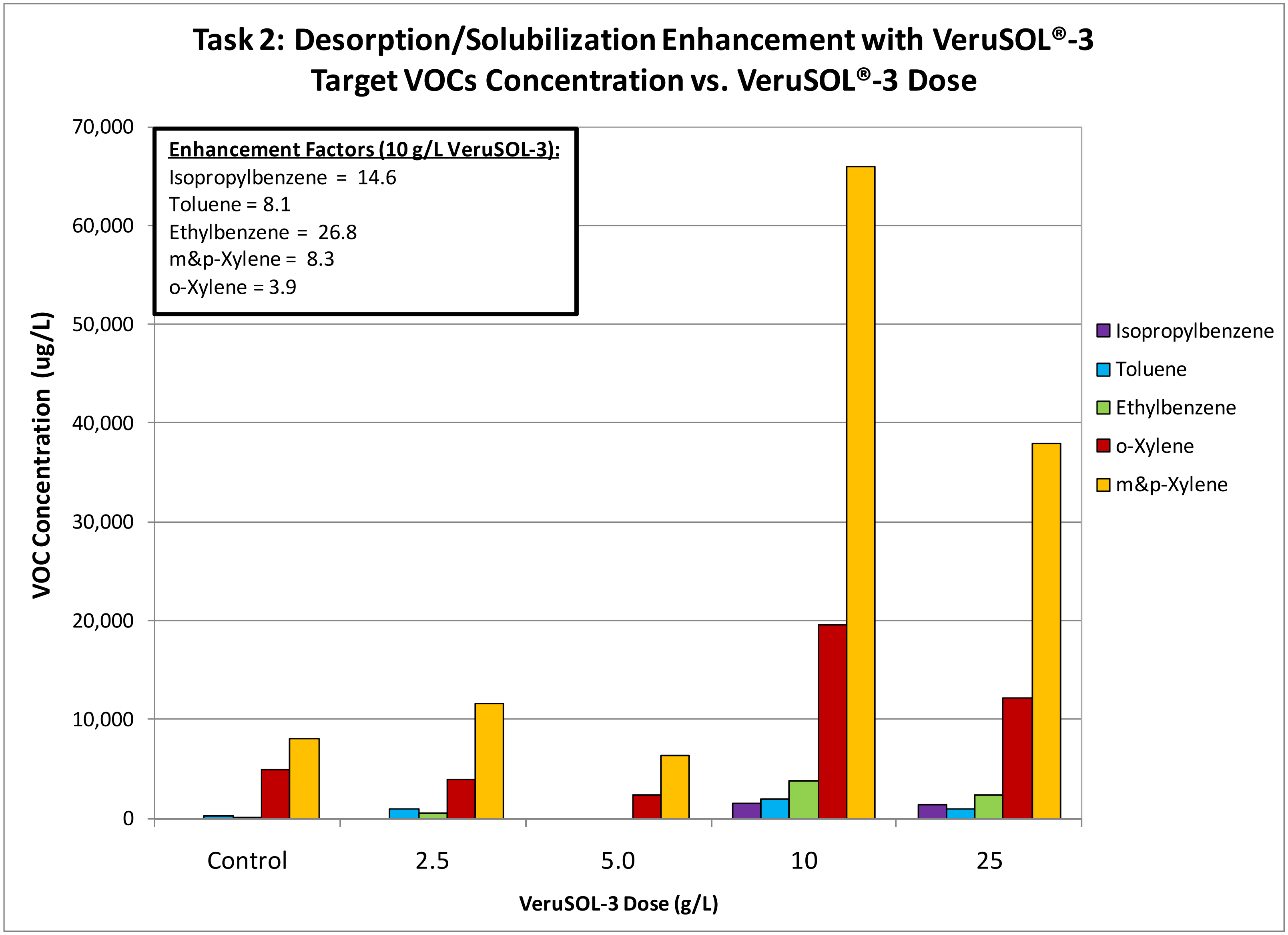


Figure 1c – Soil Desorption/Solubilization Enhancement Tests

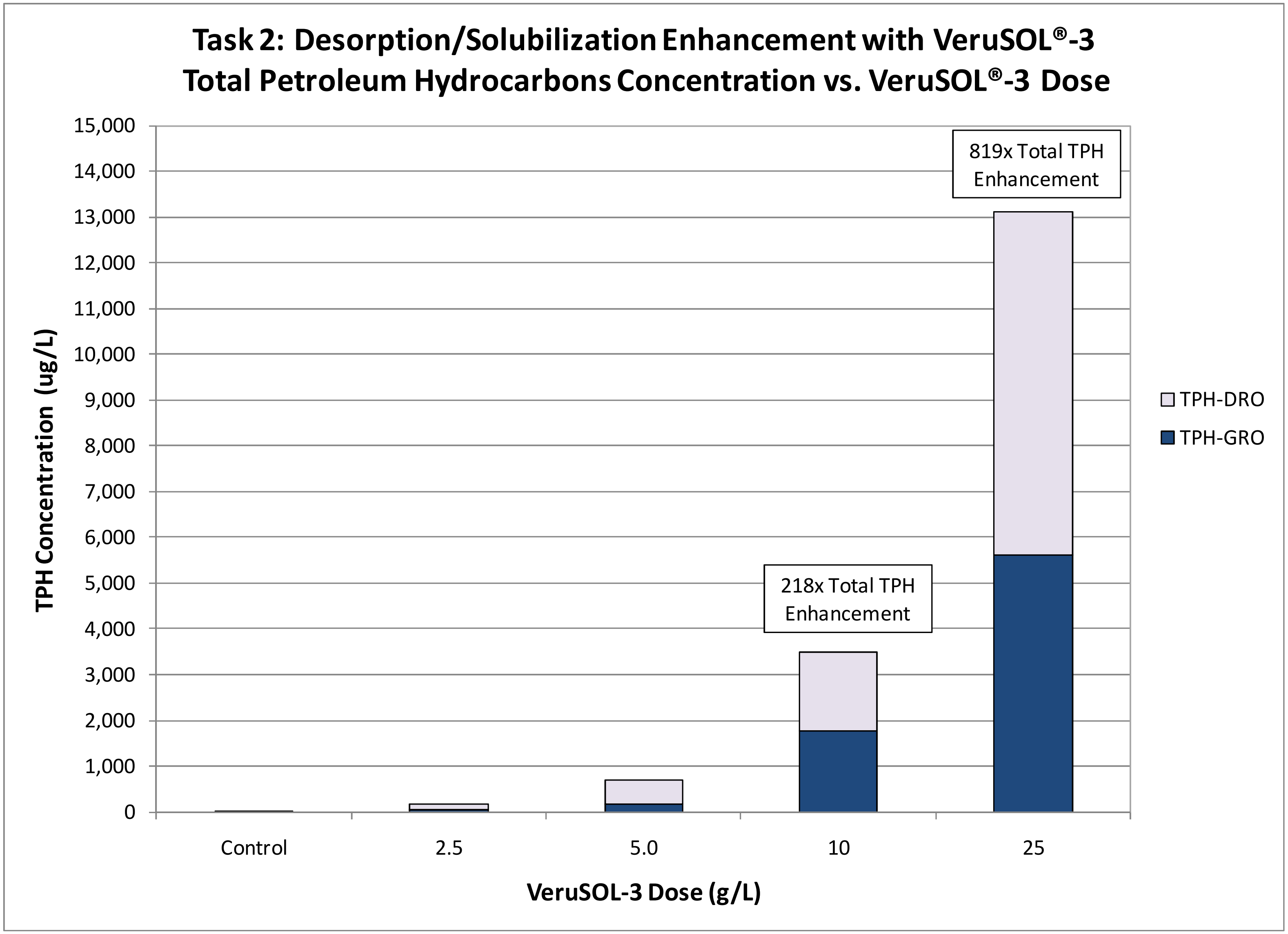


Figure 2a – Destruction of VOCs in the Emulsion Phase

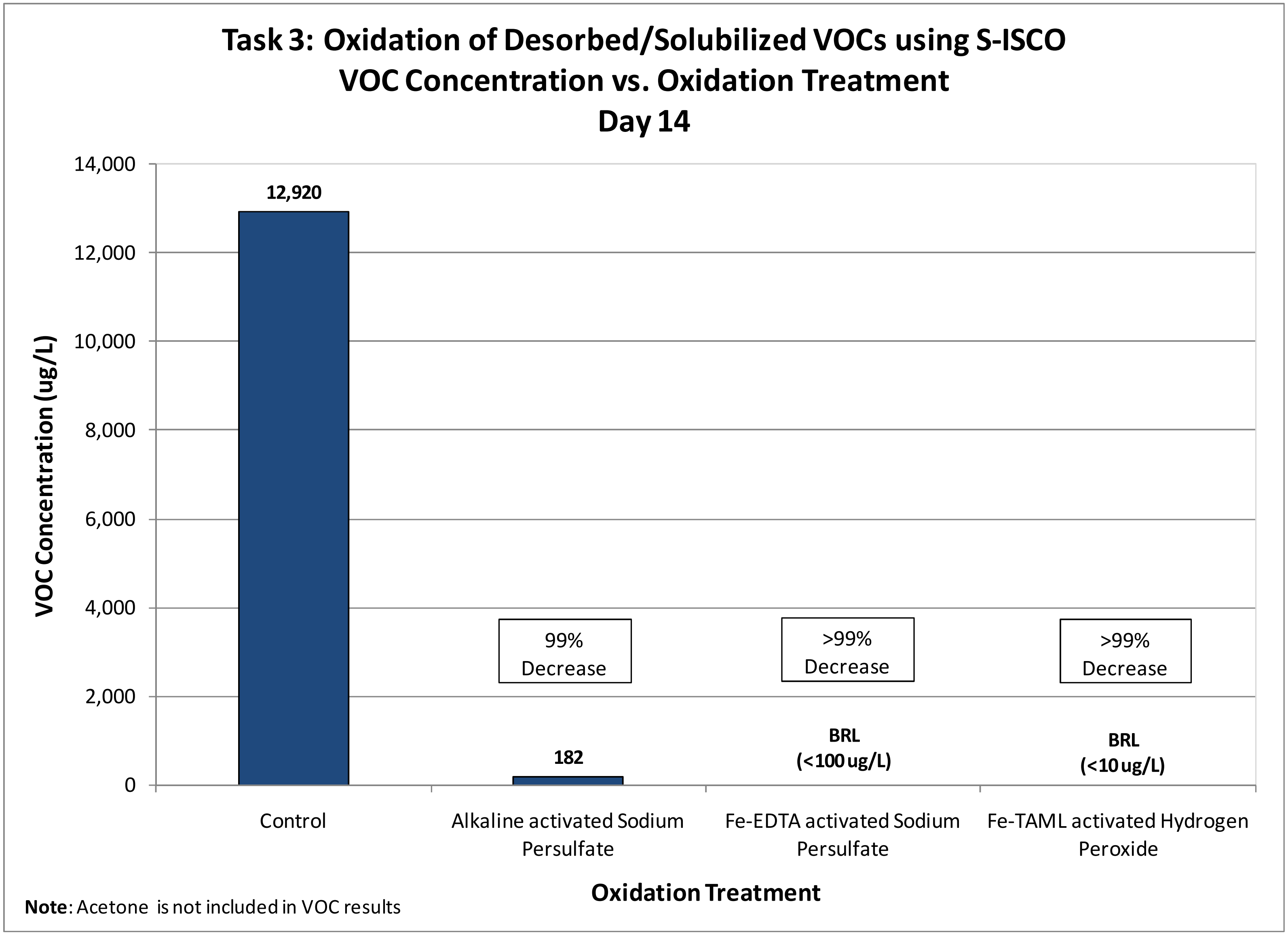


Figure 2b – Destruction of Target VOCs in the Emulsion Phase

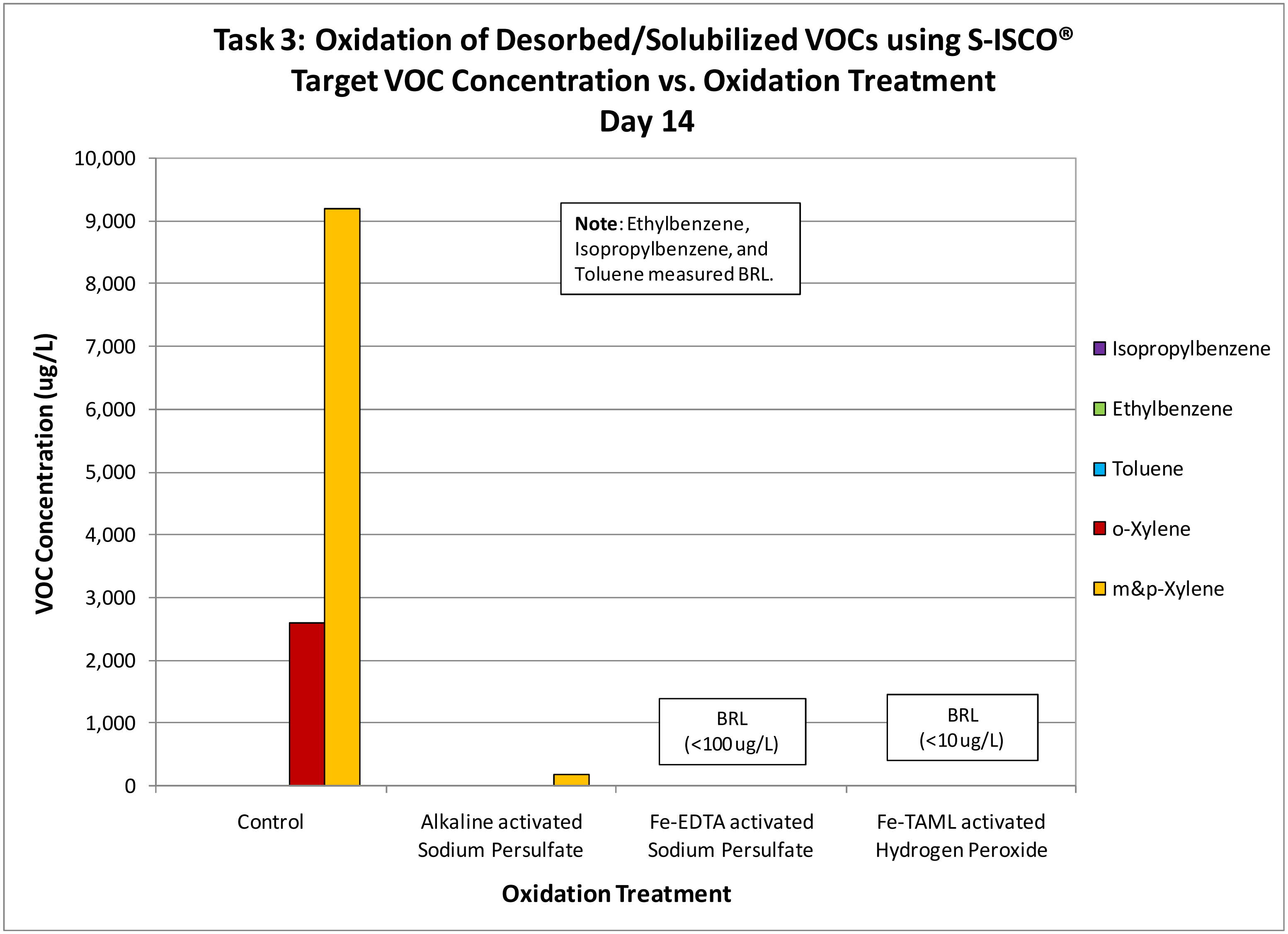


Figure 2c – Destruction of TPH in the Emulsion Phase

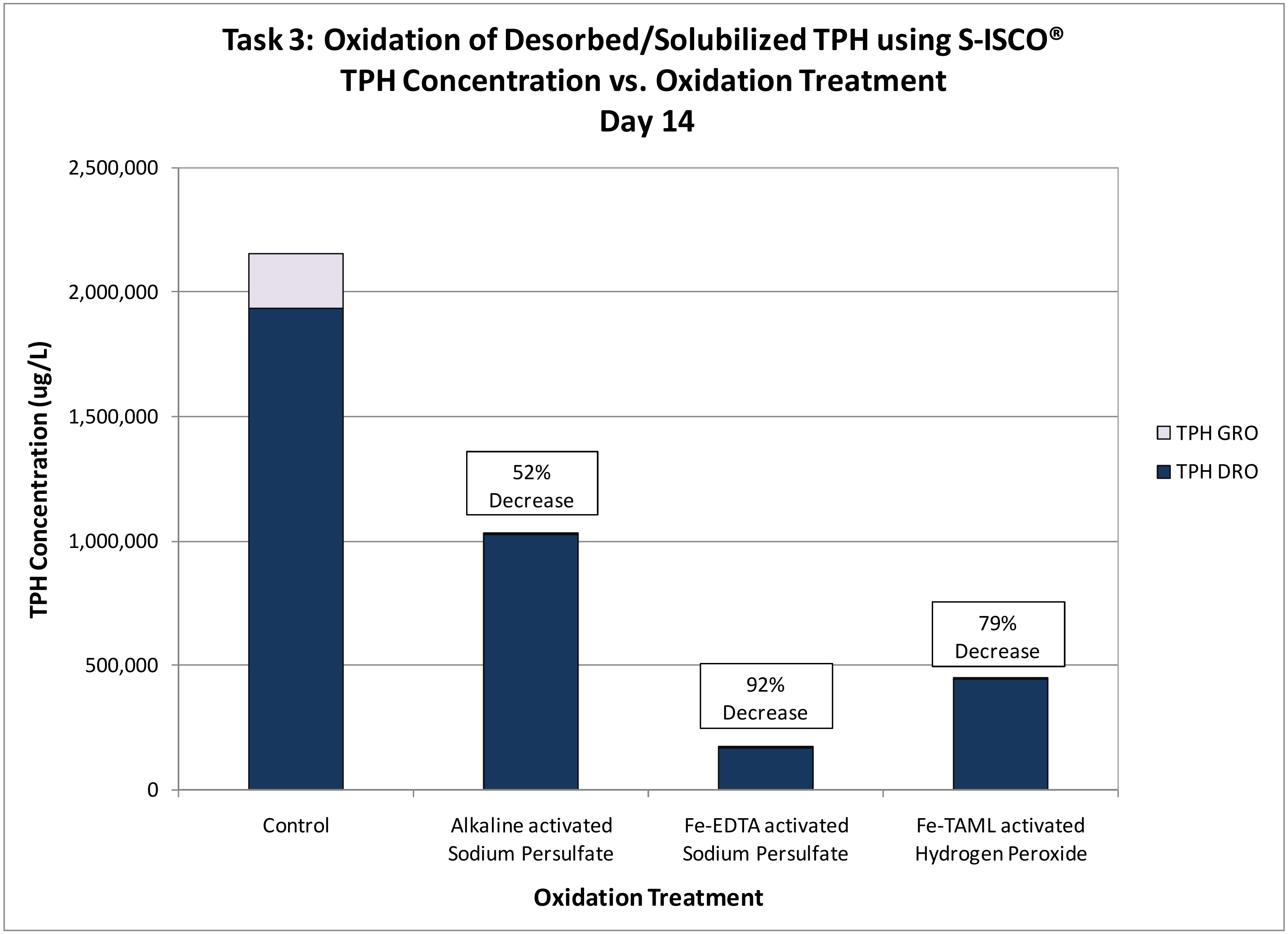


Figure 3a – Soil Column Tests (Task 4)

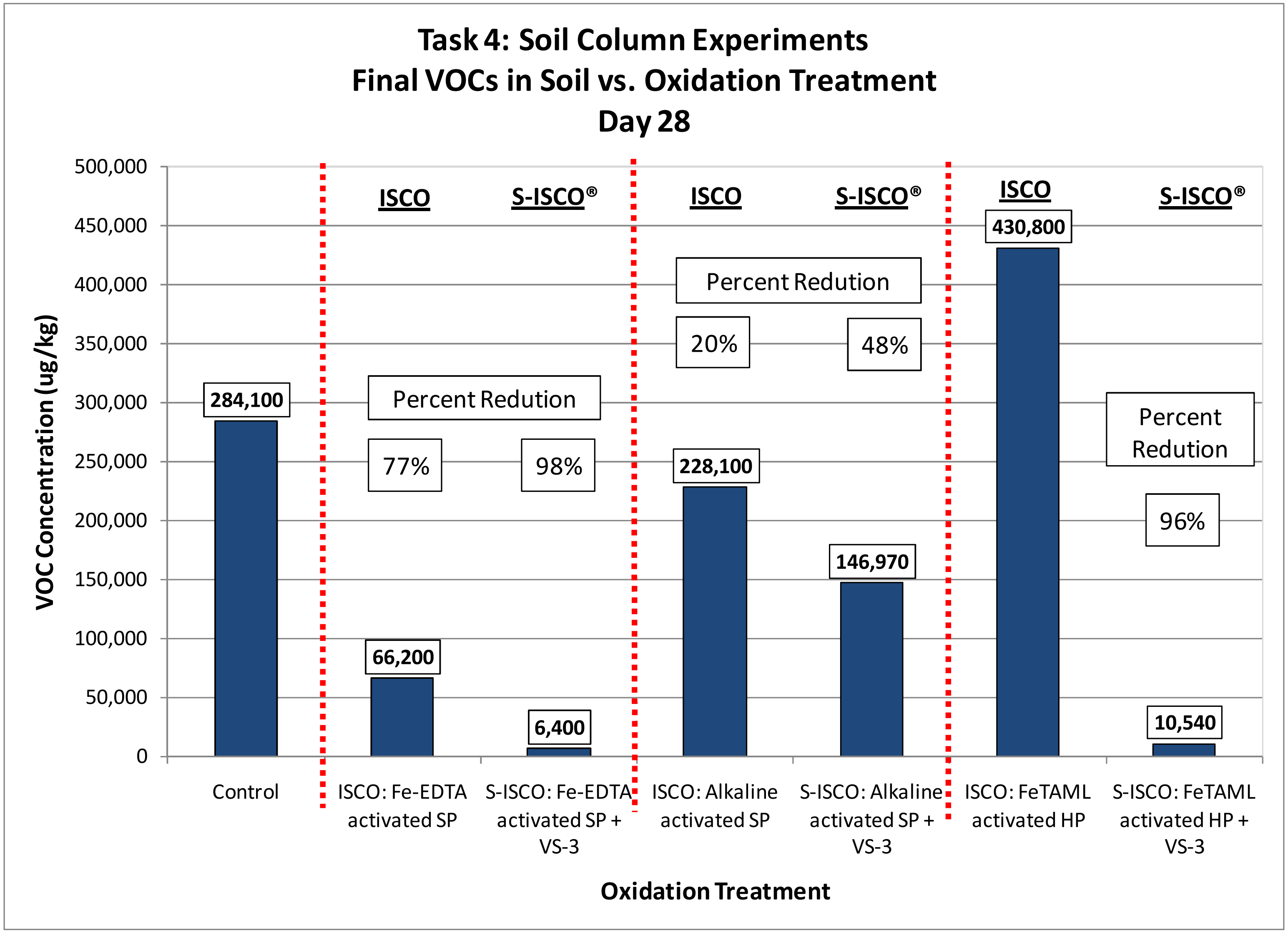
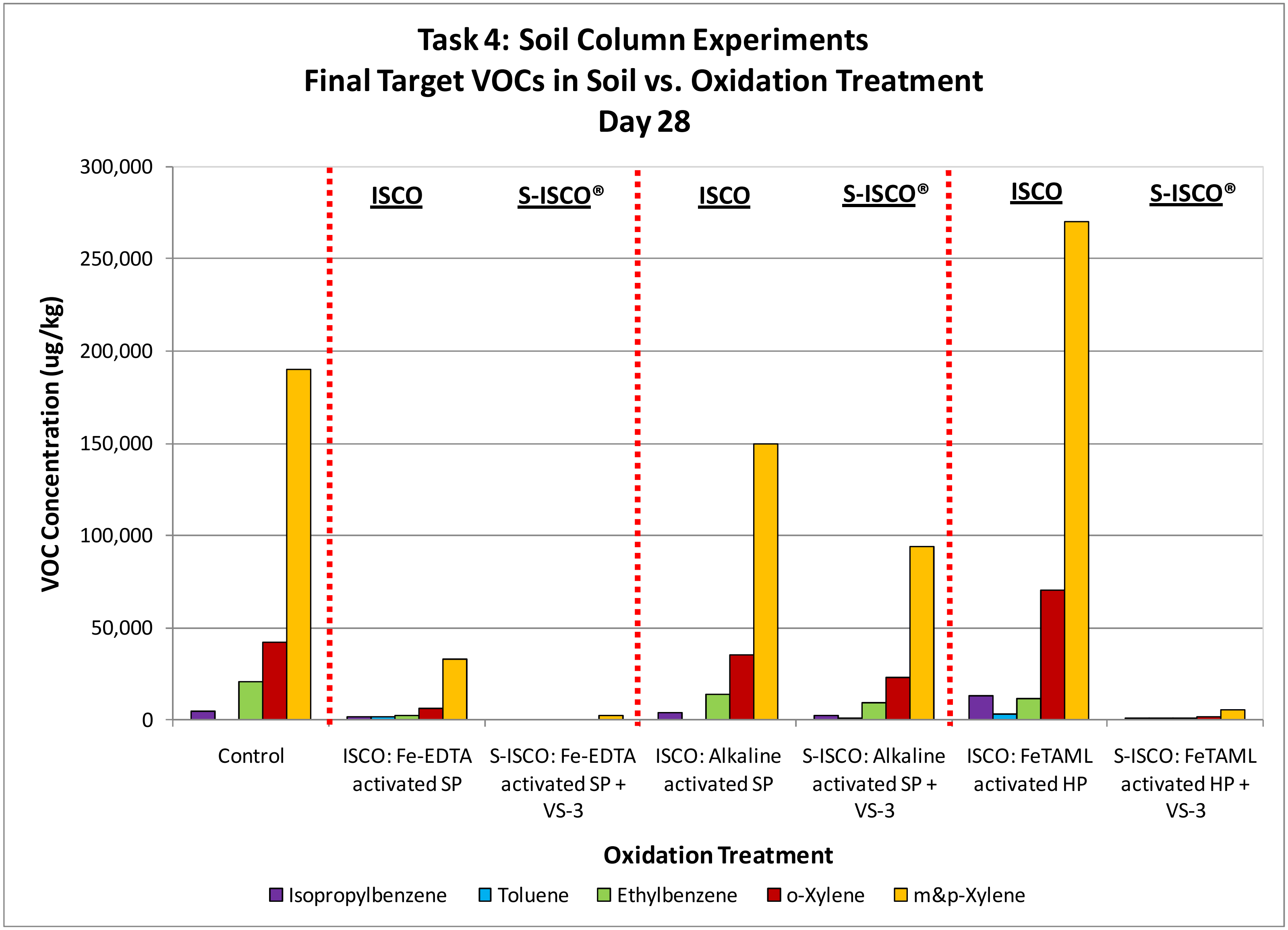


Figure 3b – Soil Column Tests (Task 4)



APPENDIX C

Design Calculations

Tables C-1 through C-8

URS Corporation

Essex Jamestown Site
UST Area ISCO
Pore Volume Estimates

Table C-1

Treatment Area Pore Volume Estimates

Area	Vadose (4-8 ft BGS)			Groundwater (8-16 ft BGS)				
	Area, SF	Pore Volume, gal		Area, SF	Pore Volume, gal			
Porosity:		***0.3***	***0.2***		***0.3***	***0.2***		
West 1	2125	19074	12716	2125	38148	25432		
West 2	2550	22889	15259	3400	61037	40691		
West 3	0			6700	120278	80186		
Subtotal West		41963	27975		219463	146309		
East 1	650	5834	3890	650	11669	7779		
East 2				7600	136435	90957		
Subtotal East		5834	3890		148104	98736		
Total Site		***47797***			***367567***		***415364***	*Gallons*

Injection Point Pore Volume Estimates

Injection Spacing ft	Thickness of Treatment Zone,ft		Total Volume, gal	Injection Point Pore Volume by Porosity, gal								
	Vadose	***Saturated***		***0.4***			***0.3***			***0.2***		
				total	***per ft***	***per/sf/ft***	***total***	***per ft***	***per/sf/ft***	***total***	***per ft***	***per/sf/ ft***
10	4	8	8976	3590	299	2.99	2693	224	2.24	1795	150	1.5
10	4	10	10472	4189	299	2.99	3142	224	2.24	2094	150	1.5
20	4	8	35904	14362	1197	2.99	10771	898	2.24	7181	598	1.5
20	4	10	41888	16755	1197	2.99	12566	898	2.24	8378	598	1.5
30	4	8	80784	32314	2693	2.99	24235	2020	2.24	16157	1346	1.5
30	4	10	94248	37699	2693	2.99	28274	2020	2.24	18850	1346	1.5

Notes:
1. Volume based on an assumed injection area of influence of (2r*2r), square area > circular injection area (conservative estimate)
2. Formation is a fine-coarse sand and gravel with interspersed clayey-silt lenses, Porosity estimated to be 0.3.
3. Site-specific design injection spacing is 10 ft based on site soil lithology.

URS Corporation

TABLE C-2

Essex Jamestown Site
UST Area ISCO
Injection Pressure to Prevent Ground Uplift

Theoretical Injection Pressure to Prevent Ground Uplift

Injection Depth, ft	Density of Treatment Zone, lb/cf (Note 1)		Static Head, ft (Note 2)		Dw, lb/cf	***Injection Pressure***	
	Vadose	***Saturated***	***Vadose***	***Sat***		***psf***	***psi***
6	120	125	6	0	62.4	720	5.0
10	120	125	6	4	62.4	970.4	6.7
15	120	125	6	9	62.4	1283.4	8.9

P= [(Dv x Hv + Dsat x Hsat) - Dw x Hsat] psf

Ref:Subsurface Injection of ISRRs within the the LA RWQC Board Jurisdiction, Sept, 2009. Sec 4.1.

Where:

P= Injection pressure, insitu

Dv- Density vadose soil

Dsat-Density saturated zone

Hv- Height or thickness of vadose zone above injection point

Hw- Height or thickness of saturated zone above injection point

Dw- density of water, 62.4 pcf

Notes:

1. Fine to coarse sand and gravel- 120-125 pcf
2. Depth to saturated zone average 6 ft. Thickness of saturated zone average 9 ft.
3. Calculation of P neglects soil bending resistance (tensile) - conservative approach.

TABLE C-3

Essex Jamestown Site
UST Area ISCO
Injection Time vs Injection Pressure

Injection Time vs Injection Pressures

Injection Plan		Kv		***Injection Time (min) vs Pressure (psi),*** Note (1)			
Spacing ft	***Radius, ft***	***ft/d***	***ft/sec***	***5***	***10***	***20***	***50***
10	5	2.69	0.0000311	695.2	347.6	173.8	69.5
20	10	2.69	0.0000311	2780.9	1390.4	695.2	278.1
40	20	2.69	0.0000311	11123	5562	2781	1112

Darcy's Law, Vs = K*i/n

Where:
Vs = seepage velocity (during presurized injection)
Kv- Vertical hydraulic conductivity (use 2.69 ft/d based on shallow zone slug tests Kavg = 20.1 gal/day- sf)
I = hydraulic gradient= H/L, or (psi x 144) / (62.4 x 0.5 R)
n = formation porosity, = 0.3

Note:

1. Injection time is the estimated time to reach the radius of influence for 1 pore volume (PV) of injected solution

Essex Jamestown Site
UST Area ISCO
Oxidant Delivery Acceptance Rate to Minimize Groundwater Mounding

TABLE C-4

Injection Hydraulic Acceptance Rate to Minimize Groundwater Mounding

Injection Plan			Kv, ft/d	Mound Head, ft	Injection Depth, ft	P, lb/sf	Dw, lb/cf	***Acceptance Flow Rate***		
Spacing, ft	***Radius, ft***	***Area, sf***						***gal/d/sf***	***gal/d***	***gal/min/inj***
10	5	100	2.69	6	6	720	62.4	18.6	1858	1.3
10	5	100	2.69	6	10	970	62.4	32.0	3202	2.2
10	5	100	2.69	6	15	1283	62.4	48.8	4884	3.4
10	5	100	2.69	4	6	720	62.4	37.9	3793	2.6
10	5	100	2.69	4	10	970	62.4	58.1	5809	4.0
10	5	100	2.69	4	15	1283	62.4	83.3	8333	5.8
10	5	100	2.69	2	6	720	62.4	96.0	9599	6.7
10	5	100	2.69	2	10	970	62.4	136.3	13631	9.5
10	5	100	2.69	2	15	1283	62.4	186.8	18678	13.0

Q/A = Kv (P - Dw* H)/H *Ref:Subsurface Injection of ISRRs within the the LA RWQC Board Jurisdiction, Sept, 2009. Sec 4.1.*

Where:

Q/A- Injection flow rate applied over the area of interest (area a function of injection plan)

Kv- Vertical hydraulic conductivity (use 2.69 ft/d based on shallow zone slug tests Kavg = 20.1 gal/day- sf)

P= Injection pressure, (See Table C-2)

H- Groundwater mound height above saturated zone (max 6 ft at ground surface)

Dw- density of water, 62.4 pcf

Notes:

1. Depth to saturated zone average 6 ft. Thickness of saturated zone average 9 ft.

Essex Jamestown Site
UST Area ISCO
Treatment Area Bulk Oxidant Estimate

Treatment Area Bulk Dry Oxidant Estimate

Area	**VOC Mass by Zone (See Note 1)**						**Oxygen Equivalent, lbs**		**Bulk Oxidant Req't, lbs**	
	Vadose (4-8 ft BGS)			Groundwater (8-16 ft BGS)			See Note (2)		See Note (3)	
	Avg Conc, ppm	Area, SF	Mass, lbs	Avg Conc, ppm	Area, SF	Mass, lbs	Vadose	Groundwater	Vadose	Groundwater
West 1	500	2125	357	100	2125	31.8	1371	122	21090	1880
West 2	500	2550	428.4	1	3400	0.5	1645	8	25309	125
West 3	0	0	0	1	6700	1.0	0	16	0	247
Subtotal West			785.4			33.3	***3016***	***146***	***46399***	***2252***
East 1	10	650	2.18	1	650	0.1	8	1.6	129	24
East 2	0	0	0	1	7600	1.1	0	18	0	280
Subtotal East			2.2			1.2	***8.4***	***20***	***129***	***304***
Total Site			**788**			**35**	**3024**	**166**	**46528**	**2557**
								Volume, cy:	***24.6***	***1.4***
							@ 70 pcf			

Notes:

1. Treatment zones are shown on Drawing C-3
2. Oxygen equivalents based on:
    - Xylene oxidation stoichiometry = 3.2 lbs Oxygen/lb VOC
    - NOD factor of 5.0 x for low VOC groundwater zones (1-10 ppm), and
    - NOD/TPH factor of 1.2 x for vadose zones and high VOC groundwater zones (100 ppm)
3. Oxidant bulk dry weight requirements based on 6.5% available oxygen in sodium persulfate product.

Treatment Area Oxidant Solution Estimate

Area	Bulk Dry Oxidant Requirement, lbs		Oxidant Solutions, gal by % solution (by weight)						
See Note (1)	See Notes (2, 3)		See Note (4)						
	Vadose	Groundwater	***Vadose***			***Groundwater***			
			10%	20%	1%	10%	1%	0.10%	0.05%
West 1	21090	1880	25108	12554	251077	2238	22382	223817	447634
West 2	25309	125	30129	15065	301292	149	1492	14921	29842
West 3	0	247	0	0	0	294	2940	29403	58807
Subtotal West	*46399*	*2252*	***55237***	***27619***	***552369***	***2682***	***26814***	***268142***	***536283***
East 1	129	24	154	77	1536	29	285	2853	5705
East 2	0	280	0	0	0	334	3335	33353	66706
Subtotal East	*129.0*	*304.1*	***154***	***77***	***1536***	***362***	***3621***	***36206***	***72411***
Total Site	46528	2557							

Notes:

1. Treatment zones are shown on Drawing C-3
2. Oxidant requirements are minimum required for VOC treatment (summarized on Table C-5.)
3. Bulk ddry oxidant requirements based on 6.5% available oxygen in sodium persulfate product.
4. Sodium persulfate solutions at 100g/L (10%), 200g/L (20%) and 10g/L (1%) ~ 8.4 lbs/gal. Max solubility of NaSO ~ 730g/L at 25 deg C

Essex Jamestown Site
UST Area ISCO
Unit Area Oxidant Solution Estimates

Unit Area Oxidant Solution Estimates

Treatment Area Bulk Dry Oxidant Estimate

Treatment Zone Area, See Note (1)	VOC Average Conc., ppm		Injection Dry Oxidant Req't, lbs/ft, See Notes (2, 3, 4)		Infiltration Dry Oxidant Req't, lbs/sf, See Notes (2, 3, 5)	
	Vadose	***Groundwater***	***Vadose***	***Groundwater***	***Vadose***	***Groundwater***
West 1	500	100	NA	***37***	***3.5***	NA
West 2	500	1	NA	***1.5***	***3.5***	NA
West 3	0	1	NA	***1.5***	***NA***	NA
East 1	10	1	NA	***1.5***	***0.07***	NA
East 2	0	1	NA	***1.5***	***NA***	NA

Groundwater Zone Oxidant Solutions

Oxidant Solution Volume per Injection Point (gal/ft by % solution) and Pore Volume, See Notes (4 and 6)

Area	***1%***	PVs	***10%***	PVs	***0.1%***	PVs	***0.05%***	PVs
West 1	442	2.0	44.2	0.2	4420	19.7	8840	39.5
West 2	18	0.08	1.8	0.008	184	0.8	368	1.6
West 3	18	0.08	1.8	0.008	184	0.8	368	1.6
East 1	18	0.08	1.8	0.008	184	0.8	368	1.6
East 2	18	0.08	1.8	0.008	184	0.8	368	1.6

Vadose Zone Oxidant Solutions

Oxidant Solution Volume per Infiltration Area (gal/sq-ft/ft by % solution) and Pore Volume, See Notes (5 and 6)

Area	***1%***	PVs	***5%***	PVs	***10%***	PVs	***20%***	PVs
West 1	42.5	19.0	8.5	3.79	4.3	1.90	2.1	0.9
West 2	42.5	19.0	8.5	3.79	4.3	1.90	2.1	0.9
West 3	*groundwater injection only*							
East 1	0.9	0.4	0.2	0.08	0.1	0.04	0.04	0.02
East 2	*groundwater injection only*							

Notes:

1. Treatment zones are shown on Drawing C-3
2. Oxygen requirements summarized on Table C-5.
3. Oxidant requirements based on 6.5% available oxygen in sodium persulfate product.
4. Injection point based on injections at 10 ft centers (5 ft radius of influence). Use 100 sf/ft injection. PV= 1 Pore volume of formation at porosity = 0.3 = 2.24 gal/cf = 224 gal/100 sf-ft (See Table C-1)
5. Infiltration application based on per square foot of surface area. PV= Pore volume of formation at porosity = 0.3 (See Table C-1)
6. Oxidant requirements calculated at injected persulfate solutions of 10g/L (1%), 50g/L (5%), 100g/L (10%), 200g/L (20%) and 1g/L (0.1%). Density ~ 8.4 lbs/gal. Max solubility of NaSO ~ 730g/L at 25 deg C

Essex Jamestown Site
UST Area ISCO
Unit Area Oxidant Delivery Plan

Oxidant Solution Delivery Plan

INJECTION PLAN- GROUNDWATER

	Oxidant Mix per Injection Point (10 ft spacings)						***Bulk Dry Mixtures***		
	Oxidant Solution		***Fe-EDTA, 0.35%***	***VeruSol 3, 1%***	***Oxidant Solution***	***PVs***	***Fe-EDTA, 0.35%***	***VeruSol 3, 0.2-1%***	***Oxidant. NaSO***
Area	***%***	***gal/ft***	**Total lbs**	**Total Gallons**			**lbs/1000 gal**		
West 1	5	88	1.5	11	1061	0.4	1.5	10	417
West 2	0.5	37	0.1	4	442	0.16	0.15	2	42
West 3	0.5	37	0.1	4	442	0.16	0.15	2	42
East 1	0.5	37	0.1	4	442	0.16	0.15	2	42
East 2	0.5	37	0.1	4	442	0.16	0.15	2	42

INFILTRATION PLAN- VADOSE ZONES

	Oxidant Mix per Infiltration Area						***Bulk Dry Mixtures***		
	Oxidant Solution		***Fe-EDTA, 0.35%***	***VeruSol 3, 1%***	***Oxidant Solution***	***PVs***	***Fe-EDTA, 0.35%***	***VeruSol 3, 0.2-1%***	***Oxidant. NaSO***
Area	***%***	***gal/sq ft/ft***	**Total lbs**	**Total Gallons**			**lbs/1000 gal**		
West 1	20	2.1	105	181	18063	0.95	5.8	10	1667
West 2	20	2.1	126	217	21676	0.95	5.8	10	1667
West 3	groundwater-injection only								
East 1	0.5	1.7	0.6	44	4420	0.76	0.15	2	42
East 2	groundwater-injection only								

Notes:

1. Injection dosing based on an average 16 foot deep injection point and a treatment zone from 4-16 ft BGS.
2. Injection point at 10 ft centers (5 ft radius of influence). Use 100 sf/ft injection. PV= Pore volume (1) = 2.24 gal/cf = 224 gal/100 sf-ft
3. Infiltration application based on per square foot of surface area. PV= 2.24 gal/sf/ft

APPENDIX D

Oxidant and Additives Chemical Properties and MSDSs

VeruSOL-3®

MATERIAL SAFETY DATA SHEET

Section 1: PRODUCT AND COMPANY IDENTIFICATION

Manufacturer: VeruTEK® Technologies, Inc.
Address: 65 West Dudley Town Road, Suite 100, Bloomfield, CT 06002
Phone Number: (860) 242-9800

Product Name: VeruSOL-3®
Issue Date: January 2010

Section 2: HAZARDS IDENTIFICATION

Emergency Overview

Appearance/Odor: Yellow to amber, slightly viscous with citrus odor.

Product is combustible.

Stability: Product is stable under normal conditions.

Slippery when spilled.

Potential Health Effects: See Section 11 for more information.

Likely Routes of Exposure: Eye contact, skin contact, inhalation.

Eye:	Causes moderate to severe irritation.
Skin:	May cause slight redness. Prolonged or repeated exposure may cause drying of the skin.
Inhalation:	May cause nose, throat, and respiratory tract irritation, coughing, headache.
Ingestion:	Not likely to be toxic, but may cause vomiting, headache, or other medical problems.

Medical Conditions Aggravated By Exposure: May irritate the skin of people with pre-existing skin conditions.

This product does not contain any carcinogens or potential carcinogens as listed by OSHA, IARC, or NTP.

OSHA Regulator Status
This material is combustible, which is defined as having a flash point between 100°F (37.8°C) and 200°F (93.3°C)

Section 3: COMPOSITION/INFORMATION ON INGREDIENTS

	Percent by wt.	CAS
Citrus Terpenes	10-40	94266-47-4
Non-ionic Surfactant	10-40	N/A
Non-ionic Surfactant	10-40	N/A
Non-ionic Surfactant	10-40	N/A

Section 4: FIRST AID MEASURES

Eye Contact:
Flush with water for at least 15 minutes. If irritation persists, seek medical attention.

Skin Contact:
Wash affected area with copious amounts of soap and water for at least 15 minutes. Remove contaminated clothing. If irritation develops, seek medical attention.

Inhalation:
Move to fresh air immediately. If breathing is difficult or discomfort persists, seek medical attention.

Ingestion:

Rinse mouth with water. Dilute by drinking 1 or 2 glasses of water. Do not induce vomiting. Seek medical attention immediately. Do not administer anything by mouth to an unconscious person.

Notes to Medical Doctor:
Direct contact may be minimally irritating. Treatment is by dilution and is symptomatic and supportive.

Section 5: FIRE FIGHTING MEASURES

Flash Point (Method): N/A **Explosion Limits:** Upper: N/A Lower: N/A

Suitable Extinguishing Media:
Carbon dioxide, foam, or dry chemical. Caution: Carbon dioxide will displace air in confined spaces and may create an oxygen deficient atmosphere.

Protection of Firefighters:
Vapors may be irritating to eyes, skin and respiratory tract. Firefighters should wear self-contained breathing apparatus (SCBA) and full fire-fighting turnout gear.

Section 6: ACCIDENTAL RELEASE MEASURES

Personal Precautions: Use personal protection recommended in Section 8. Product is slippery when spilled. Isolate the hazard area. Deny entry to unnecessary and unprotected personnel.

Environmental Precautions: Keep out of drains, sewers, ditches, and waterways.

Methods for Containment: Dike spill area and cap leaking containers as necessary to prevent further spreading of spilled material. Absorb spilled liquid with suitable material.

Methods for Clean Up: Eliminate all ignition sources. Use equipment rated for use around combustible materials. Oil-soaked rags may spontaneously combust; place in appropriate disposal container.

Other Information: There are no special reporting requirements for spills of this material.

Section 7: HANDLING AND STORAGE

Handling
Keep away from heat, sparks, and flame. Open container slowly to release pressure caused by temperature variations. Do not allow this material to come in contact with eyes. Avoid prolonged contact with skin. Use in well-ventilated areas. Do not breathe vapors.As with any chemical, employees should thoroughly wash hands with soap and water after handling this material

Storage

Product may be packaged in phenolic-lined, steel containers or fluorinated plastic containers. Store in well-ventilated area. Storage temperature should not exceed flashpoint for extended periods of time. Keep container closed when not in use. Air should be excluded from partially-filled containers by displacing with nitrogen or carbon dioxide. Do not cut, drill, grind, or weld on or near this container; residual vapors may ignite.

Section 8: EXPOSURE CONTROLS/PERSONAL PROTECTION

Exposure Guidelines

Citrus Terpenes	8h TWA=30ppm (AIHA Standard)
Nonionic Surfactant	N/E (N/E - Not Established)
Nonionic Surfactant	N/E
Nonionic Surfactant	N/E

Engineering Controls:

Provide ventilation to minimize the release of vapors and mist into the work environment. Spills should be minimized or confined to prevent release from work area. Remove contaminated clothing immediately and wash before reuse. Keep away from sparks and flames.

Eye/Face Protection:
Wear chemical splash-type safety glasses or goggles. Use full face mask if severe splashing is expected during use.

Skin Protection:
Liquid proof neoprene gloves are recommended. Nitrile gloves are adequate. Wear boots, apron, or bodysuits as necessary.

Respiratory Protection:
Not normally required. If adequate ventilation is unavailable, use NIOSH approved air-purifying respirator with organic vapor cartridge or canister.

General Hygiene Considerations:
As with any chemical, wash hands thoroughly after handling. Have eyewash facilities immediately available.

Section 9: PHYSICAL AND CHEMICAL PROPERTIES

Color:	Yellow to amber	**Odor:**	Citrus odor.
Physical State:	Liquid	**Boiling Point:**	212ºF (100ºC)
Specific Gravity:	0.972 to 0.984 @ 77ºF (25ºC)	**Vapor Pressure:**	<2mmHg @ 68°F (20°C)
Flash Point:	130°F (54.4°C)	**Solubility in Water:**	Soluble.

Volatile Organic Compound (VOC) Content: <10 to 40% by volume.

Note: These specifications represent a typical sample of this product, but actual values may vary. Certificates of Analysis and Specification Sheets are available upon request.

Section 10: STABILITY AND REACTIVITY

Stability: Stable.

Conditions to Avoid: Keep away from heat, sparks, flames, and contamination.

Incompatible Materials: Strong oxidizing agents and strong acids, including acidic clays, peroxides, halogens, vinyl chloride, and iodine pentafluoride.

Hazardous Decomposition Products: Oxides of citrus terpenes, which can result from improper storage and handling, are known to cause skin sensitization.

Possibility of Hazardous Reactions: BHT, an antioxidant, has been added to prevent oxidation. Avoid long-term exposure to air. If storing partially-filled container, fill headspace with an inert gas such as nitrogen or carbon dioxide

Section 11: TOXICOLOGICAL INFORMATION

Acute Effects
Citrus terpenes have been shown to have low oral toxicity (LD50>5 g/kg) and low dermal toxicity (LD50> 5g/kg) when tested on rabbits. Citrus terpenes also showed low toxicity by inhalation (RD50>1 g/kg) when tested on mice. Product may be a skin and eye irritant. Inhalation may cause irritation of the nose, throat, and respiratory tract.

Chronic Effects
This product is not classified as a carcinogen by OSHA, IARC, or NTP. This product has not been shown to produce genetic changes when tested on bacterial or animal cells. This product does not contain known reproductive or developmental toxins. Prolonged or repeated exposure can cause drying or dermatitis of skin. Improper storage and handling may lead to the formation of a possible skin sensitizer.

Section 12: ECOLOGICAL INFORMATION

Ecotoxicity: N/A

Persistence/Degradability: Product is expected to be readily biodegradable.

Bioaccumulation/Accumulation: No appreciable bioconcentration is expected in the environment.

Mobility in Environment: Citrus terpenes volatilize rapidly.

Section 13: DISPOSAL CONSIDERATIONS

Disposal:
An acceptable method of disposal is to dilute with large amounts of water and allow the hydrogen peroxide to decompose, at which point it may be discharged into a suitable treatment system in accordance with regulatory agencies.

Section 14: TRANSPORT INFORMATION

US DOT Shipping Classification
Hazard Class: 3
Identification No.: UN2319
Packing Group: III
Label/Placard: exception §173.150(f) applies.

TDG Status: Hazardous
IMO Status: Hazardous
IATA Status: Hazardous

The listed transportation classification does not address regulatory variations due to changes in package size, mode of shipment, or other regulatory descriptions.

Section 15: REGULATORY INFORMATION

Global Inventories
The components of this product are included in the following inventories:
USA (TSCA)
Canada (DSL)
Australia (AICS)
Korea (KECL)
Philippines (PICCS)

Proposition 65: California Safe Drinking Water and Toxic Enforcement Act of 1986
This product is not known to contain any chemicals currently listed as carcinogens or reproductive toxins under California Proposition 65 at levels which would be subject to the proposition.

Section 16: OTHER INFORMATION

NFPA 704: National Fire Protection Association

Health – 1	Fire – 2	Reactivity – 0

Legend
OSHA – United States Occupational Health and Safety Administration
IARC – International Agency for Research on Cancer
NTP – National Toxicology Program
NIOSH – National Institute for Occupational Safety and Health
EPA – United States Environmental Protection Agency

Caution: The user should conduct his/her own experiments and establish proper procedures and control before attempting use on critical parts.

The information contained herein is based on current knowledge and experience: no responsibility is accepted that the information is sufficient or correct in all cases. Users should consider these data only as a supplement to other information obtained by the user. No warranty is expressed or implied regarding the accuracy of this data, the results to be obtained from the use thereof, or that any such use will not infringe any patent. Users should make independent determinations of suitability and completeness of information from all sources to assure proper use and disposal of these materials, the safety and health of employees and customers, and the protection of the environment. This information is furnished upon the condition the person receiving it shall determine the suitability for the particular purpose. This MSDS is to be used as a guideline for safe work practices and emergency response.

Material Safety Data Sheet

Material Name: Sodium Persulfate

ID: C1-180

* * * Section 1 - Chemical Product and Company Identification * * *

Chemical Name: Sodium Persulfate
Product Use: For Commercial Use, Not To Be Used As A Pesticide
Synonyms: Peroxydisulfuric Acid, Disodium Salt; Disodium Peroxodisulphate; Disodium Peroxodisulfate; Disodium Peroxydisulfate; Disodium Persulfate; Sodium Peroxodisulfate; Sodium Peroxydisulfate

Supplier Information

Chem One Ltd.
8017 Pinemont Drive, Suite 100
Houston, Texas 77040-6519

Phone: (713) 896-9966
Fax: (713) 896-7540
Emergency # (800) 424-9300 or (703) 527-3887

General Comments

NOTE: Emergency telephone numbers are to be used only in the event of chemical emergencies involving a spill, leak, fire, exposure, or accident involving chemicals. All non-emergency questions should be directed to customer service.

* * * Section 2 - Composition / Information on Ingredients * * *

CAS #	Component	Percent
7775-27-1	Sodium Persulfate	90-100%

Component Information/Information on Non-Hazardous Components

This product is considered hazardous under 29 CFR 1910.1200 (Hazard Communication).

* * * Section 3 - Hazards Identification * * *

Emergency Overview

Sodium Persulfate is an odorless, white solid in crystalline powder form. The primary health hazard associated with this product is the potential for irritation of the eyes, skin, nose and other tissues that come in contact with dusts or particulates of this product. Contact with this product may cause allergic reactions. This product is a powerful oxidizer and can act to initiate and sustain the combustion of combustible materials. Thermal decomposition of this product produces irritating vapors and toxic gases (e.g. sulfur oxides and sodium oxides). Emergency responders should wear proper personal protective equipment for the releases to which they are responding.

Hazard Statements

DANGER! STRONG OXIDIZER. CONTACT WITH COMBUSTIBLE MATERIALS MAY CAUSE FIRE. HARMFUL OR FATAL IF SWALLOWED. HARMFUL IF INHALED. CAUSES IRRITATION TO EYES, SKIN, AND RESPIRATORY TRACT. MAY CAUSE RESPIRATORY SENSITIZATION AND ALLERGIC REACTION BY INHALATION. Keep from contact with combustible materials. Avoid contact with eyes and skin. Avoid breathing dusts. Wash thoroughly after handling. Keep container closed. Use with adequate ventilation.

Potential Health Effects: Eyes

Exposure to particulates or solution of this product may cause irritation of the eyes with symptoms such as stinging, tearing and redness. Prolonged contact may cause chemical burns.

Potential Health Effects: Skin

This product can cause irritation of the skin, with symptoms such as reddening, discomfort and itching. Prolonged skin contact may lead to severe irritation or chemical burns. Prolonged or repeated contact may cause allergic skin reactions.

Potential Health Effects: Ingestion

Ingestion of this product can cause nausea, vomiting, abdominal cramps, headache, and possible burns. Ingestion of large volumes of this product may be fatal.

Potential Health Effects: Inhalation

Breathing dusts or particulates generated by this product can lead to irritation of the nose, throat or respiratory system. Symptoms of such exposure could include coughing and sneezing. Repeated or prolonged exposure can cause an asthma-like allergic reaction. Symptoms of such reaction can include wheezing, difficulty breathing, and nasal congestion.

HMIS Ratings: Health Hazard: 2* **Fire Hazard:** 0 **Physical Hazard:** 1
Hazard Scale: 0 = Minimal 1 = Slight 2 = Moderate 3 = Serious 4 = Severe * = Chronic hazard

* * * Section 4 - First Aid Measures * * *

First Aid: Eyes

In case of contact with eyes, rinse immediately with plenty of water for at least 20 minutes. Seek immediate medical attention.

First Aid: Skin

Remove all contaminated clothing. For skin contact, wash thoroughly with soap and water for at least 20 minutes. Seek immediate medical attention if irritation develops or persists.

* * * Section 4 - First Aid Measures (Continued) * * *

First Aid: Ingestion

DO NOT INDUCE VOMITING. Have victim rinse mouth thoroughly with water, if conscious. Never give anything by mouth to a victim who is unconscious or having convulsions. Contact a physician or poison control center immediately.

First Aid: Inhalation

Remove source of contamination or move victim to fresh air. Apply artificial respiration if victim is not breathing. Do not use mouth-to-mouth method if victim ingested or inhaled the substance; induce artificial respiration with the aid of a pocket mask equipped with a one-way valve or other proper respiratory medical device. Administer oxygen if breathing is difficult. Get immediate medical attention.

First Aid: Notes to Physician

Provide general supportive measures and treat symptomatically.

* * * Section 5 - Fire Fighting Measures * * *

Flash Point: Not flammable

Method Used: Not applicable

Upper Flammable Limit (UEL): Not applicable

Lower Flammable Limit (LEL): Not applicable

Auto Ignition: Not applicable

Flammability Classification: Not applicable

Rate of Burning: Not applicable

General Fire Hazards

Sodium Persulfate is not combustible; however, it is a strong oxidizer, which can act to initiate and sustain the combustion of flammable materials. Contact with combustible materials, flammable materials or powdered metals can cause fire or explosion. Sodium Persulfate can ignite when shocked. Damp Sodium Persulfate in contact with combustible materials may cause spontaneous combustion. When involved in a fire, this material may decompose and produce irritating vapors, acrid smoke and toxic gases (e.g. sulfur oxides and sodium oxide). Closed containers may explode when exposed to heat.

Hazardous Combustion Products

Sodium oxide and sulfur oxides.

Extinguishing Media

Use water only, do not use dry chemical, CO2 or halon. Flood fire with water from a distance.

Fire Fighting Equipment/Instructions

Firefighters should wear full protective clothing including self-contained breathing apparatus. Cool containers with flooding quantities of water. For large fires, use unmanned hoses or monitor nozzles; if this is not possible, withdraw from area and let fire burn. If possible control runoff from fire control or dilution water to prevent environmental contamination.

NFPA Ratings: Health: 2 **Fire:** 0 **Reactivity:** 1 **Other:** Oxidizer

Hazard Scale: 0 = Minimal 1 = Slight 2 = Moderate 3 = Serious 4 = Severe

* * * Section 6 - Accidental Release Measures * * *

Containment Procedures

Stop the flow of material, if this can be done without risk. Contain the discharged material. If sweeping of a contaminated area is necessary use a dust suppressant agent, which does not react with product. Wipe down area routinely to avoid the accumulation of dusts.

Clean-Up Procedures

Keep combustible materials away from spilled material. Small releases can be cleaned-up wearing gloves, goggles and suitable body protection. In case of a large spill (in which excessive dusts can be generated), clear the affected area, protect people, and respond with trained personnel. Place all spill residues in an appropriate container and seal. Thoroughly wash the area after a spill or leak clean-up. Prevent rinsate of spill area from contamination to sewer, groundwater or soil.

Evacuation Procedures

Evacuate the area promptly and keep upwind of the spilled material. Isolate the spill area to prevent people from entering. In case of large spills, follow all facility emergency response procedures.

Special Procedures

Remove soiled clothing and launder before reuse. Avoid all skin contact with the spilled material. Have emergency equipment readily available.

* * * Section 7 - Handling and Storage * * *

Handling Procedures

All personnel who handle this material, should be thoroughly trained to handle it safely. Do not breathe dust. Avoid all contact with skin and eyes. Wherever dust clouds may be generated, eliminate sparks, flames and other ignition sources. Use this product only with adequate ventilation. Wash thoroughly after handling. Care should be taken to avoid the accumulation of dusts, which can create a serious dust-explosion hazard.

Storage Procedures

Keep container tightly closed when not in use. Store containers in a cool, dry location, away from direct sunlight, sources of intense heat, or where freezing is possible. Material should be stored in secondary containers or in a diked area, as appropriate. Store containers away from incompatible chemicals (see Section 10, Stability and Reactivity). Storage areas should be made of corrosion- and fire-resistant materials. Post warning and "NO SMOKING" signs in storage and use areas, as appropriate. Use corrosion-resistant structural materials, lighting, and ventilation systems in the storage area. Floors should be sealed to prevent absorption of this material. Inspect all incoming containers before storage, to ensure containers are properly labeled and not damaged. Have appropriate extinguishing equipment in the storage area (i.e., sprinkler system, portable fire extinguishers).

Empty containers may contain residual particulates; therefore, empty containers should be handled with care. Do not cut, grind, weld, or drill near this container. Never store food, feed, or drinking water in containers that held this product. Keep this material away from food, drink and animal feed. Do not store this material in open or unlabeled containers. Limit quantity of material stored.

* * * Section 8 - Exposure Controls / Personal Protection * * *

Exposure Guidelines

A: General Product Information

Follow the applicable exposure limits.

B: Component Exposure Limits

Sodium Persulfate (7775-27-1)

ACGIH: 0.1 mg/m^3 TWA

Engineering Controls

Use mechanical ventilation such as dilution and local exhaust.

PERSONAL PROTECTIVE EQUIPMENT

The following information on appropriate Personal Protective Equipment is provided to assist employers in complying with OSHA regulations found in 29 CFR Subpart I (beginning at 1910.132) or equivalent Standards of Canada. Please reference applicable regulations and standards for relevant details.

Personal Protective Equipment: Eyes/Face

Wear safety glasses with side shields or chemical goggles. If necessary, refer to U.S. OSHA 29 CFR 1910.133.

Personal Protective Equipment: Skin

Wear impervious gloves. Neoprene, PVC, rubber or equivalent gloves are recommended. Wear long-sleeved shirt and trousers. If necessary, refer to U.S. OSHA 29 CFR 1910.138.

Personal Protective Equipment: Respiratory

No specific guidelines are available. If airborne concentrations are above the applicable exposure limits, use NIOSH-approved respiratory protection. Special applications may necessitate the use of more stringent respiratory protection. If respiratory protection is needed, use only protection authorized in the U.S. Federal OSHA Standard (29 CFR 1910.134), applicable U.S. State regulations. Oxygen levels below 19.5% are considered IDLH by OSHA. In such atmospheres, use of a full-facepiece pressure/demand SCBA or a full facepiece, supplied air respirator with auxiliary self-contained air supply is required under OSHA's Respiratory Protection Standard (1910.134-1998). If airborne concentrations are above the applicable exposure limits, use NIOSH-approved respiratory protection.

Personal Protective Equipment: General

Have an eyewash fountain and safety shower available in the work area. Wash hands thoroughly after handling material.

* * * Section 9 - Physical & Chemical Properties * * *

Physical Properties: Additional Information

The data provided in this section are to be used for product safety handling purposes. Please refer to Product Data Sheets, Certificates of Conformity or Certificates of Analysis for chemical and physical data for determinations of quality and for formulation purposes.

Appearance:	White crystalline powder	**Odor:**	Odorless
Physical State:	Solid	**pH:**	6.0 (1% solution)
Vapor Pressure:	Not applicable	**Vapor Density:**	Not applicable
Boiling Point:	Not available	**Melting Point:**	Not available
Solubility (H2O):	549 g/L @ 20 deg C	**Specific Gravity:**	2.4 (H2O = 1)
Freezing Point:	Not applicable	**Particle Size:**	Not available
Softening Point:	Not applicable	**Bulk Density:**	Not available
Molecular Weight:	238.13	**Chemical Formula:**	Na2S2O8

* * * Section 10 - Chemical Stability & Reactivity Information * * *

Chemical Stability

Gradually decomposes; promoted by moisture and high temperatures.

Chemical Stability: Conditions to Avoid

Avoid high temperatures, exposure to air, moisture, friction, shock and incompatible materials.

Incompatibility

Sodium Persulfate is a strong oxidizing agent and presents a serious fire and explosion risk. Do not permit contact with combustible, organic or other oxidizable materials. Avoid contact with strong acids, alkalis, halides, reducing agents, organic materials, combustibles, finely powdered metals, iron, copper, zinc, sodium peroxide, aluminum + water, magnesium, alcohols, hydrazine and organic monomers.

Hazardous Decomposition

Sulfur oxides and sodium oxide.

Hazardous Polymerization

Will not occur.

* * * Section 11 – Toxicological Information * * *

Acute and Chronic Toxicity

A: General Product Information

May cause eye, skin, nose, throat and respiratory tract irritation. Depending on the duration of contact, over-exposures can irritate or burn the eyes, skin, mucous membranes and any other exposed tissue. If inhaled, irritation of the respiratory system can occur, with coughing and breathing difficulty. May cause allergic skin and respiratory sensitization. Harmful or fatal if swallowed. Chronic: Long term skin overexposure to this product may lead to dermatitis (red, itchy skin).

B: Component Analysis - LD50/LC50

Sodium Persulfate (7775-27-1):

LD_{50} (Intraperitoneal-Mouse) 226 mg/kg

B: Component Analysis - TDLo/LDLo

LDLo (Intravenous-Rabbit, adult) 178 mg/kg Carcinogenicity

A: General Product Information

No information available.

B: Component Carcinogenicity

This compound is not listed by ACGIH, IARC, OSHA, NIOSH or NTP.

Epidemiology

No information available.

Neurotoxicity

No information available.

Mutagenicity

No information available.

Teratogenicity

No information available.

Other Toxicological Information

None.

* * * Section 12 - Ecological Information * * *

Ecotoxicity

A: General Product Information

No information available.

B: Ecotoxicity

Sodium Persulfate:

LC_{50} (*Poecilia reticulata* Guppy) 48 hours = 631000 µg/L; LC_{50} (*Cyclops strenuus* Cyclopoid copepod) 48 hours = 649,000 µg/L

Environmental Fate

No data available for this product.

* * * Section 13 - Disposal Considerations * * *

US EPA Waste Number & Descriptions

A: General Product Information

This product may be considered an EPA Waste D001 (Ignitable-Oxidizer).

B: Component Waste Numbers

No EPA Waste Numbers are applicable for this compound.

Disposal Instructions

All wastes must be handled in accordance with local, state and federal regulations or with regulations of Canada and its Provinces. This product, if unaltered by use, may be disposed of by treatment at a permitted facility or as advised by your local hazardous waste regulatory authority.

* * * Section 14 - Transportation Information * * *

NOTE: The data in this section (Section 14) are meant as a guide to the overall classification of the product. However, transportation classifications may be subject to change with changes in package size. Consult shipper requirements under I.M.O., I.C.A.O. (I.A.T.A.) and 49 CFR to assure regulatory compliance.

US DOT Information

UN/NA #: UN 1505
Shipping Name: Sodium persulfate
Hazard Class: 5.1
Packing Group: III
Required Label(s): 5.1

Additional Shipping Information

The Limited Quantities of Division 5.1 materials exception [49 CFR 173.152 (b)] may be applicable to shipments of Sodium Persulfate if each inner packaging does not exceed 5.0 kg (11 pounds) and packaged in strong outer packages not to exceed 30 kg (66 pounds). Such shipments need not be marked with the Proper Shipping Name of the contents, but shall be marked with the UN Number (1505) of the contents, preceded by the letters "UN", placed within a diamond. The width of the line forming the diamond shall be at least 2 mm; the number shall be at least 6 mm high For a shipment by air the class 5.1 label will be required.

International Air Transport Association (IATA):

For Shipments by Air transport: This information applies to air shipments both within the U.S. and for shipments originating in the U.S., but being shipped to a different country

UN/NA #: UN 1505
Proper Shipping Name: Sodium persulphate
Hazard Class: 5.1
Packing Group: III
Passenger & Cargo Aircraft Packing Instruction: 516
Passenger & Cargo Aircraft Maximum Net Quantity: 25 kg
Limited Quantity Packing Instruction (Passenger & Cargo Aircraft): Y516
Limited Quantity Maximum Net Quantity (Passenger & Cargo Aircraft): 10 kg
Cargo Aircraft Only Packing Instruction: 518
Cargo Aircraft Only Maximum Net Quantity: 100 kg
Special Provisions: None
ERG Code: 5L

Limited Quantity Shipments: Such shipments must be marked with the proper shipping name, UN number, and must be additionally marked with the words "LIMITED QUANTITIES" or "LTD. QTY". The total weight of each outer packaging cannot exceed 30 kg (66 pounds) . For a shipment by air the class 5.1 label will be required.

* * * Section 14 - Transportation Information (Continued) * * *

International Maritime Organization (I.M.O.) Classification

For shipments via marine vessel transport, the following classification information applies.

UN/NA #: UN 1505
Proper Shipping Name: SODIUM PERSULPHATE
Hazard Class: class 5.1
Packing Group: III
Special Provisions: None
Limited Quantities: 5 kg
Packing Instructions: P002, LP02
IBC Instructions: IBC08
IBC Provisions: B3
EmS: F-A, S-Q
Stowage and Segregation: Category A.

Limited Quantity Shipments: Such shipments need not be marked with the Proper Shipping Name of the contents, but shall be marked with the UN Number (1505) of the contents, preceded by the letters "UN", placed within a diamond. The width of the line forming the diamond shall be at least 2 mm; the number shall be at least 6 mm high. The total weight of each outer packaging cannot exceed 30 kg (66 pounds).

* * * Section 15 - Regulatory Information * * *

US Federal Regulations

A: General Product Information

No additional information.

B: Component Analysis

This material contains no chemical component required to be identified under SARA Section 302 (40 CFR 355 Appendix A), SARA Section 313 (40 CFR 372.65) and/or CERCLA (40 CFR 302.4).

SARA 302 (EHS TPQ) There are no specific Threshold Planning Quantities for Sodium Persulfate. The default Federal MSDS submission and inventory requirement filing threshold of 10,000 lbs. (4,540 kg) therefore applies, per 40 CFR 370.20.

C: Sara 311/312 Tier II Hazard Ratings:

Component	CAS #	Fire Hazard	Reactivity Hazard	Pressure Hazard	Immediate Health Hazard	Chronic Health Hazard
Sodium Persulfate	7775-27-1	Yes	No	No	Yes	Yes

State Regulations

A: General Product Information

California Proposition 65

Sodium Persulfate is not on the California Proposition 65 chemical lists.

B: Component Analysis - State

Sodium Persulfate appears on one or more of the following state hazardous substance lists:

Component	CAS #	CA	FL	MA	MN	NJ	PA
Sodium Persulfate	7775-27-1	No	No	No	No	Yes	No

Other Regulations

A: General Product Information

No other information available.

B: Component Analysis - Inventory

Component	CAS #	TSCA	DSL	EINECS
Sodium Persulfate	7775-27-1	Yes	Yes	Yes

C: Component Analysis - WHMIS IDL

Sodium Persulfate is not identified under the Canadian Hazardous Products Act Ingredient Disclosure List.

* * * Section 15 - Regulatory Information (Continued)* * *

ANSI LABELING (Z129.1): **DANGER!** STRONG OXIDIZER. CONTACT WITH COMBUSTIBLE MATERIALS MAY CAUSE FIRE. MAY BE FATAL IF SWALLOWED. MAY CAUSE SKIN AND EYE IRRITATION OR BURNS. HARMFUL IF INHALED. MAY CAUSE RESPIRATORY SENSITIZATION AND ALLERGIC REACTION BY INHALATION. Keep from contact with clothing and other combustible material. Do not taste or swallow. Do not get on skin or in eyes. Avoid breathing dusts and particulates. Keep container closed. Use only with adequate ventilation. Wash thoroughly after handling. Wear gloves, goggles, faceshields, suitable body protection, and NIOSH/MSHA-approved respiratory protection, as appropriate. **FIRST-AID:** In case of contact, immediately flush skin or eyes with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. If inhaled, remove to fresh air. If ingested, do not induce vomiting. Get medical attention. **IN CASE OF FIRE:** Use water only. Do not use dry chemical, CO_2, or “alcohol” foam. **IN CASE OF SPILL:** Clean-up spilled material by dry-sweeping or vacuum, avoiding the generation of dusts. Place residue in suitable container. Consult Material Safety Data Sheet for additional information.

* * * Section 16 - Other Information * * *

Other Information

Chem One Ltd. ("Chem One") shall not be responsible for the use of any information, product, method, or apparatus herein presented ("Information"), and you must make your own determination as to its suitability and completeness for your own use, for the protection of the environment, and for health and safety purposes. You assume the entire risk of relying on this Information. In no event shall Chem One be responsible for damages of any nature whatsoever resulting from the use of this product or products, or reliance upon this Information. By providing this Information, Chem One neither can nor intends to control the method or manner by which you use, handle, store, or transport Chem One products. If any materials are mentioned that are not Chem One products, appropriate industrial hygiene and other safety precautions recommended by their manufacturers should be observed. Chem One makes no representations or warranties, either express or implied of merchantability, fitness for a particular purpose or of any other nature regarding this information, and nothing herein waives any of Chem One's conditions of sale. This information could include technical inaccuracies or typographical errors. Chem One may make improvements and/or changes in the product (s) and/or the program (s) described in this information at any time. If you have any questions, please contact us at Tel. 713-896-9966 or E-mail us at Safety@chemone.com.

Key/Legend

EPA = Environmental Protection Agency; TSCA = Toxic Substance Control Act; ACGIH = American Conference of Governmental Industrial Hygienists; IARC = International Agency for Research on Cancer; NIOSH = National Institute for Occupational Safety and Health; NTP = National Toxicology Program; OSHA = Occupational Safety and Health Administration

Contact: Sue Palmer-Koleman, PhD **Contact Phone:** (713) 896-9966

Revision Log

09/19/00 3:00 PM SEP Changed company name, Sect 1 and 16, from Corporation to Ltd.
08/20/01 4:30 PM CLJ Changed contact to Sue, non-800 Chemtrec Num.
03/18/21 5:26 PM HDF Checked exposure limits; overall review, add SARA 311/312 Haz Ratings.
07/31/03 5:30 pm HDF General review of entire MSDS. Up-graded Section 10 Reactivity Information. Up-Dated entire Section 14 Transportation Information to include IATA, IMO transport information.
06/22/05 1:32 PM SEP Update IATA Section 14
09/05/06 4:33 pm SEP Updated DOT and IMO Section 14

This is the end of MSDS # C1-180

FMC®

Persulfates

Technical Information

AMMONIUM POTASSIUM SODIUM SALTS

QUALITY PERSULFATES
RELIABLE SUPPLY

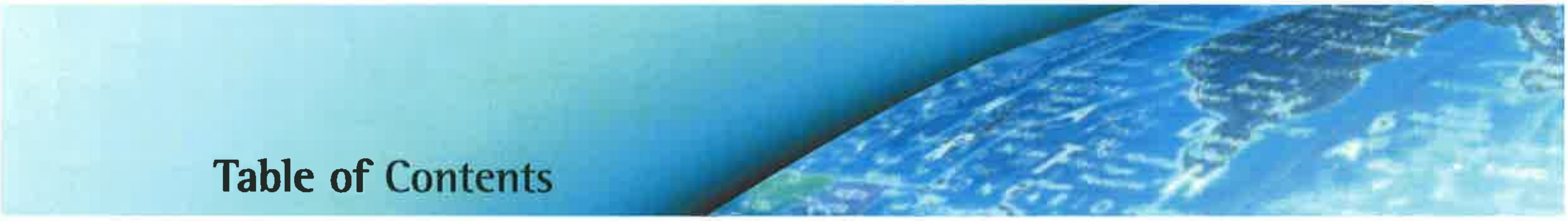


Table of Contents

Applications and Chemistry

Physical and Chemical Data

General Material Information

Customer Support Services

FMC Active Oxidants Sales & Marketing
Pictured from left to right:
Paula Scott, Account Manager
Rosanne Menzel, Senior Product Representative
Robert Mulholland, Account Manager
Richard White, Sales & Marketing Director

Leading the persulfate market with improved products and reliable supply.

Persulfates are the most chemically active of the peroxygens, with great utility in a variety of chemical processes. FMC persulfates, backed by years of experience, are manufactured to strict specifications for thermal stability, making them among the most stable available.

FMC is the leading producer of peroxygen chemicals and a major researcher in active oxidant chemistry. We are the world's largest and North America's only producer of peroxydisulfates, a group of chemicals commonly referred to as persulfates. FMC manufactures ammonium, potassium, and sodium persulfates at a plant in Tonawanda, New York. Our dedicated plant employees contribute to FMC's 70 years of peroxygen production experience.

FMC provides a reliable supply of high-quality, stable persulfates to the global market. The Tonawanda plant is an ISO-9002 certified facility near the Niagara River outside Buffalo, NY. This location provides abundant local resources, including reliable supplies of hydroelectric power and cooling water.

FMC has been the world's leading producer of persulfates for decades, yet we continually find ways to improve our products, especially their safety.

Our research into the characteristics of peroxydisulfates has improved the quality and the stability of all FMC persulfates. An understanding of the crystalline structure of persulfates and the interplay with heat and moisture have changed quality control procedures, manufacturing processes, and storage requirements for these products. We have established new specifications for thermal stability which make persulfates among the most stable available.

Persulfates are strong oxidants, have excellent shelf life when stored properly, and are economical to use. These properties make persulfates suitable for a variety of applications.

FMC is committed to the principles of Product Stewardship and to manufacturing, transporting, storing, and using chemicals in a safe manner. The commitment begins with the manufacturing process and continues throughout the life cycle of our products. Our continuing effort is to ensure that safety, health, and environmental issues are addressed wherever persulfates are handled or used.

Applications and Chemistry

Applications

Persulfates are key components in many industrial processes and commercial products.

The polymer industry uses aqueous solutions of persulfates as initiators in the polymerization of latex and synthetic rubber. The electronics industry considers sodium persulfate an efficient microetchant in the manufacture of printed circuit boards. The following examples further illustrate the chemical versatility of persulfates.

Polymerization

Plastics and rubber — Ammonium, potassium, and sodium persulfates are used as initiators for emulsion polymerization reactions in the preparation of acrylics, polyvinyl chlorides, polystyrenes, and neoprene.

They are used as polymerization initiators in the manufacture of synthetic rubber (styrene butadiene and isoprene) for automobile and truck tires.

Persulfate initiation is used to prepare latex polymers for paints, coatings, and carpet backing.

Structural materials — Persulfates are used as initiators in polymeric concrete formulations.

Inorganic chemicals and minerals — Persulfates are also initiators for the polymeric coating of graphite filaments.

Soil stabilization — Ammonium persulfate is used as a curing agent in chemical grout systems used to stabilize soil near dams, tunnels, and buildings.

Oxidation

Surface preparation — The oxidation power of persulfates is used to clean and microetch a variety of printed circuit board substrates.

Persulfates are important oxidants in plating and coating processes. They are also etchants for nickel, titanium, and zink alloys.

Persulfates are used to clean and mill aluminum, brass, copper, and many other metal surfaces prior to plating or adhesive bonding.

Persulfates are used to clean and activate carbon and charcoal before and after their use as absorbents.

Cosmetics — The cosmetic industry has developed formulations which use persulfates to boost hair bleaching performance.

Organic synthesis — Persulfates are oxidizing agents in the preparation of aldehydes, ketones, carboxylic acids, quinones, and a variety of other compounds.

The pharmaceutical industry uses sodium persulfate as a reagent in the preparation of antibiotics.

Other Applications

Adhesive — Persulfates are used in the preparation of adhesive films and metal bonding adhesives.

Gas and oil production — In enhanced oil recovery, persulfates are used "down hole" for gel forming and breaking.

Inks, pigments, and dispersants — Persulfates are used to graft substrates to polymers (for example, carbon black to sodium acrylate). Persulfates are used in the preparation of dispersants for ink jetting and toner formulations.

Mining — Persulfates can be used in nickel and cobalt separation processes.

Peroxymonosulfate — FMC developed a process using ammonium and sodium persulfates to prepare peroxymonosulfate solutions. This patented process allows fast, efficient, on-site production of an alternative to Caro's acid and potassium caroate.

Photography — Persulfates are used in many photographic applications, including bleaching solutions, solution regeneration, equipment cleaning, and waste water treatment.

Pulp and paper — Persulfates are used in the sizing of paper, preparation of binders and coatings, and production of special papers.

An activated alkali metal persulfate effectively repulps neutral/alkaline wet-strength broke and decolorizes dyes and optical brightener.[1]

Textiles — Ammonium and sodium persulfates are used in the desizing and bleaching of textiles and the development of dyestuffs.

Swimming pools — Clear Advantage® shock treatment is used to oxidize non-filterable waste in swimming pools and other recreational water. Clear Advantage® shock clarifies water and prevents the formation of combined chlorine.

Environmental — Persulfates are very strong oxidants, have excellent shelf life when stored properly, and are economical to use. These properties make persulfates suitable for a variety of environmental applications, such as soil remediation and wastewater/groundwater cleanup.

Oxidation Chemistry

The persulfate anion is the most powerful oxidant of the peroxygen family of compounds.

The electromotive force data listed below compares three commonly used peroxygens:

$$S_2O_8^{-2} + 2H^+ + 2e^- \longrightarrow 2HSO_4^- \qquad E = 2.12V$$

$$H_2O_2 + 2H^+ + 2e^- \longrightarrow 2H_2O \qquad E = 1.77V$$

$$HSO_5^- + 2H^+ + 2e^- \longrightarrow HSO_4^- + H_2O \qquad E = 1.44V$$

Many metals are oxidized by persulfate to form soluble metal sulfates, for example, copper:

$$Cu + S_2O_8^{-2} \longrightarrow CuSO_4 + SO_4^{-2}$$

Under certain circumstances, hydrolysis of the persulfate anion will yield the bisulfate anion and hydrogen peroxide a kinetically faster oxidant than persulfate:

$$S_2O_8^{-2} + 2H_2O \xrightarrow{H^+} 2HSO_4^{-2} + H_2O_2$$

Another reaction of note is the acid-catalyzed hydrolysis of persulfate to form peroxymonosulfate anion.

Fast, high-temperature, acid hydrolysis followed by thermal quenching will yield solutions of peroxymonosulfate:

$$S_2O_8^{-2} + H_2O \xrightarrow{H^+} HSO_4^- + HSO_5^-$$

The resulting solution is a useful replacement for Caro's acid, H_2SO_5 and potassium caroate, $KHSO_5$.

Reactions at different pH:

Neutral (pH 3 to 7)

$$S_2O_8^{-2} + H_2O \longrightarrow 2HSO_4^- + 1/2O_2$$

Dilute acid (pH > 0.3; [H+] < 0.5M)

$$S_2O_8^{-2} + 2H_2O \longrightarrow 2HSO_4^- + H_2O_2$$

Strong acid ([H+] > 0.5M)

$$S_2O_8^{-2} + H_2O \xrightarrow{H^+} HSO_4^- + HSO_5^-$$

Alkaline (pH > 13)

$$S_2O_8^{-2} + OH^- \longrightarrow HSO_4^- + SO_4^{-2} + 1/2O_2$$

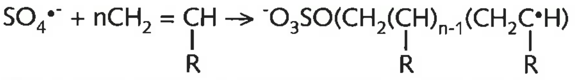
Free Radical Chemistry

Persulfates produce free radicals in many diverse reaction situations.

When solutions of the persulfates are heated, free radicals are formed:

$$S_2O_8^{-2} + heat \longrightarrow 2SO_4^{\bullet -}$$

In the presence of suitable monomers, the radical anions act as polymerization initiators to produce polymer molecules:



$$SO_4^{\bullet -} + nCH_2 = \underset{R}{CH} \rightarrow {}^-O_3SO(CH_2(\underset{R}{CH})_{n-1}(CH_2\underset{R}{C}{}^\bullet H)$$

Free radicals suitable as polymerization initiators are also generated in the presence of reducing agents, for example, the bisulfite anion:

$$S_2O_8^{-2} + HSO_3^- + 1/2O_2 \longrightarrow HSO_4^- + 2SO_4^{\bullet -}$$

Free radicals can also be generated in the presence of transition metals:

$$S_2O_8^{-2} + Fe^{+2} \longrightarrow Fe^{+3} + SO_4^{-2} + SO_4^{\bullet -}$$

and mercaptans:

$$S_2O_8^{-2} + 2RSH \longrightarrow 2HSO_4^- + 2RS^\bullet$$

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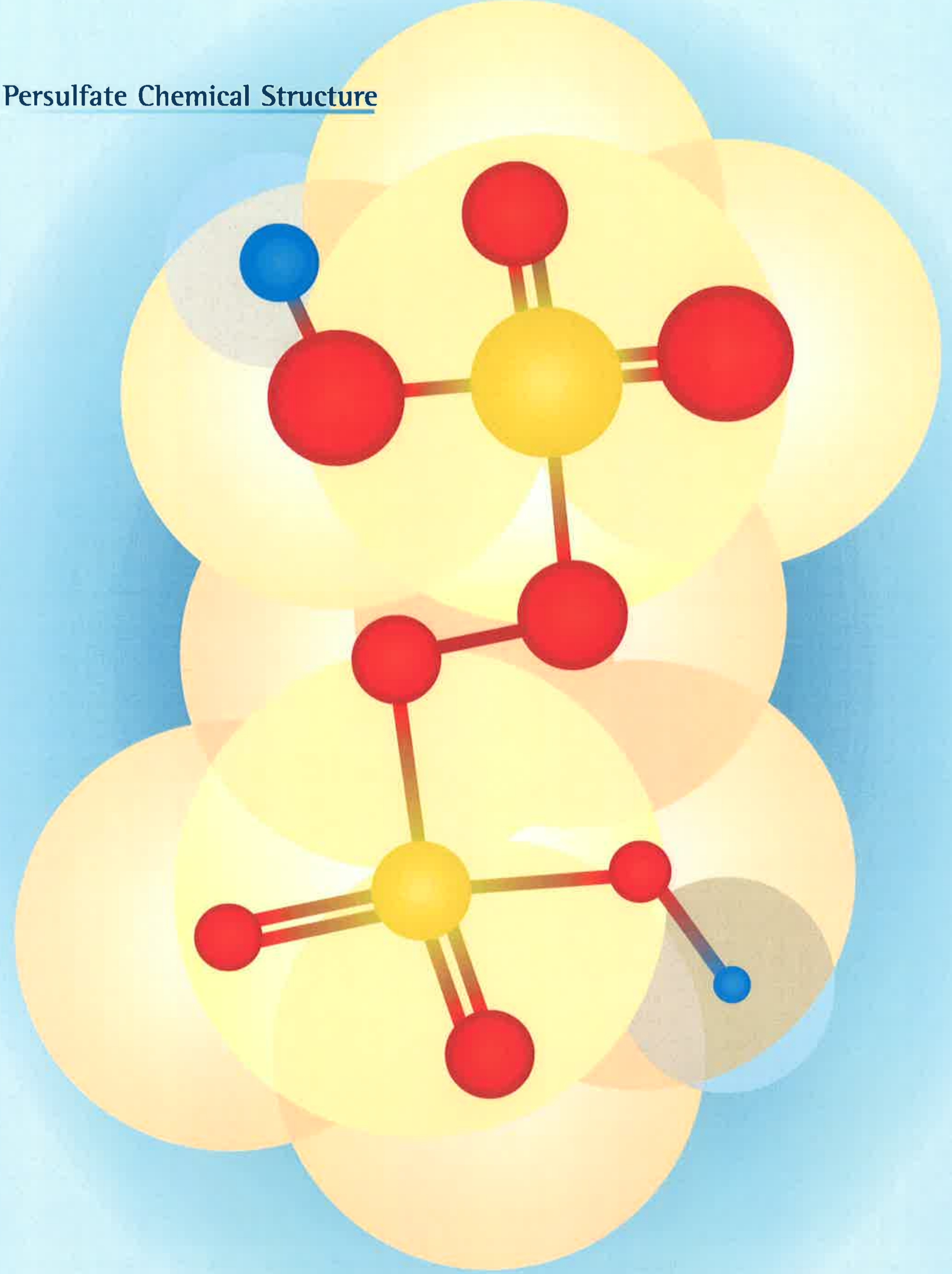
[1] Sold under the tradename Kybreak® a registered trademark of Hercules, Inc.

Persulfate Chemical Structure



Physical and Chemical Data

FMC conducted physical and chemical studies of persulfates to provide the data for this section. You will find the data useful for applying persulfate chemicals to various processes and products.

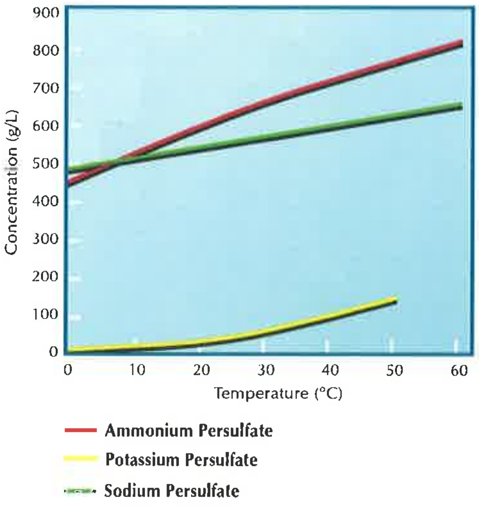
The density, viscosity, electrical conductance, and solution heat capacity data are presented in graphic and equation form. This format enables you to view the general trend of the physical data. Then, with the aid of equations, you can calculate the correct values for your application.

If you have any questions with regard to the information in this section, contact the FMC Research and Development Center in Princeton, NJ. Contact information is listed on the back cover.

Physical and Chemical Properties of Persulfates

Common name	**Ammonium persulfate**	**Potassium persulfate**	**Sodium persulfate**
Chemical name	Ammonium peroxydisulfate	Potassium peroxydisulfate	Sodium peroxydisulfate
Physical form	Crystalline (monoclinic)	Crystalline (triclinic)	Crystalline (monoclinic)
Formula	$(NH_4)_2S_2O_8$	$K_2S_2O_8$	$Na_2S_2O_8$
Molecular weight	228.2	270.3	238.1
Crystal density (g/cc)	1.98	2.48	2.59
Color	Off-white	White	White
Odor	None	None	None
Loose bulk density (g/cc)	1.05	1.30	1.12

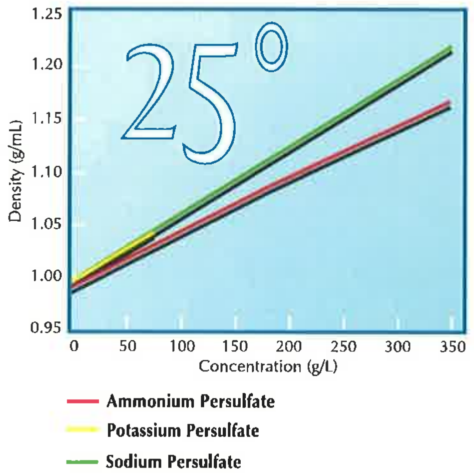
Solubilities of Persulfate Salts



Maximum solubility of persulfate salts in water

Solubility (g/100g of H_20)	**Ammonium Persulfate**	**Potassium Persulfate**	**Sodium Persulfate**
25°C	85	6	73
50°C	116	17	86

Density of Aqueous Solutions



Equation for calculation of density

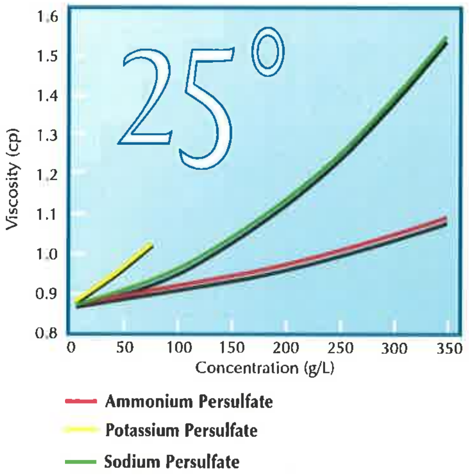
Density (g/mL) = density $H_2O + (A/1000)X + (B/1000)X^{1.5}$,
where X = solution concentration in grams per liter (g/L).

Salt	Constant	25°C	35°C	45°C
Ammonium	A	0.4903	0.4860	0.4789
	B	-2.6730×10^{-4}	-7.6254×10^{-4}	-5.0971×10^{-4}
Potassium	A	0.6368	0.6273	0.6294
	B	-1.4934×10^{-3}	-8.1965×10^{-4}	-1.6472×10^{-3}
Sodium	A	0.6709	0.6727	0.6610
	B	-1.4934×10^{-3}	-1.4909×10^{-3}	-1.0038×10^{-4}

Density of water

	25°C	35°C	45°C
Density H_2O	0.99707	0.99406	0.99025

Viscosity of Aqueous Solutions



Equation for calculation of viscosity

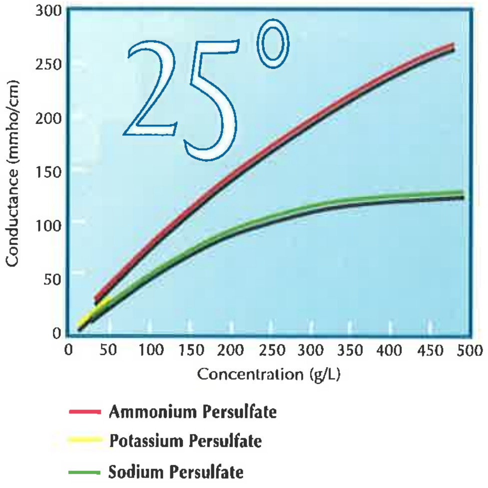
Viscosity (cp) = viscosity $H_2O + CX^{0.5} + DX + EX^{1.5}$,
where X = solution concentration in grams per liter (g/L).

Salt	Constant	25°C	35°C	45°C
Ammonium	C	-1.0686×10^{-3}	6.8050×10^{-3}	5.3134×10^{-3}
	D	1.7140×10^{-4}	-9.4542×10^{-4}	-5.8450×10^{-4}
	E	2.4670×10^{-5}	5.9785×10^{-5}	4.5080×10^{-5}
Potassium	C	0	5.9187×10^{-3}	3.5413×10^{-3}
	D	1.0661×10^{-3}	-1.0551×10^{-3}	-9.5623×10^{-5}
	E	9.8884×10^{-5}	1.0674×10^{-4}	1.2477×10^{-5}
Sodium	C	4.3857×10^{-3}	6.1743×10^{-3}	1.3461×10^{-2}
	D	-1.2218×10^{-3}	-4.6619×10^{-4}	-1.9741×10^{-3}
	E	1.5146×10^{-4}	8.1093×10^{-5}	1.3540×10^{-4}

Viscosity of water

	25°C	35°C	45°C
Viscosity H_2O	0.8904	0.7194	0.5960

Electrical Conductance of Aqueous Solutions

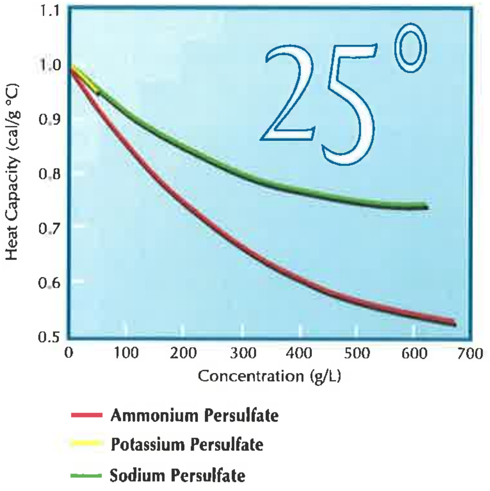


Equation for calculation of electrical conductance

Conductance (mmho/cm) = $F + GX + HX^2$,
where X = solution concentration in grams per liter (g/L).

Salt	Constant	25°C	35°C	45°C
Ammonium	F	3.9016	6.6081	6.2538
	G	0.8568	0.9804	1.1578
	H	-6.2904×10^{-4}	-7.1312×10^{-4}	-8.8912×10^{-4}
Potassium	F	2.9603	3.7314	4.1673
	G	0.6704	0.7972	0.9525
	H	-1.0456×10^{-3}	-1.1982×10^{-3}	-1.9173×10^{-3}
Sodium	F	5.9501	7.1826	8.1825
	G	0.5880	0.6967	0.8123
	H	-6.6193×10^{-4}	-7.5821×10^{-4}	-8.6226×10^{-4}

Heat Capacity of Aqueous Solutions



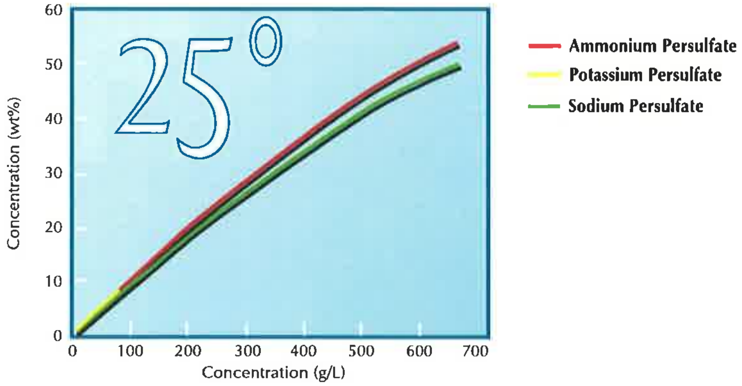
Equation for calculation of heat capacity

Heat capacity (cal/g °C) = $K - LX + MX^{1.5}$,
where X = solution concentration in grams per liter (g/L).

Salt	Constant	25°C
Ammonium	K	0.994
	L	-1.863×10^{-3}
	M	4.531×10^{-5}
Potassium	K	0.997
	L	1.150×10^{-3}
	M	2.670×10^{-5}
Sodium	K	0.997
	L	1.190×10^{-3}
	M	3.112×10^{-5}

Conversion cal/g °C = Btu/lb °F = $\frac{\text{J/g °C}}{4.184}$

Conversion: Grams/Liter to Weight %

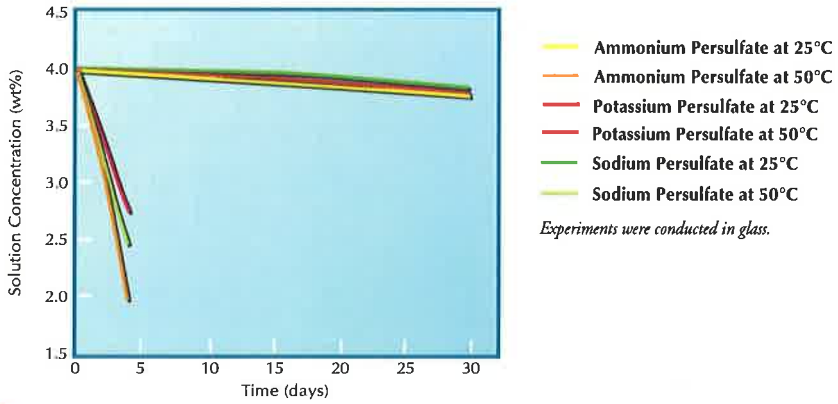


Conversion grams/liter to weight percent

Note: Potassium persulfate is the least soluble of the three FMC persulfate salts.

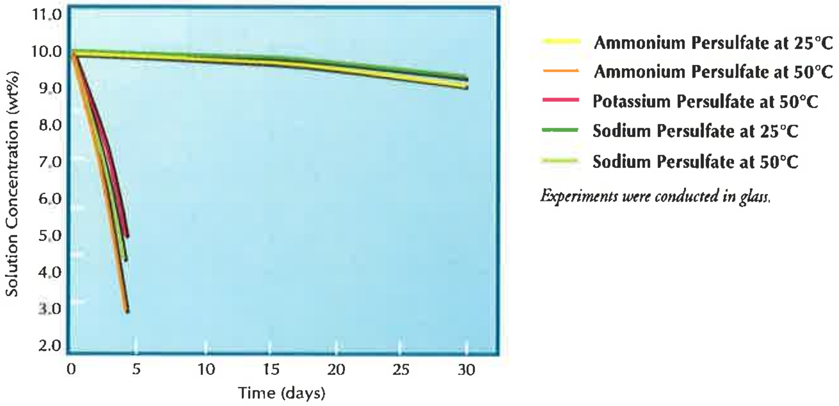
	Ammonium persulfate (wt%)			Potassium persulfate (wt%)			Sodium persulfate (wt%)		
g/L	25°C	35°C	45°C	25°C	35°C	45°C	25°C	35°C	45°C
0	0	0	0	0	0	0	0	0	0
25	2.477	2.485	2.495	2.468	2.476	2.486	2.466	2.474	2.484
50	4.895	4.911	4.931	4.861	4.877	4.896	4.854	4.868	4.888
75	7.256	7.281	7.311	7.183	7.208	7.237	7.167	7.187	7.219
100	9.562	9.598	9.635	—	9.470	9.510	9.410	9.435	9.479
125	11.815	11.863	11.912	—	11.668	11.719	11.586	11.616	11.672
150	14.017	14.077	14.136	—	—	13.868	13.699	13.733	13.801
175	16.170	16.244	16.311	—	—	15.959	15.751	15.790	15.870
200	18.275	18.364	18.440	—	—	17.994	17.745	17.788	17.880
250	22.349	22.471	22.564	—	—	—	21.572	21.620	21.738
300	26.251	26.411	26.519	—	—	—	25.197	25.250	25.394
350	29.993	30.194	30.316	—	—	—	28.634	28.695	28.864
400	33.583	33.831	33.964	—	—	—	31.910	31.969	32.164
450	37.031	37.329	37.473	—	—	—	35.026	35.087	35.307
500	40.346	40.699	40.850	—	—	—	37.998	38.060	38.305
550	43.536	43.946	44.104	—	—	—	40.836	40.898	41.168
600	46.607	47.079	47.241	—	—	—	43.551	43.613	43.905
650	49.566	50.103	50.268	—	—	—	46.150	46.211	46.527
700	52.420	53.025	53.191	—	—	—	48.642	48.702	49.040

Decomposition Rates of 4% Solutions



Experiments were conducted in glass.

Decomposition Rates of 10% Solutions



Experiments were conducted in glass.

Typical Analysis of Persulfates

Analysis	Ammonium persulfate	Potassium persulfate	Sodium persulfate
Purity %	99.5	99.5	99.4
Active oxygen (%)	6.98	5.90	6.68
Moisture (%)	0.02	0.02	0.01
Ammonium persulfate (%)	—	0.14	0.01
Sodium sulfate (%)	—	—	0.70
pH (1% solution)	5.2	6.4	6.0
Iron (ppm)	1	3	2
Insolubles (ppm)	21	18	29
Copper (ppm)	<0.3	<0.2	<0.2
Chloride (ppm)	<10	<10	<10
Heavy metals, as lead (ppm)	<1	<1	<1
Manganese (ppm)	<0.5	<0.5	<0.5
Chromium (ppm)	<0.5	<0.5	<0.5
Sodium (ppm)	20	—	—
Potassium (ppm)	50	—	—

Screen analysis Mesh size	Ammonium persulfate % passing	Potassium persulfate % passing	Sodium persulfate % passing
8	100	100	100
30	78	97	99
50	24	75	80
70	9	54	48
100	3	40	15
140	1	24	2

Every phase of persulfate manufacturing is monitored and controlled electronically, including the crystallization and drying steps critical to the product's thermal stability.

Analytical Chemistry

Persulfates or their solutions can be conveniently assayed by the methods described below. In each method, persulfate is determined by titration of a standardized potassium permanganate or ceric ammonium sulfate solution with a standardized ferrous ammonium sulfate solution, a back-titration technique.

Reagents can be purchased prestandardized or prepared from commercially available chemicals. All reagents, chemicals, and apparatus used are common, off-the-shelf items, and can be purchased from commercial supply houses.

Assay Procedures

Solids

To a 250 mL Erlenmeyer flask, add about 1 gram of sample weighed to the nearest milligram and about 50 mL of 1N H_2SO_4. Dissolve the sample and add exactly 40 mL of 0.5 N ferrous ammonium sulfate solution. Swirl constantly while adding the ferrous ammonium sulfate solution. Let this stand for one minute and titrate with 0.5 N $KMnO_4$ to permanent pink endpoint or with 0.5 N $Ce(SO_4)_2$ to a Ferroin indicator endpoint. The calculations require a blank titration on exactly 40 mL of ferrous ammonium sulfate solution, as used above, in 50 mL of the 1 N H_2SO_4.

$$\%\ \text{active oxygen} = \frac{(A - B)C \times 0.8}{D}$$

$$\%\ \text{ammonium persulfate} = \frac{(A - B)C \times 11.4}{D}$$

$$\%\ \text{potassium persulfate} = \frac{(A - B)C \times 13.5}{D}$$

$$\%\ \text{sodium persulfate} = \frac{(A - B)C \times 11.9}{D}$$

A = mL $KMnO_4$ or $Ce(SO_4)_2$ solution used for titrating the blank.
B = mL $KMnO_4$ or $Ce(SO_4)_2$ solution used for titrating the sample.
C = Normality of the $KMnO_4$ or $Ce(SO_4)_2$ solution used.
D = Weight of sample in grams.

Solutions

To a 250 mL Erlenmeyer flask, pipette 2-20 mL of persulfate solution (depending on the approximate solution concentration). Add about 50 mL of about 1 N H_2SO_4 solution. Add exactly 40 mL of 0.5 N ferrous ammonium sulfate solution. Swirl constantly while adding the ferrous ammonium sulfate solution. Let stand for one minute and titrate with 0.5 N $KMnO_4$ to a permanent pink endpoint or with 0.5 N $Ce(SO_4)_2$ to a Ferroin indicator endpoint. The calculations require a blank titration on exactly 40 mL of ferrous ammonium sulfate solution, as used above, in 50 mL of the 1 N H_2SO_4.

$$\text{g/L active oxygen} = \frac{(A - B)C \times 8}{D}$$

$$\text{g/L ammonium persulfate} = \frac{(A - B)C \times 114}{D}$$

$$\text{g/L potassium persulfate} = \frac{(A - B)C \times 135}{D}$$

$$\text{g/L sodium persulfate} = \frac{(A - B)C \times 119}{D}$$

A = mL $KMnO_4$ or $Ce(SO_4)_2$ solution used for titrating the blank.
B = mL $KMnO_4$ or $Ce(SO_4)_2$ solution used for titrating the sample.
C = Normality of the $KMnO_4$ or $Ce(SO_4)_2$ solution used.
D = Volume of sample in milliliters.

General Material Information

Persulfate Handling and Safety

Persulfates are oxidizing chemicals that require careful attention to all aspects of handling and use. For more information, you may request a Material Safety Data Sheet (MSDS) which is available from any FMC office.

Personal Protective Equipment

When handling persulfate chemicals, follow the guidelines listed here and in the MSDS.

Protect your eyes — Wear chemical-type goggles or a face mask whenever splashing, spraying, or any eye contact is possible.

Protect your respiratory system — Use dust respirators approved by NIOSH/MSA whenever exposure may exceed the established standard listed in the current MSDS.

Protect your hands — Wear general purpose neoprene gloves.

Protect yourself with proper clothing — Wear ordinary work clothes with long sleeves and full-length pants.

Protect yourself with proper footwear — Wear shoes with neoprene soles.

First Aid

Eye contact — Flush with water for at least 15 minutes. If irritation occurs and persists, obtain medical attention.

Skin contact — Wash with plenty of soap and water. If irritation occurs and persists, obtain medical attention. Wash clothing before reuse.

Inhalation — Get fresh air. If breathing difficulty or discomfort occurs, call a physician.

Ingestion — Drink one to two glasses of water. Do not induce vomiting. Do not give anything by mouth to an unconscious individual. Call a physician immediately.

When properly handled and stored, persulfates and their solutions do not present serious health hazards. The MSDS provides information concerning exposure, emergency, first aid, and disposal of persulfates.

Disposal

Persulfate crystals should never be discarded to trash bins. Contact with moisture, contaminants, and/or reducing agents can initiate a chemical reaction or a persulfate decomposition. Persulfate crystals which become a waste material are classified as hazardous waste because they are oxidizers. Persulfates which are spilled on the floor, or otherwise contaminated, are best dissolved in copious quantities of water.

An acceptable disposal method for spent persulfate solutions is to dilute with large quantities of water and dispose via a treatment system.

Any disposal method must be in full accordance with all local, state, and federal regulations.

Shipping

The U.S. Department of Transportation classifies persulfates as OXIDIZER and regulates them as hazardous materials for transport by air, water, and rail. The "Code of Federal Regulation – Title 49" details specific requirements for packaging, marketing, labeling, and describing these materials for shipment.

Containers and Packaging

FMC packages and ships crystalline persulfate chemicals in three different container types, according to customer requests.

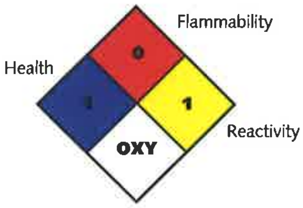
For more information, contact your nearest FMC Sales Office.

Type	Construction	Persulfate wt/container	Containers per pallet	Persulfate wt/pallet
Bag	Polypropylene	55 lbs	42	2,310 lbs
Drum	Fiber drums, polyethylene liner	225 lbs	8	1,800 lbs
IBC*	Polypropylene sack, polyethylene liner	1,000 – 2,200 lbs	1 – 2	1,000 – 2,200 lbs

**IBC = Intermediate Bulk Container, equipped with easy opening bottom spout for discharging into tanks or hoppers.*

Storage

Persulfates should be stored in accordance with the National Fire Protection Association's (NFPA) 430 *Code for the Storage of Solid and Liquid Oxidizers*. FMC personnel can provide additional support in reviewing storage facilities.



General Precautions — Persulfates should be kept in a cool, dry storage area, in a configuration that is appropriate for the sprinkler capacity of the building per NFPA 430.

Personnel should be trained to handle persulfates safely, properly dispose of spilled materials, and prevent contamination.

If material gets wet or spills, it must be isolated and disposed of properly.

Handling — To remove and transport persulfates from the shipping containers, use clean plastic or stainless steel scoops, shovels, pails, etc. Cleanliness is essential.

Solution Storage — Aqueous solutions of ammonium persulfate are more susceptible to decomposition than the solid product. The recommended materials of construction for storage and conveyance equipment (tanks, pipelines, etc.) are 304 and 316 stainless steel. Other acceptable materials include polyvinyl chloride, polyethylene, Plexiglas® plastic (or other suitable generic), Teflon® resin (or other suitable generic), chemical stoneware, and glass. Metals other than 304 and 316 stainless steel cause decomposition of the persulfate solutions or may be corroded by them. This is particularly true of Monel, copper, brass, and iron.

Do not store or process persulfate solutions in sealed or closed containers or vessels. Normal solution decomposition will release oxygen gas which may overpressurize a sealed container and cause rupture.

Storage of persulfate solutions above 25°C will accelerate the rate of decompostition. See data on pages 10 and 11.

Decomposition Hazard

Overheating or contamination of persulfates can lead to a runaway decomposition. The persulfate salt will begin to effervesce with an acid-like odor. Persulfates decompose to form solid sulfate salts and emit noxious fog or fumes of SO_x and NO_x. This decomposition may form a high temperature melt. The material will flow like magma and may ignite nearby combustible materials such as wood or paper. Oxygen produced by persulfate decomposition can increase the intensity of the fire.

The only way to halt a decomposition event is to apply LARGE quantities of water to the reacting material. Eight pounds of water per pound of decomposing materials is recommended, but no less than two pounds of water should be applied. Insufficient amounts of water will intensify the reaction and increase the acid mist concentration.

Please note that carbon dioxide (CO_2) or other gas-filled extinguishers will have NO effect on decomposing persulfate. The use of water as an extinguishing agent is emphasized. Control of the melt and firefighting efforts are enhanced if persulfates are stored within containment areas.

Persulfate decomposition will require emergency responders wearing full protective rubber clothing, face and head protection, plus self-contained breathing apparatus (SCBA).

Decomposition Prevention

Observe the following precautions to prevent decomposition:

Do not expose persulfates or their containers to moisture. Moisture significantly lowers the decomposition temperature.

Do not store persulfates near incompatible materials such as reducing agents, acids, bases, halide salt solutions, organics, ammoniacal solutions, alkaline cleansers, or other oxidizers. These materials can initiate decomposition.

Do not store near point sources of heat such as steam pipes, electrical appliances, heating vents, gas flames, welding sparks, or radiant heaters. Do not store at ambient temperatures above 113°F or 45°C.

Do not return spilled or unused portions of persulfates to the original container. Dirt, metal, moisture, or other contaminants can induce the decomposition of persulfates.

Do not cross-contaminate with scoops, cups, or stirrers that may have been exposed to or used with other chemicals. Use only dedicated clean, dry plastic or stainless steel scoops and utensils for transfer.

Do not grind or dry mix in equipment or machines that develop frictional heat.

Customer Support Services

Quality Assurance

FMC persulfate products are produced under an ISO 9002 certified quality system. Statistical Process Control (SPC) and a distributed control system combine to provide consistent process control. FMC operators monitor key parameters to ensure consistent quality for all products.

DNV
ANSI · RAB
OMS
ACCREDITED
DNV Certification, Inc.
ISO 9002 REGISTERED FIRM

All materials–raw, intermediate and final–are checked and tested in a new, modern laboratory employing the latest analytical technology. Quality test results are maintained on each batch of product. Certificates of Analysis and other end-product information can be customized to meet your system requirements.

Our production facility uses SPC methods to improve and assure the quality of persulfate chemical products. FMC operators chart key operating parameters to maintain process control; this assures that quality is built in to each customer's order.

The SPC system is designed to meet your specific quality standards. Product is analyzed and identified as it leaves the packaging areas. Product quality is maintained by batch number. The information is then stored in a computer database, enabling FMC to issue Certificates of Analysis that are specific to each batch of materials received by our customers.

FMC is the only persulfate producer that uses cutting-edge technology to ensure that our products are stable for storage or transport and use. We have established new product safety standards for thermal stability to ensure a high-quality, stable persulfate.

Distribution

Domestic — All FMC persulfates are distributed throughout North America. Our persulfate distribution facilities are located in:

Bridgeview, Illinois
Carteret, New Jersey
Tonawanda, New York

Minimum shipment from any domestic FMC distribution center is 24,000 lbs of FMC products. Persulfates may be any portion of the total weight. Contact us for more information.

International — Persulfates are also available from a network of chemical supply distributors that represent FMC persulfate products worldwide.

Technical Services

All FMC customers have access to a staff of technical service representatives at the Research and Development Center in Princeton, NJ and at the plant in Tonawanda, NY. These chemists and engineers are experienced in the production, sale, and distribution of peroxygen chemicals. They are fully capable of answering questions on the safe handling and usage of persulfates. In fact, FMC specialists have helped our customers pioneer many successful applications for persulfate chemicals.

Our engineering services include the design and construction of storage facilities, or the safety inspection of your present warehouse or production facilities. FMC also offers a complete list of technical articles, bulletins, data sheets, and patents. For more information, call or write the nearest FMC sales office.

Consistent process control and monitoring ensure a reliable supply of quality persulfates to a global market.

FMC's Tonawanda warehouse reflects state-of-the-art design, featuring monitors and detectors which close the fire doors in any emergency and sprinklers powerful enough to handle any fire or decomposition. Let FMC help you with your persulfate storage and warehousing.

Domestic and International Offices

Domestic Offices

FMC Corporation
Chemical Products Group
1735 Market Street
Philadelphia, PA 19103
(215) 299-6000
(215) 299-6272 Fax

FMC Manufacturing
FMC Active Oxidants Division
78 Sawyer Avenue
Town of Tonawanda, NY 14150
(716) 879-0400
(716) 879-0433 Fax

Technical Office

FMC Research and Development
Active Oxidants Division
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Princeton, NJ 08543
(800) 206-9980
(609) 951-3668 Fax

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1050 Brussels, Belgium
011+ 32 2/645 9211
011+ 32 2/646 4454 Fax

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Sales Office
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111 Paseo de Roxas
1229 Makati City
Metro Manila, Philippines
011+ 63 2/894 1615
011+ 63 2/894 1605 Fax

The persulfate applications referred to in this publication are solely for illustrative purposes. It is the responsibility of the user to determine whether a persulfate compound may be suitable for any specific application, in accordance with accepted good practices and applicable regulatory restrictions.

The information contained herein is, to our knowledge, true and accurate. However, we make no warranty or representation, expressed or implied, except that FMC products discussed herein conform to the chemical description shown on their labels. Nothing contained herein shall be construed as permission or recommendation to infringe any patent. No agent, representative or employee of this company is authorized to vary any of the terms of this notice.

FMC9487–2500 12/01 Burgess

REMEDIAL ACTION WORK PLAN
UST AREA CHEMICAL OXIDATION

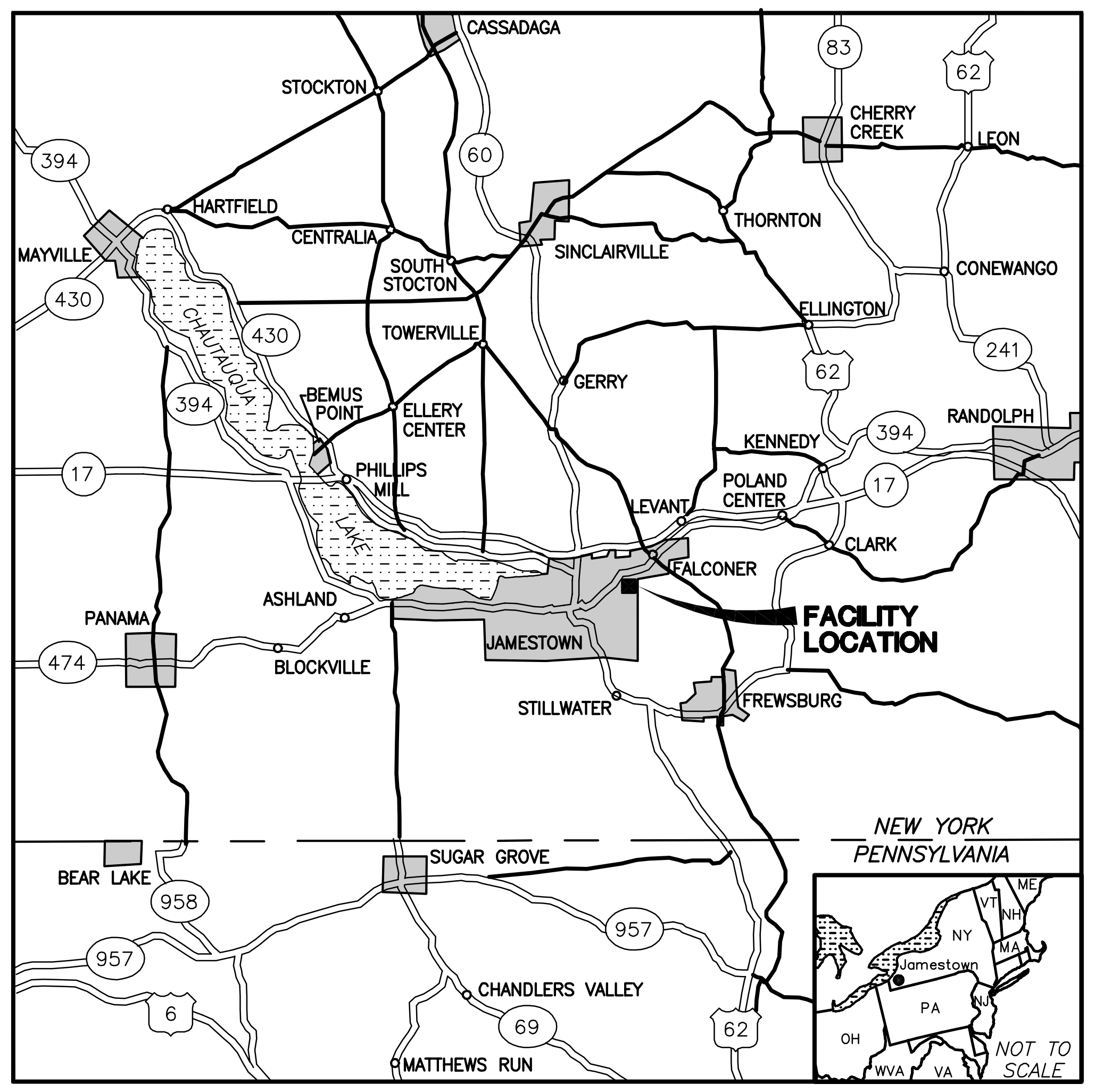
PREPARED FOR

ESSEX SPECIALTY PRODUCTS, INC.

JAMESTOWN, NEW YORK

MAY, 2011

DRAWING NO.	TITLE
C-1	SITE CONDITIONS
C-2	SITE PREPARATION
C-3	TREATMENT PLAN
C-4	SITE CLOSURE PLAN
C-5	MONITORING PLAN
C-6	CROSS-SECTIONS AND DETAILS
C-7	GEOLOGIC CROSS-SECTIONS



FACILITY LOCATION

1 5
SCALE IN MILES

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URS

PITTSBURGH, PENNSYLVANIA

MAY, 2011	ISSUED FOR NYDEC SUBMITTAL
DATE	ISSUE RECORD

MAP REFERENCE AND CONTROL NOTES:

1. BASE MAPPING INCLUDING THE LOCATIONS OF SOME OF THE BUILDINGS, ROADS, CURBS/SIDEWALKS, FENCING, PAVED AREAS, ALL UTILITIES (UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE), AND PROPERTY BOUNDARY WAS PROVIDED BY MICHAEL J. RODGERS AND ASSOCIATES, LAND SURVEYORS, BEMUS POINT, NEW YORK, N.Y.S. LICENSE No. 49232. THE BASE MAP WAS A SEPIA HARD COPY AT A SCALE OF 1"=20', DATED APRIL 15, 1992, LAST REVISION DATE MARCH 10, 1993. RECOVERY WELLS, SPARGE WELLS, AND SVE WELLS WERE SURVEYED AUGUST, 1997. MONITORING WELLS IN THE VICINITY OF THE REMEDIAL ACTION CONSTRUCTION WERE SURVEYED AUGUST, 1997, MONITORING WELLS MW–18, MW–21D,MW–22D, MW–23S, MW–23D, MW–24S, ALL RECOVERY WELLS (RW), ALL GEOPROBES (GP) (EXCEPT GP–4S), ALL PIEZOMETERS (PZ), AND ALL VAPOR PROBES (VP) (EXCEPT VP–3S) WERE LOCATED BY URS FIELD SURVEY AUGUST 2006. RW–6 PIPELINE LOCATED BY FIELD MEASUREMENTS ON 10/17/2008. RW–6, MW–25S AND MW–25D LOCATED BY URS FIELD SURVEY JUNE 30, 2009. COORDINATE INFORMATION SHOWN AT THE BUILDING CORNERS CAME FROM THE MICHAEL J. ROGERS SURVEY DONE ON JANUARY 9, 1998. ALL OTHER BUILDING CORNERS ARE APPROXIMATE. THE SITE AREA BEYOND THE 1998 SURVEY WAS MAPPED BY URS CORPORATION IN AUGUST 2006. THIS MAPPING USED THE SAME VERTICAL AND HORIZONTAL REFERENCE DATA AS THE PREVIOUS SURVEY. THE MAPPING WAS MERGED WITH THE 1998 DATA TO PRODUCE A COMPOSITE SITE BASE MAP. THE LIMITS OF THE COMPOSITE SURVEY MAP ARE SHOWN ON THE DRAWING. SEE MAP REFERENCE 3.

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LEGEND – EXISTING

- ◕ MONITORING WELL
  MW – ESSEX WELL
  HW – HOPE WELL
- RW ◎ RECOVERY WELL
- GP ◐ GEOPROBE PIEZOMETER (1")
- VP ▲ VAPOR PROBE
- PZ ◆ TEMPORARY PIEZOMETER (0.5–1")
- ◈ TEST BORING (TBT1 – TBT4), 2000
- TB ◑ GEOPROBE BORING (TBUST1 – TBUST12) NOV. 2003, DIRECT PUSH SOIL BORING LOCATION –
  PHASE I (TBUST13 – TBUST36 AND TBN1 – TBN13) COMPLETED APRIL–MAY 2005,
  PHASE II (TBUST–37 – TBUST–43, TBN14 – TBN–20) DEC. 2005 THROUGH JAN. 2006,
  APPROXIMATE LOCATIONS
- ✱ **TEST BORING – CHEMOX TREATABILITY STUDY SAMPLES**
- —×——×— FENCE
- ━ ━ ━ PROPERTY LINE
- o2 PROPERTY CORNER & I.D. NUMBER
- G/V ⌧ GAS VALVE
- — GAS — GAS LINE
- W/V ⌧ WATER VALVE
- — 6" WATER WATER LINE
- SAN —— SANITARY SEWER
- —··—··— PROPERTY LINE FROM TAX MAP APROXIMATE LOCATION
- —o——o— FENCE LINE APROXIMATE LOCATION
- ⫽⫽⫽ BUILDING

0	06/10/11	ISSUED FOR NYDEC SUBMITTAL	MJD	MJD
REV	DATE	ISSUE/REVISION DESCRIPTION	CHK'D	APPR'D

DESIGNED BY	MJD	DATE	07/07/10	SEAL
DRAWN BY	KG	DATE	07/07/10	
CHECKED BY	MJD	DATE	05/16/11	
APPROVED BY	MJD	DATE	–	

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CLIENT **ESSEX SPECIALTY PRODUCTS, INC.**
ESSEX\HOPE FACILITY
JAMESTOWN, NEW YORK

REMEDIAL ACTION WORK PLAN
UST AREA CHEMICAL OXIDATION

GENERAL SITE CONDITIONS

CAD FILE NAME J:\ESSEXHOP\2006–MAP\REM–ACT–WORK–PLAN\SITE–PLAN	SCALE AS SHOWN

URS JOB NUMBER 41568097.10000	DRAWING NUMBER C–1	REV 0

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- G/V GAS VALVE
- GAS GAS LINE
- W/V WATER VALVE
- 6" WATER WATER LINE
- SAN SANITARY SEWER
- PROPERTY LINE FROM TAX MAP APROXIMATE LOCATION
- FENCE LINE APROXIMATE LOCATION

LEGEND – PROPOSED

- ⊕ NEW 2" MONITORING WELLS (SHALLOW GROUNDWATER)

STORMWATER STRUCTURES SCHEDULE

No.	TYPE	SIZE	INLET PIPE		OUTLET PIPE	
			dia/mat'l	Invert EL	dia/mat'l	Invert EL
J1	Junction/Inlet	3 x 3 ft	8-in STL	tbd	8-in HDPE	tbd
J2	Junction/Inlet	3 x 3 ft	8-in STL	tbd	8-in HDPE	tbd
J3	Junction/Inlet	3 x 3 ft	8-in STL	tbd	8-in HDPE	tbd
J4	Junction/MH	5 ft dia.	8-in HDPE	tbd	16-in HDPE	tbd
			8-in HDPE	tbd		
			8-in HDPE	tbd		
J5	Junction/Inlet	3 x 4 ft	16-in HDPE	tbd		
			16-in CPM	existing	16-in CPM	existing

Notes:
1. See Details 1 and 2, Drawing C-6.

NOTES

1. NEW STORMWATER DRAINAGE SYSTEM SHALL BE CONSTRUCTED PRIOR TO SITE TREATMENT ACTIVITIES. THE SYSTEM SHALL BE PROTECTED DURING TREATMENT OPERATIONS. THE EXISTING DRY WELL SUMPS SHALL BE DEMOLISHED IN-PLACE TO ACCOMODATE THE NEW JUNCTION BOXES. ADDITIONAL CLEAN BACKFILL SHALL BE PLACED IN THE SUMPS AS NEEDED TO ACHIEVE SUBGRADE FOR THE STRUCTURES.
2. THE EXISTING DRAINAGE DITCH AND TIE-IN CATCH BASIN SHALL BE CLEANED AND REGRADED AS NECESSARY TO MAINTAIN STORMWATER DRAINAGE DURING THE WORK ACTIVITIES.
3. THE EXISTING DECON PAD (FORMER TANK FARM) AND TRUCK PIT ARE NOT USEABLE IN THEIR CURRENT CONDITIONS. THESE STRUCTURES SHALL BE MAINTAINED IN A DRAINED STATE DURING THE WORK ACTIVITIES. WATER SHALL BE CONVEYED TO THE SURFACE WATER DRAINAGE DITCH AS NECESSARY.
4. PROTECT ALL MONITORING WELLS, RECOVERY WELLS, PIEZOMETERS AND VAPOR PROBES DURING ISCO WORK. PROVIDE VISIBLE FENCING AROUND WELLS PRIOR TO START OF SITE PREPARATION ACTIVITIES.

REV	DATE	ISSUE/REVISION DESCRIPTION	CHK'D	APPR'D
0	06/10/11	ISSUED FOR IN-HOUSE REVIEW	MJD	MJD

DESIGNED BY	MJD	DATE	03/30/11
DRAWN BY	KG	DATE	03/30/11
CHECKED BY	MJD	DATE	05/16/11
APPROVED BY	MJD	DATE	–

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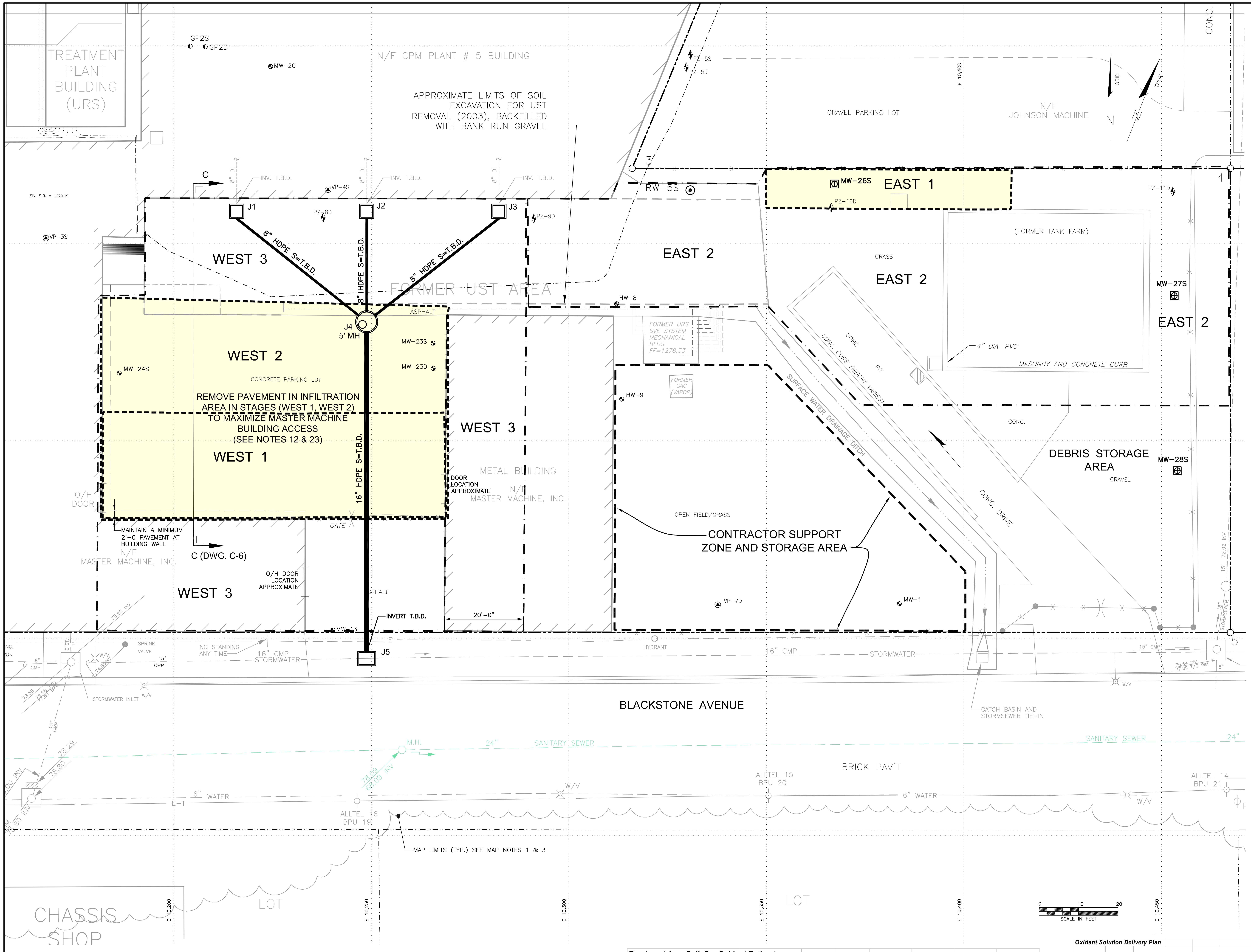
ESSEX SPECIALTY PRODUCTS, INC.
ESSEX\HOPE FACILITY
JAMESTOWN, NEW YORK

REMEDIAL ACTION WORK PLAN
UST AREA CHEMICAL OXIDATION

SITE PREPARATION

CAD FILE NAME: J:\ESSEXHOP\2006-MAP\REM-ACT-WORK-PLAN\SITE-PLAN
SCALE: AS SHOWN
URS JOB NUMBER: 41568097.10000
DRAWING NUMBER: C-2
REV: 0



NOTES

GENERAL CRITERIA FOR INJECTIONS ARE AS FOLLOWS:

1. INJECTIONS IN ANY TREATMENT AREA SHALL BE PERFORMED PRIOR TO INFILTRATION IN THAT SAME AREA, IF BOTH ARE PLANNED.
2. PRIOR TO INJECTION, ANY SURFACE/OVERHEAD UTILITIES OR OBSTRUCTIONS AND ANY UNDERGROUND UTILITIES/PIPING SHALL BE IDENTIFIED. SURFACE PAVEMENT SHALL BE PRE-CORED PRIOR TO INJECTIONS TO ACHIEVE A CLEAN HOLE FOR FUTURE REPAIR, IF THE INJECTION POINT IS NOT WITHIN A PLANNED INFILTRATION ZONE.
3. EACH INJECTION POINT SHALL BE UNIQUELY IDENTIFIED, AND EACH INJECTION POINT SHALL HAVE AN INJECTION LOG FORM THAT CONTAINS THE FOLLOWING INFORMATION: INJECTION NUMBER, DATE/TIME, OXIDANT DOSAGE, OXIDANT FLOW RATE AND VOLUME, INJECTION PRESSURE AT INJECTION DRIVE-HEAD PIPE,
4. THE REQUIRED OXIDANT DOSAGES SHALL BE PRE-MIXED IN BATCHES PRIOR TO INJECTION. THE ACTIVATORS SHOULD NOT BE ADDED TO THE INJECTION MIX UNTIL THE OXIDANT SOLUTION IS THOROUGHLY MIXED. A BATCH TANK WITH A MIXER IS RECOMMENDED FOR PREPARING THE REQUIRED VOLUME OF OXIDANT FOR EACH INJECTION POINT. THE NOMINAL BATCH TANK SIZE REQUIRED WOULD BE A MINIMUM 1000 GALLONS BASED ON THE MAXIMUM OXIDANT SOLUTION VOLUME ESTIMATED FOR ANY SINGLE INJECTION POINT AS OUTLINED IN THE PROPOSED INJECTION PLAN. THE BATCHES MAY ALSO BE MIXED IN SMALLER PROPORTIONS (500-1000 GAL) IF NECESSARY TO FACILITATE FIELD OPERATIONS. ALL OXIDANT BATCHES SHALL BE MIXED FOR AT LEAST 5 MINUTES PRIOR TO INJECTION TO ASSURE A HOMOGENEOUS MIXTURE. MIXED OXIDANT BATCHES SHALL BE USED UP ON A DAILY BASIS.
5. INJECTIONS SHALL BE ON NOMINAL 10 FOOT CENTERS SPACING. THE SPACING MAY BE MODIFIED BASED ON THE RESULTS OF THE PRE-WORK INJECTION TESTING.
6. SINGLE OR MULTIPLE INJECTION POINTS MAY BE EMPLOYED AT ONE TIME. IF MULTIPLE INJECTION POINTS ARE USED, A MANIFOLD PIPING SYSTEM MAY BE USED FOR OXIDANT DELIVERY.
7. INJECTIONS SHALL BE PERFORMED FROM THE BOTTOM OF THE ZONE FIRST, WORKING TOWARDS THE UPPER PART OF THE ZONE OF TREATMENT. INJECTIONS MAY BE DELIVERED ON 1-FOOT INTERVALS OR CONTINUOUSLY TO ACHIEVE A UNIFORM OXIDANT DOSAGE ACROSS THE TREATMENT ZONE VERTICAL INTERVAL, DEPENDING ON THE INJECTION ROD CONFIGURATION AND THE RESULTS OF THE PRE-WORK INJECTION TESTING.
8. TREATMENT AREA PERIMETER INJECTIONS SHALL BE PERFORMED FIRST. INJECTIONS SHALL BE STAGGERED SO AS NOT TO INJECT NEXT TO A POINT THAT WAS INJECTED IMMEDIATELY PRIOR.
9. INJECTION PRESSURES SHALL BE WITHIN THE GUIDELINES DESCRIBED IN THE RAWP AND THEY SHALL NOT BE INJECTION PRESSURE SHALL BE MONITORED CONTINUOUSLY DURING INJECTION OPERATIONS. UNIFORM OXIDANT FLOW RATE SHALL BE MAINTAINED, IF PRACTICABLE WITHOUT GENERATING EXCESSIVE BACK PRESSURE IN THE INJECTION PIPE OR FORMATION.
10. EXISTING MONITORING WELLS AND PIEZOMETERS IN AND NEAR THE TREATMENT ZONE SHALL BE MONITORED DAILY FOR WATER LEVELS. WELLS OR PIEZOMETERS CLOSEST TO THE INJECTION POINT SHALL BE MONITORED MORE FREQUENTLY DURING INJECTION TO CHECK WATER LEVELS. SEE THE RAWP FOR SPECIFIC MONITORING REQUIREMENTS.
11. COMPLETED INJECTION BORINGS SHALL BE BACKFILLED AND SEALED IMMEDIATELY AFTER INJECTION OF THE SPECIFIED VOLUME OF OXIDANT. THE INJECTION ZONE INTERVAL SHALL BE BACKFILLED WITH A CLEAN SAND, IF POSSIBLE. ABOVE THE TREATMENT ZONE THE BORING SHALL BE GROUTED WITH A PORTLAND CEMENT-BENTONITE GROUT MIXTURE TO THE GROUND SURFACE.

GENERAL CRITERIA FOR INFILTRATION BEDS ARE AS FOLLOWS:

12. THE WEST 2 AREA SHOULD BE IMPLEMENTED PRIOR TO THE WEST 1 AREA TO ALLOW ACCESS TO THE MASTER MACHINE BUILDING BY THEIR EMPLOYEES DURING TREATMENT OF THE WEST 2 AREA. NONE OF THE PROPOSED INFILTRATION TREATMENT AREAS WILL REQUIRE ACCESS TO BUILDING INTERIORS. ANY CHANGES TO THE OXIDANT INJECTION PLAN AS A RESULT OF FIELD PRE-WORK INFILTRATION TESTING OR OTHER FIELD CHANGES SHALL BE AS APPROVED AND DIRECTED BY URS.
13. PRIOR TO CONSTRUCTING THE INFILTRATION BEDS, ANY SURFACE/OVERHEAD UTILITIES OR OBSTRUCTIONS AND ANY UNDERGROUND UTILITIES/PIPING SHALL BE IDENTIFIED. SURFACE PAVEMENT SHALL BE REMOVED FROM THE INFILTRATION AREA AND REMOVED FROM THE SITE FOR OFFSITE DISPOSAL IN ACCORDANCE WITH NYDEC AND CITY OF JAMESTOWN REQUIREMENTS.
14. THE INFILTRATION BEDS SHALL BE EXCAVATED TO A NOMINAL DEPTH OF 2 FEET BGS. THE FINISHED BED FLOORS SHALL BE LEVEL. EXCAVATION SPOILS MAY BE TEMPORARILY STORED ONSITE FOR LATER BACKFILL INTO THE INFILTRATION BED AFTER TREATMENT. THE INFILTRATION BEDS MAY BE THE ENTIRE TREATMENT ZONE AREA, APPROXIMATELY 5000 SF IN THE WEST AREA, OR THEY MAY BE SUBAREAS OF THE TREATMENT ZONES.
15. THE PERIMETER OF THE BED EXCAVATIONS SHALL BE SECURED WITH TEMPORARY CONSTRUCTION FENCING TO PREVENT ONSITE WORKER ACCESS OR OTHER VISITOR ACCESS.
16. SURFACE RUNOFF INTO THE BEDS SHALL BE MINIMIZED BY DITCHES AND/OR BARRIERS.
17. EACH INFILTRATION BED SHALL BE UNIQUELY IDENTIFIED AND HAVE AN INFILTRATION BED LOG THAT CONTAINS THE FOLLOWING INFORMATION: INFILTRATION BED NUMBER, DATE/TIME, OXIDANT DOSAGE, OXIDANT FLOW RATE AND VOLUME, AND BED LIQUID DEPTHS OVER TIME.
18. THE REQUIRED OXIDANT DOSAGES SHALL BE PRE-MIXED IN BATCHES PRIOR TO PLACEMENT IN THE INFILTRATION BED. MULTIPLE BATCHES ARE ANTICIPATED FOR EACH INFILTRATION AREA BASED ON THE TOTAL VOLUME REQUIREMENTS.THE ACTIVATOR SHOULD NOT BE ADDED TO THE MIX UNTIL THE OXIDANT SOLUTION IS THOROUGHLY MIXED. A BATCH TANK WITH A MIXER IS RECOMMENDED FOR PREPARING THE REQUIRED VOLUME OF OXIDANT FOR EACH INJECTION POINT. ALL OXIDANT BATCHES SHALL BE MIXED FOR AT LEAST 5 MINUTES PRIOR TO BED PLACEMENT TO ASSURE A HOMOGENEOUS MIXTURE. MIXED OXIDANT BATCHES SHALL BE USED UP ON A DAILY BASIS.
19. MIXED OXIDANT SHALL BE PLACED UNIFORMLY OVER THE ENTIRE INFILTRATION BED BY SPRAYING OR FLOODING, DEPENDING ON THE VOLUME OF OXIDANT SOLUTION, THE BED AREA, AND THE INFILTRATION RATE. THE MAXIMUM LIQUID LEVEL IN ANY OF THE BEDS IS EXPECTED TO BE 1 FT. OR LESS BASED ON THE PROPOSED OXIDANT DELIVERY PLAN. THE LARGEST BEDS, WEST 1 & 2, HAVE A TOTAL SURFACE AREA OF APPROXIMATELY 4700 SF, AND A DESIGN OXIDANT SOLUTION VOLUME OF APPROXIMATELY 40,000 GALLONS. MAXIMUM LIQUID DEPTH AT TOTAL VOLUME WOULD BE APPROXIMATELY 13.5 INCHES.
20. EXISTING MONITORING WELLS AND PIEZOMETERS IN AND NEAR THE TREATMENT ZONE SHALL BE MONITORED DAILY FOR WATER LEVELS. WELLS OR PIEZOMETERS CLOSEST TO THE INFILTRATION AREA SHALL BE MONITORED FREQUENTLY TO CHECK WATER LEVELS. SEE THE RAWP FOR SPECIFIC PERFORMANCE MONITORING REQUIREMENTS.
21. AFTER INFILTRATION OF THE OXIDANT SOLUTION THE BEDS SHALL BE FLUSHED WITH CLEAN WATER. A MINIMUM WATER VOLUME OF 20% OF THE OXIDANT VOLUME SHALL BE APPLIED. FLUSH VOLUMES ARE AS FOLLOWS:

	OXIDANT SOLUTION			CLEAN WATER FLUSH
AREA	%	GAL/SQ. FT./FT.	GALLONS	GALLONS
WEST 1	20	2.1	18063	3600
WEST 2	20	2.1	21676	4300
EAST 1	0.5	1.7	4410	880

22. TREATED INFILTRATION BEDS SHALL BE BACKFILLED IMMEDIATELY AFTER THE TOTAL REQUIRED OXIDANT VOLUME HAS INFILTRATED INTO THE SUBSURFACE AND THE BED SURFACE IS RELATIVELY DRY. ONSITE CLEAN SPOIL MATERIALS PREVIOUSLY REMOVED FROM THE AREA OR CLEAN IMPORTED FILL WILL BE USED FOR BACKFILL OF THE BEDS.
23. IN AREAS OF PREVIOUS PAVEMENT, A MINIMUM OF 8-INCHES OF BITUMINOUS ASPHALT PAVEMENT SHALL BE PLACED. SEE DRAWING C-4 SITE CLOSURE PLAN. THE SCHEDULE FOR BACKFILL AND PAVING OF INFILTRATION AREAS WILL BE AS DIRECTED BY URS BASED ON THE RESULTS OF POST-TREATMENT MONITORING.

MAP REFERENCE AND CONTROL NOTES:

1. BASE MAPPING INCLUDING THE LOCATIONS OF SOME OF THE BUILDINGS, ROADS, CURBS/SIDEWALKS, FENCING, PAVED AREAS, ALL UTILITIES (UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE), AND PROPERTY BOUNDARY WAS PROVIDED BY MICHAEL J. RODGERS AND ASSOCIATES, LAND SURVEYORS, BEMUS POINT, NEW YORK, N.Y.S. LICENSE No. 49232. THE BASE MAP WAS A SEPIA HARD COPY AT A SCALE OF 1"=20', DATED APRIL 15, 1992, LAST REVISION DATE MARCH 10, 1993. RECOVERY WELLS, SPARGE WELLS, AND SVE WELLS WERE SURVEYED AUGUST, 1997. MONITORING WELLS IN THE VICINITY OF THE REMEDIAL ACTION CONSTRUCTION WERE SURVEYED AUGUST, 1997, MONITORING WELLS MW-18, MW-21D,MW-22D, MW-23S, MW-23D, MW-24S, ALL RECOVERY WELLS (RW), ALL GEOPROBES (GP) (EXCEPT GP-4S), ALL PIEZOMETERS (PZ), AND ALL VAPOR PROBES (VP) (EXCEPT VP-3S) WERE LOCATED BY URS FIELD SURVEY AUGUST 2006. RW-6 PIPELINE LOCATED BY FIELD MEASUREMENTS ON 10/17/2008. RW-6, MW-25S AND MW-25D LOCATED BY URS FIELD SURVEY JUNE 30, 2009. COORDINATE INFORMATION SHOWN AT THE BUILDING CORNERS CAME FROM THE MICHAEL J. ROGERS SURVEY DONE ON JANUARY 9, 1998. ALL OTHER BUILDING CORNERS ARE APPROXIMATE. THE SITE AREA BEYOND THE 1998 SURVEY WAS MAPPED BY URS CORPORATION IN AUGUST 2006. THIS MAPPING USED THE SAME VERTICAL AND HORIZONTAL REFERENCE DATA AS THE PREVIOUS SURVEY. THE MAPPING WAS MERGED WITH THE 1998 DATA TO PRODUCE A COMPOSITE SITE BASE MAP. THE LIMITS OF THE COMPOSITE SURVEY MAP ARE SHOWN ON THE DRAWING. SEE MAP REFERENCE 3.

2. VERTICAL BENCH MARK INFORMATION CAME FROM U.S.G.S. PLAQUE U-88-S.E. ABUTT. ERIE R.R. BRIDGE OVER BUFFALO ST., ELEV.=1296.034 (NATIONAL GEODETIC VERTICAL DATUM, 1929).
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3. AREAS OUTSIDE OF CLOUD LINE: PROPERTY LINES AND MAPPING ADJACENT TO BIGELOW AVENUE, NORTH & SOUTH OF HOPKINS AVENUE & EAST OF BIGELOW AVENUE, AND SOUTH OF BLACKSTONE AVENUE WERE TAKEN FROM A VARIETY OF SOURCES INCLUDING SEPIA MYLAR SITE MAP (SEE REFERENCE 1), USGS 7.5 MINUTE TOPOGRAPHIC MAP – JAMESTOWN, NY, CITY OF JAMESTOWN TAX MAP RECORDS, AND URS FIELD RECONAISSANCE. LOCATIONS AND DIMENSIONS IN THESE AREAS ARE APPROXIMATE.

LEGEND – EXISTING

◕	MONITORING WELL MW – ESSEX WELL HW – HOPE WELL
RW ◎	RECOVERY WELL
GP ◐	GEOPROBE PIEZOMETER (1")
VP ▲	VAPOR PROBE
PZ ◆	TEMPORARY PIEZOMETER (0.5–1")
—X—X—	FENCE
━ ━ ━	PROPERTY LINE
○2	PROPERTY CORNER & I.D. NUMBER
G/V ⊠	GAS VALVE
— GAS —	GAS LINE
W/V ⊠	WATER VALVE
— 6" WATER	WATER LINE
SAN —	SANITARY SEWER
—··—	PROPERTY LINE FROM TAX MAP APPROXIMATE LOCATION
—○—○—	FENCE LINE APPROXIMATE LOCATION

LEGEND – PROPOSED

⊕	NEW 2" MONITORING WELLS (SHALLOW GROUNDWATER)
▬ ╷ ▬ ╷ ▬	GROUNDWATER TREATMENT ZONE – (INJECTION)
▨	SOIL TREATMENT ZONE – (INFILTRATION)

Treatment Area Bulk Dry Oxidant Estimate

Area	VOC Mass by Zone (See Note 1)						Oxygen Equivalent, lbs		Bulk Oxidant Req't, lbs	
	Vadose (4-8 ft BGS)			Groundwater (8-16 ft BGS)			See Note (2)		See Note (3)	
	Avg Conc, ppm	Area, SF	Mass, lbs	Avg Conc, ppm	Area, SF	Mass, lbs	Vadose	Groundwater	Vadose	Groundwater
West 1	500	2125	357	100	2125	31.8	1371	122	21090	1880
West 2	500	2550	428.4	1	3400	0.5	1645	8	25309	125
West 3	0	0	0	1	6700	1.0	0	16	0	247
Subtotal West			785.4			33.3	***3016***	***146***	***46399***	***2252***
East 1	10	650	2.18	1	650	0.1	8	1.6	129	24
East 2	0	0	0	1	7600	1.1	0	18	0	280
Subtotal East			2.2			1.2	***8.4***	***20***	***129***	***304***
Total Site			**788**			**35**	**3024**	**166**	**46528**	**2557**
							Volume, cy *@ 70 pcf:*		***24.6***	***1.4***

Notes:
1. Treatment zones are shown on Drawing C-3
2. Oxygen equivalents based on:
Xylene oxidation stoichiometry = 3.2 lbs Oxygen/lb VOC
NOD factor of 5.0 x for low VOC groundwater zones (1-10 ppm), and
NOD/TPH factor of 1.2 x for vadose zones and high VOC groundwater zones (100 ppm)
3. Oxidant bulk dry weight requirements based on 6.5% available oxygen in sodium persulfate product.

Oxidant Solution Delivery Plan

INJECTION PLAN- GROUNDWATER

	Oxidant Mix per Injection Point (10 ft spacings)						*Bulk Dry Mixtures*		
	Oxidant Solution		*Fe-EDTA, 0.35%*	*VeruSol 3, 1%*	*Oxidant Solution*	*PVs*	*Fe-EDTA, 0.35%*	*VeruSol 3, 0.2-1%*	*Oxidant. NaSO*
Area	***%***	***gal/ft***	**Total lbs**	**Total Gallons**			lbs/1000 gal		
West 1	5	88	1.5	11	1061	0.4	1.5	10	417
West 2	0.5	37	0.1	4	442	0.16	0.15	2	42
West 3	0.5	37	0.1	4	442	0.16	0.15	2	42
East 1	0.5	37	0.1	4	442	0.16	0.15	2	42
East 2	0.5	37	0.1	4	442	0.16	0.15	2	42

INFILTRATION PLAN- VADOSE ZONES

	Oxidant Mix per Infiltration Area						*Bulk Dry Mixtures*		
	Oxidant Solution		*Fe-EDTA, 0.35%*	*VeruSol 3, 1%*	*Oxidant Solution*	*PVs*	*Fe-EDTA, 0.35%*	*VeruSol 3, 0.2-1%*	*Oxidant. NaSO*
Area	***%***	***gal/sq ft/ft***	**Total lbs**	**Total Gallons**			lbs/1000 gal		
West 1	20	2.1	105	181	18063	0.95	5.8	10	1667
West 2	20	2.1	126	217	21676	0.95	5.8	10	1667
West 3	Groundwater-injection only								
East 1	0.5	1.7	0.6	44	4420	0.76	0.15	2	42
East 2	Groundwater-injection only								

Notes:
1. Injection dosing based on an average 16 foot deep injection point and a treatment zone from 4-16 ft BGS.
2. Injection point at 10 ft centers (5 ft radius of influence). Use 100 sf/ft injection. PV= Pore volume (1) = 2.24 gal/cf = 224 gal/100 sf-ft
3. Infiltration application based on per square foot of surface area. PV= 2.24 gal/sf/ft

REV	DATE	ISSUE/REVISION DESCRIPTION	CHK'D	APPR'D
0	06/10/11	ISSUED FOR NYDEC SUBMITTAL	MJD	MJD

DESIGNED BY	MJD	DATE	03/30/11
DRAWN BY	KG	DATE	03/31/11
CHECKED BY	MJD	DATE	05/16/11
APPROVED BY	MJD	DATE	–

SEAL

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URS
PITTSBURGH, PENNSYLVANIA

CLIENT
ESSEX SPECIALTY PRODUCTS, INC.
ESSEX\HOPE FACILITY
JAMESTOWN, NEW YORK

REMEDIAL ACTION WORK PLAN
UST AREA CHEMICAL OXIDATION

TREATMENT PLAN

CAD FILE NAME: J:\ESSEXHOP\2006-MAP\REM-ACT-WORK-PLAN\SITE-PLAN
SCALE: AS SHOWN
URS JOB NUMBER: 41568097.10000
DRAWING NUMBER: C-3
REV: 0

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VP ▲ VAPOR PROBE
PZ ◆ TEMPORARY PIEZOMETER (0.5–1")
◈ TEST BORING (TBT1 – TBT4), 2000
—X——X— FENCE
▬ ▬ ▬ PROPERTY LINE
○2 PROPERTY CORNER & I.D. NUMBER
G/V ⊠ GAS VALVE
— GAS — GAS LINE
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— 6" WATER WATER LINE
SAN — SANITARY SEWER
—··—··— PROPERTY LINE FROM TAX MAP APPROXIMATE LOCATION
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LEGEND – PROPOSED

⊕ NEW 2" MONITORING WELLS (SHALLOW GROUNDWATER)
▨ BITUMIOUS PAVEMENT REPLACEMENT

0	06/10/11	ISSUED FOR NYDEC SUBMITTAL	MJD	MJD
REV	DATE	ISSUE/REVISION DESCRIPTION	CHK'D	APPR'D

DESIGNED BY	MJD	DATE	03/30/11	SEAL
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CLIENT **ESSEX SPECIALTY PRODUCTS, INC.**
ESSEX\HOPE FACILITY
JAMESTOWN, NEW YORK

REMEDIAL ACTION WORK PLAN
UST AREA CHEMICAL OXIDATION

SITE CLOSURE PLAN

CAD FILE NAME J:\ESSEXHOP\2006-MAP\REM-ACT-WORK-PLAN\SITE-PLAN	SCALE AS SHOWN

URS JOB NUMBER 41568097.10000	DRAWING NUMBER C-4	REV 0

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— 6" WATER	WATER LINE
SAN —	SANITARY SEWER
— · · — · · —	PROPERTY LINE FROM TAX MAP APPROXIMATE LOCATION
—o——o—	FENCE LINE APPROXIMATE LOCATION

LEGEND – PROPOSED

⊕	NEW 2" MONITORING WELLS (SHALLOW GROUNDWATER)
🟩	PERFORMANCE MONITORING WELLS INDICATOR
▭	SOIL SAMPLING AREA

ISCO Performance Monitoring Summary

Work Phase	Objective	Monitoring Locations	Parameters	Frequency
Pre-Operations	Measure Groundwater Levels and Water Quality Indicators and VOCs to establish baseline conditions.	Wells- HW-9, MWs- 20, 23S, 24S, 26S, 27S and 28S, and PZ-5S	VOCs (EPA 8260), pH, cond, ORP, DO, sulfate, alkalinity, iron, and water levels	Within 2 weeks prior to the start of site oxidant applications
Operations	Measure Groundwater Levels, Water Quality Indicators and VOCs to assess ongoing operations and short-term effects of ISCO.	Wells- HW-9, MWs- 20, 23S, 24S, 26S, 27S and 28S, and PZ-5S (use selected monitoring wells closest to weekly ISCO activities)	VOCs (EPA 8260), pH, cond, ORP, DO, sulfate, alkalinity, iron, and water levels	Chemical Parameters- Weekly during oxidant application periods. Well water levels- daily and increased to 2x/day min. for wells < 50 ft from injection points.
Post-Operations	Groundwater- Measure Well Water Levels, Water Quality Indicators and VOCs to evaluate ISCO performance. Soils- Measure soil organic constituents to evaluate ISCO performance.	Wells- HW-9, MWs- 20, 23S, 24S, 26S, 27S and 28S, and PZ-5S. Soils- maximum 20 ft grid continuous samples, 4 ft to water table. Select sample based on VOC headspace (HS) result. Sample vadose soils in west and east treatment areas on 20ft center grid, east areas on centerlines at 10ft spacing.	Groundwater- VOCs (EPA 8260), pH, cond, ORP, DO, sulfate, alkalinity, iron and water levels. Soils- Field HS, VOCs and TPH.	Wells- Quarterly for 1-year after the end of site operations monitoring. Soils- 30 and 180 days after treatment

REV	DATE	ISSUE/REVISION DESCRIPTION	CHK'D	APPR'D
0	06/10/11	ISSUED FOR NYDEC SUBMITTAL	MJD	MJD

DESIGNED BY	MJD	DATE	03/30/11
DRAWN BY	KG	DATE	03/31/11
CHECKED BY	MJD	DATE	05/16/11
APPROVED BY	MJD	DATE	–

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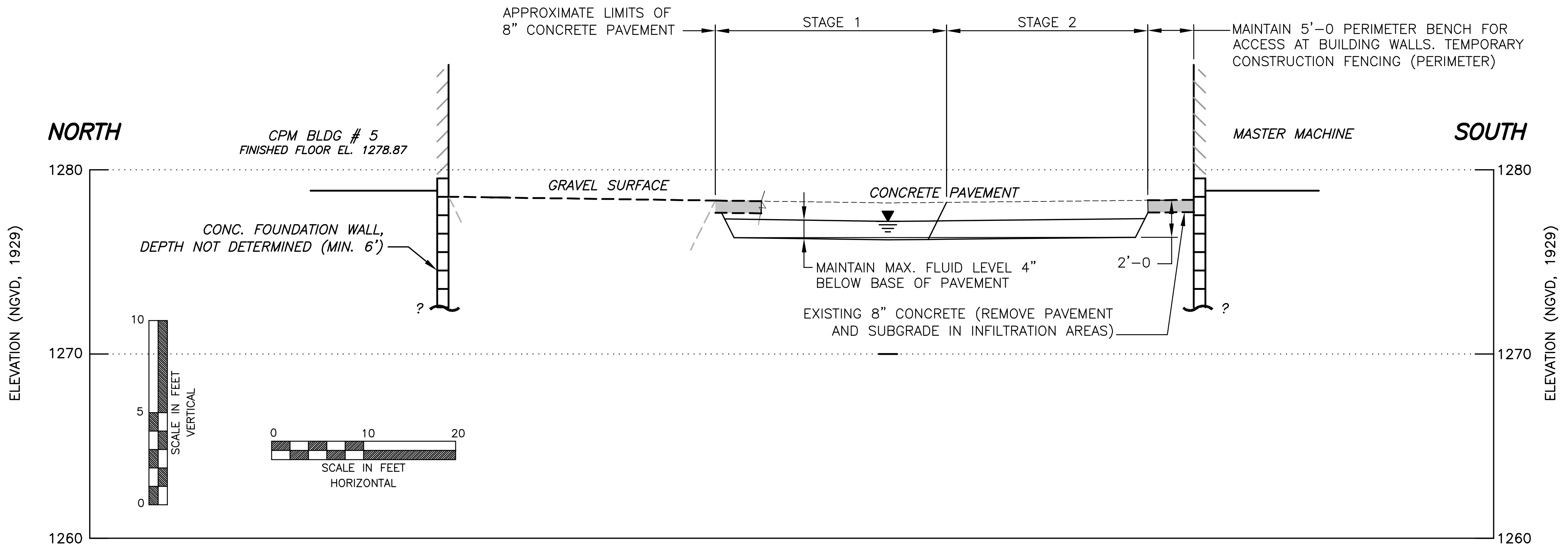
CLIENT **ESSEX SPECIALTY PRODUCTS, INC.**
ESSEX\HOPE FACILITY
JAMESTOWN, NEW YORK

REMEDIAL ACTION WORK PLAN UST AREA CHEMICAL OXIDATION

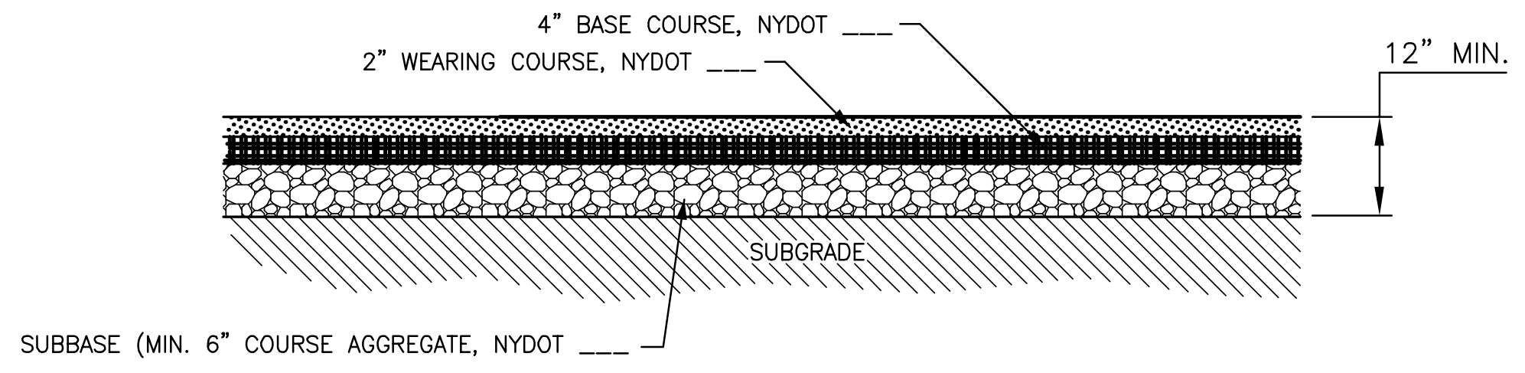
SITE MONITORING PLAN

CAD FILE NAME J:\ESSEXHOP\2006–MAP\REM–ACT–WORK–PLAN\SITE–PLAN
SCALE AS SHOWN
URS JOB NUMBER 41568097.10000
DRAWING NUMBER C–5
REV 0

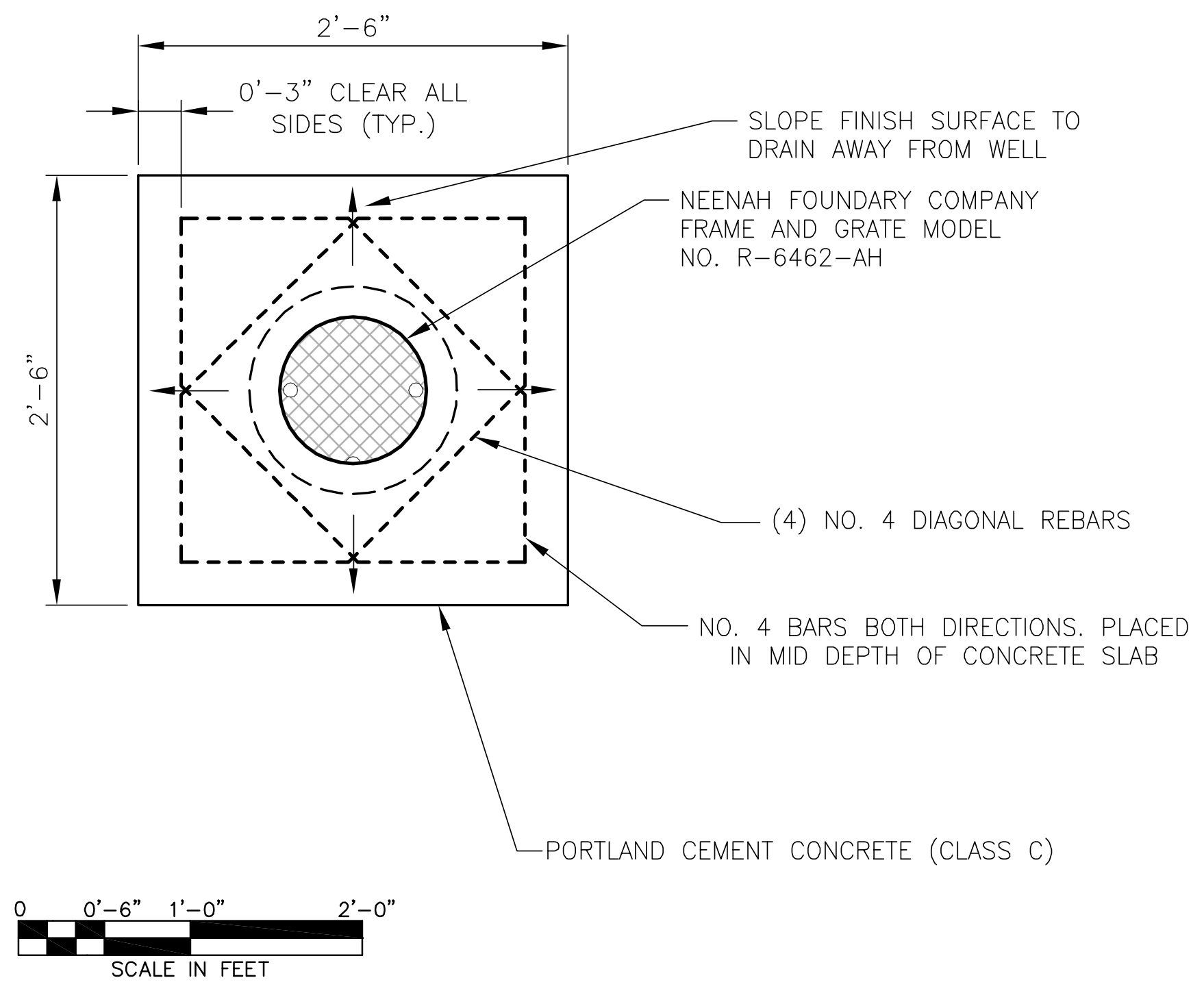


CROSS-SECTION C-C

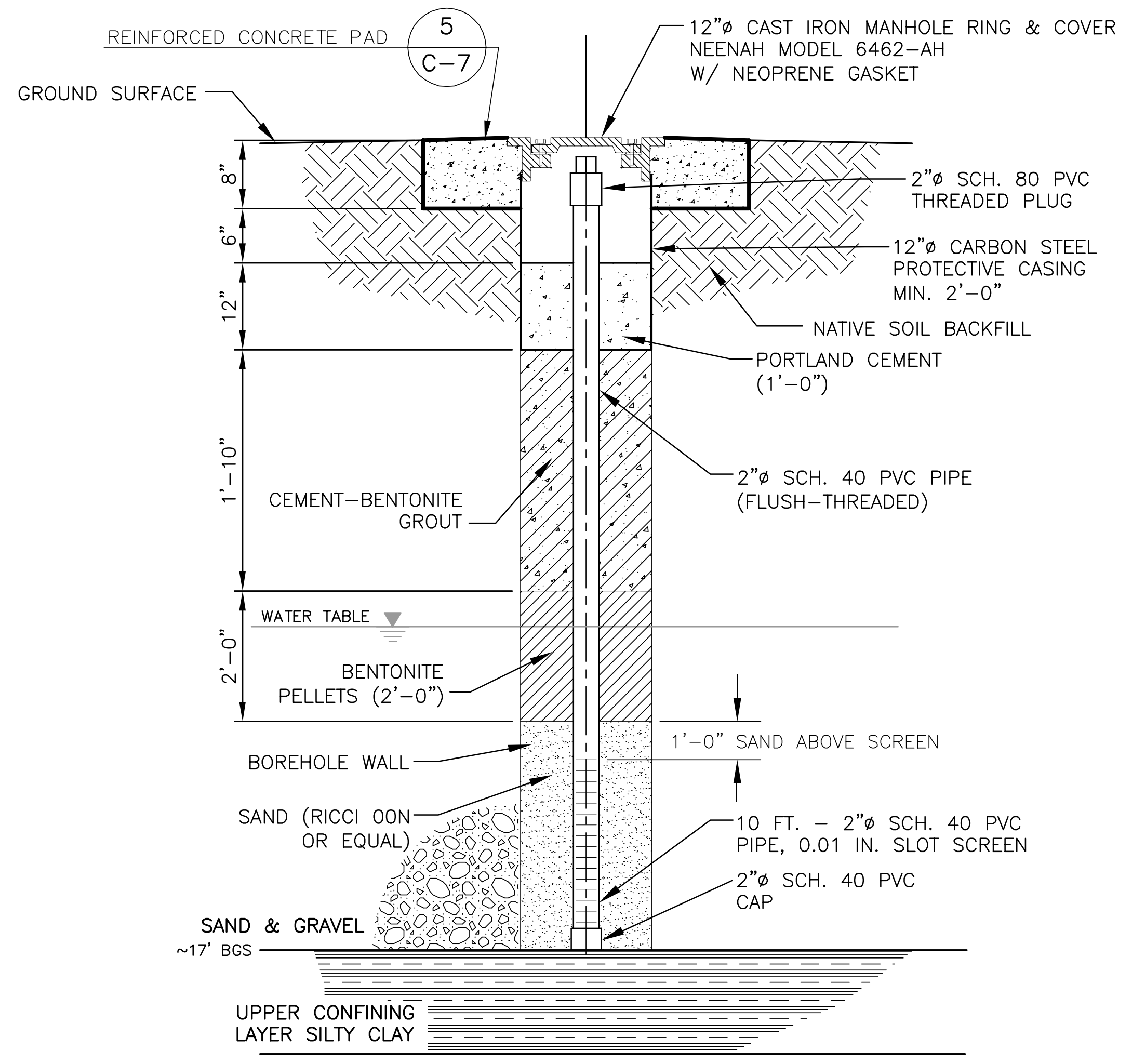
(SEE DRAWING C-3 FOR LOCATION)



4 C-3 BITUMINOUS PAVEMENT REPLACEMENT



5 C-6 REINFORCED CONCRETE PAD



C-2 C-3 NEW 2" MONITORING WELL

REV	DATE	ISSUE/REVISION DESCRIPTION	CHK'D	APPR'D
0	06/10/11	ISSUED FOR NYDEC SUBMITTAL	MJD	MJD

DESIGNED BY	MJD	DATE 04/05/11	SEAL	
DRAWN BY	KG	DATE 04/05/11		
CHECKED BY	MJD	DATE 05/16/11		
APPROVED BY	MJD	DATE –		

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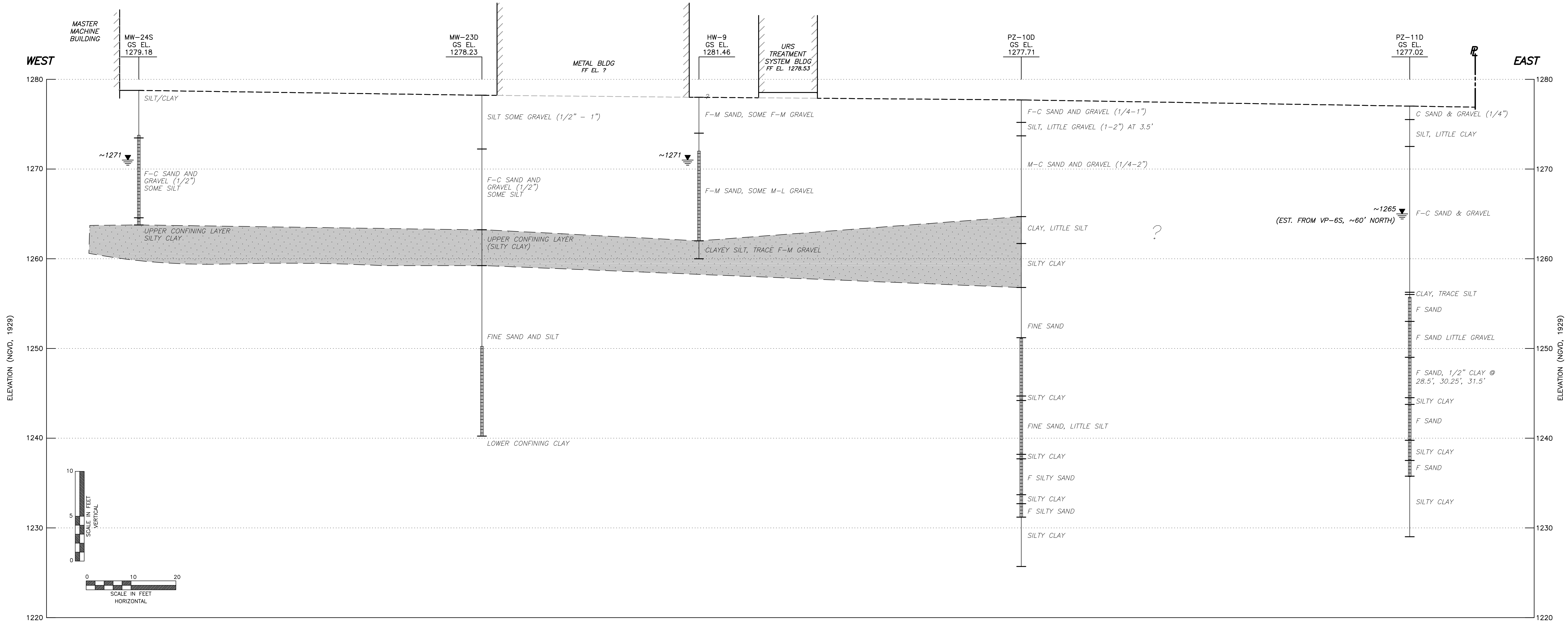
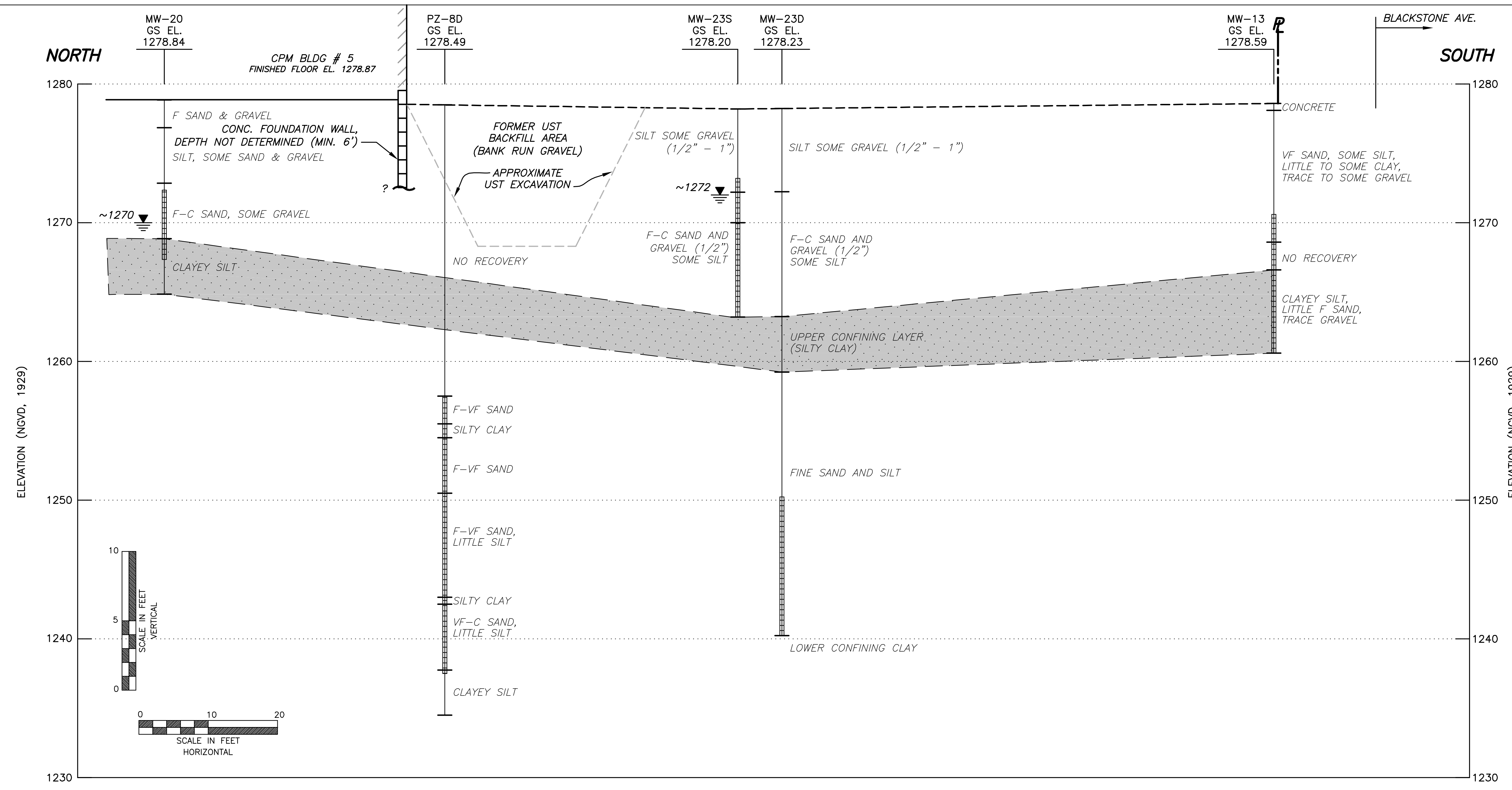
REMEDIAL ACTION WORK PLAN
UST AREA CHEMICAL OXIDATION

CROSS-SECTIONS AND DETAILS

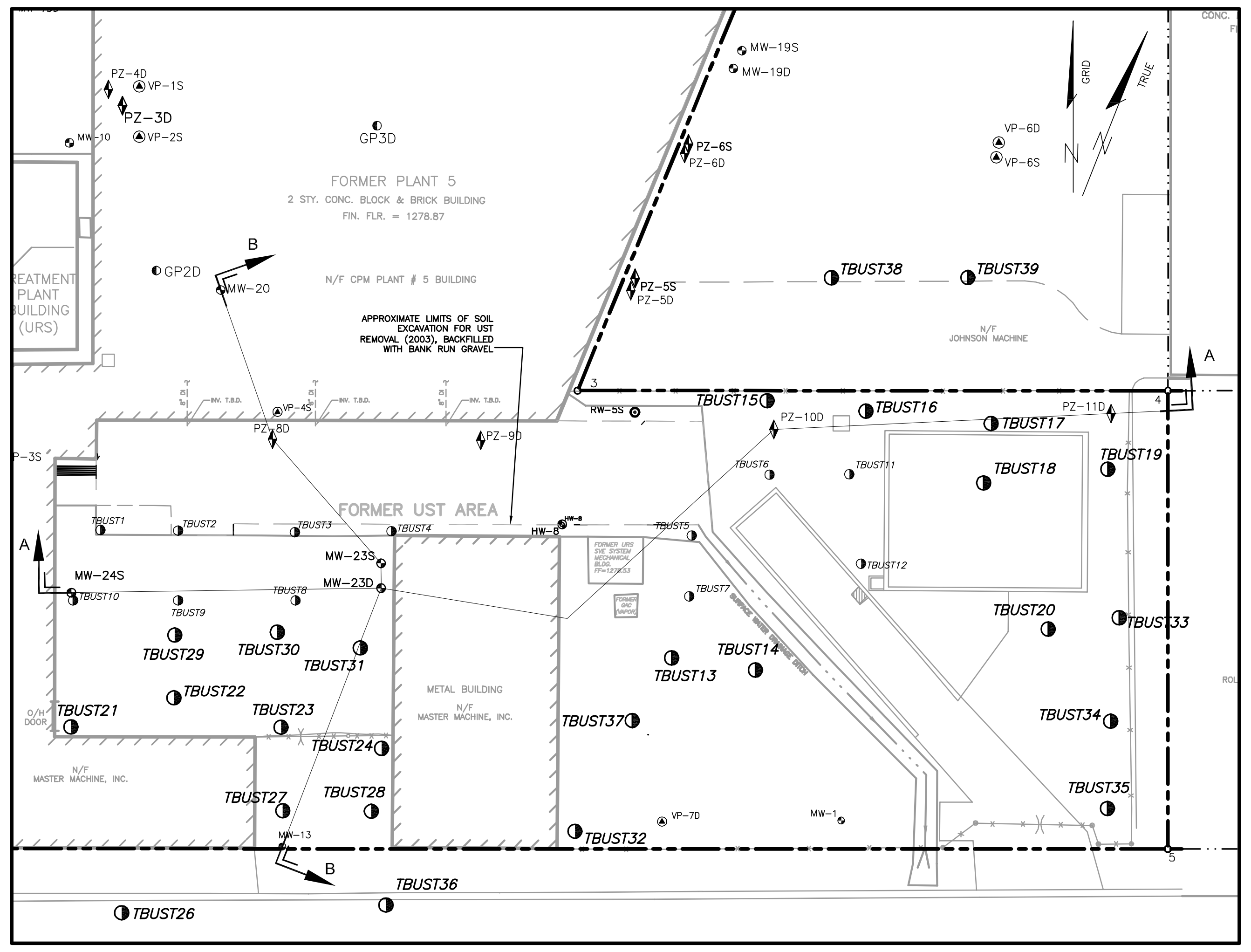
CAD FILE NAME J:\ESSEXHOP\2006-MAP\REM-ACT-WORK-PLAN\SITE-PLAN
SCALE AS SHOWN
URS JOB NUMBER 41568097.10000
DRAWING NUMBER C-6
REV 0



CROSS-SECTION A-A



CROSS-SECTION B-B



CROSS-SECTION LOCATIONS

NOTE
PLAN IS SHOWN FOR CROSS-SECTION LOCATION REFERENCE ONLY. SEE DRAWING C-1 FOR A DETAILED PLAN AT SCALE.

REV	DATE	ISSUE/REVISION DESCRIPTION	CHK'D	APPR'D
0	06/10/11	ISSUED FOR NYDEC SUBMITTAL	MJD	MJD

DESIGNED BY	MJD	DATE	08/24/10
DRAWN BY	KG	DATE	08/26/10
CHECKED BY	MJD	DATE	05/16/11
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REMEDIAL ACTION WORK PLAN UST AREA CHEMICAL OXIDATION

GEOLOGIC CROSS-SECTIONS

CAD FILE NAME J:\ESSEXHOP\2006-MAP\REM-ACT-WORK-PLAN\SITE-PLAN
SCALE AS SHOWN
URS JOB NUMBER 41568097.10000
DRAWING NUMBER C-7
REV 0