UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

REPLY TO THE ATTENTION OF: SR-6J

May 12, 2004

Commander
Southern Division
Naval Facilities Engineering Command
Attn: Dan Owens, Code ES32
P.O. Box 190010
North Charleston, SC 29419-9010

Subject: Review of the Draft Report for A Field Application to Enhance In-situ Bioremediation of Chlorinated Solvents Via Vegetable Oil Injection at the Naval Industrial Reserve Ordnance Plant, Fridley, Minnesota, March 2004

Dear Mr. Owens:

The United States Environmental Protection Agency, Region 5 (EPA) Federal Facilities Response Section has finished the review of the Draft Report for A Field Application to Enhance In-situ Bioremediation of Chlorinated Solvents Via Vegetable Oil Injection at the Naval Industrial Reserve Ordnance Plant, Fridley, Minnesota, March 2004.

The Draft Report indicates that the pilot test has provided valuable data to evaluate the potential effectiveness of the injection of vegetable oil at the NIROP site. Although the pilot test indicates that this technology may be useful in addressing the plume of chlorinated solvent contamination in groundwater beneath Anoka County Park (ACP), the results of the pilot test do not appear to be adequate to warrant the full implementation of the technology at the NIROP site. Consequently, as decided at the Technical Group meeting held at NIROP on April 14, 2004, an expanded pilot test should be conducted.

In addition, the EPA noted a number of issues regarding implementation of the vegetable oil injection technology at the NIROP site. The Draft Report should be revised as necessary to address the issues identified in the attached comments and to include a recommendation for an expanded pilot test rather than a full scale implementation of the technology. The revised Draft Report should identify issues and data gaps that should be addressed during the expanded pilot test and should include details, where possible, regarding how these issues and data gaps will be addressed during an expanded pilot test.

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If you have any questions, please call me at (312) 886-6450 or e-mail me at smith.thomasl@epamail.epa.gov and I will address your concerns as quickly as possible.

Sincerely,

Thomas L. Smith
Remedial Project Manager

cc: David N. Douglas, MPCA
Mark Sladic, Tetra Tech NUS, Inc
Venky Venkatesh, CH2M Hill
John Koehnen, TechLaw
Richard H. Kuhlthau, TechLaw

TECHNICAL REVIEW OF DRAFT REPORT FOR A FIELD APPLICATION TO ENHANCE IN-SITU BIOREMEDIATION OF CHLORINATED SOLVENTS VIA VEGETABLE OIL INJECTION MARCH 2004

NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT (NIROP) FRIDLEY, MINNESOTA

A technical review of the Draft Report for a Field Application to Enhance In-Situ Bioremediation of Chlorinated Solvents Via Vegetable Oil Injection at the Naval Industrial Ordnance Plant, Fridley, Minnesota (Draft Report) has been performed. The review indicates that the pilot test has provided valuable data to evaluate the potential effectiveness of the injection of vegetable oil at the NIROP site. Although the pilot test indicates that this technology may be useful in addressing the plume of chlorinated solvent contamination in groundwater beneath Anoka County Park (ACP), the results of the pilot test do not warrant the full implementation of the technology at the NIROP site. Consequently, as decided at the Technical Group meeting held at NIROP on April 14, 2004, an expanded pilot test should be conducted.

The Draft Report has raised a number of issues regarding implementation of the vegetable oil injection technology at the NIROP site. Review of the Draft Report has identified a number of additional potential technical issues which are documented in the following Specific Comments. The Draft Report should be revised as necessary to address these issues and to include a recommendation for an expanded pilot test rather than a full scale implementation of the technology. The revised Report should identify issues and data gaps that should be addressed during the expanded pilot test and should include details, where possible, regarding how these issues and data gaps will be addressed during an expanded pilot test.

SPECIFIC COMMENTS

1. **Section 2.3, Site Hydrogeology (Page 2-4):** The Draft Report provides several references to more detailed discussions on site geology and hydrogeology. The Annual Monitoring Reports (AMRs) should be added to this list. The AMRs include detailed discussions of site geology and hydrogeology and are updated annually as necessary to reflect any new data and analysis on site hydrogeological issues, including any developing consensus among the NIROP Technical Team on these issues. Specifically the revised Draft Report should reference the 2003 AMR.

2. **Section 2.3, Site Hydrogeology (Page 2-4):** The Draft Report states that "although monitoring wells installed in the shallow drift aquifer at the site have been designated as shallow and intermediate, there appears to be no or very little hydraulic separation between these monitored intervals; hence both of these zones make up the shallow unconfined aquifer at the site." This statement does not appear to be consistent with the current understanding of site hydrogeology. There are areas of the site where the

hydraulic separation between shallow and intermediate zone has been observed; and in these areas it may be more appropriate to associate the intermediate zone with the deeper confined or semi-confined aquifer. Revise the Draft Report to provide a more accurate and complete description of site hydrogeology.

3. **Section 2.3.1, Groundwater Flow Under Pumping Conditions (Page 2-7):** The Draft Report discusses the potential for a significant component of upward vertical flow between the Prairie du Chien (PC) aquifer and the overlying unconsolidated aquifer system. The Draft Report further indicates that "this vertical flow up into the unconsolidated aquifer system likely represents a potential source of both contaminant mass and groundwater having a different geochemical signature than the unconsolidated aquifer system." Due to the groundwater quality observed in monitoring well MS-53PC, the Draft Report concludes, however, that "upwelling of PC aquifer water into the pilot test area is expected to impact groundwater geochemistry only." This assessment of the potential impact of groundwater discharging from the PC aquifer into the overlying unconsolidated deposits appears to be overestimated. While the higher heads in the PC aquifer and associated discharge into the overly unconsolidated aquifer may be partially responsible for the upward vertical gradients from the deep zone into the intermediate and shallow zones in ACP, the current conceptual model advanced by the United States Geological Survey (USGS) attributes these gradients to other hydraulic phenomena within the unconsolidated zone at the NIROP site. Moreover, the higher heads in the deeper aquifer is unlikely to result in groundwater flow from the PC aquifer, or even the deeper portions of the unconsolidated aquifer system, into the shallow groundwater system. These gradients are more likely to force flow in the intermediate zone in upgradient areas of ACP up into the shallow zone in the downgradient areas of ACP. Revise the Draft Report to provide a more accurate and complete description of site hydrogeology.

4. **Section 2.3.2 Non-Pumping Conditions and Effect of Extraction Wells (Page 2–9):** When discussing the effects of the extraction wells on groundwater flow directions and the hydraulic divide observed in ACP, the Draft Report states that "these observations indicate that the extraction system does not directly impact the pilot test area other than to potentially influence hydraulic gradients and produce short-term effects on groundwater flow conditions in the extreme upgradient portions of the pilot test area." The Draft Report further states that "as a result, geochemical and contaminant conditions within the pilot test area do not appear to be directly impacted by the extraction system."

   The Draft Report appears to understate the impact of the extraction system on the pilot study area. The water level surfaces depicted in the 2003 AMR (Figures 4-6 and 4-7) indicate that pumping may reduce water levels at MS-46S by approximately three feet. While seasonal water-level data taken during the pilot test may indicate a large seasonal component in these water-level changes, the recent USGS analysis of data taken during a different seasonal period appears to confirm water level changes of more than one and one-half feet. Moreover, the analysis of vertical gradient presented in the 2003 AMR indicates significant change between pumping and non-pumping conditions in the

magnitude and direction of vertical gradients between the shallow and intermediate zone at MS-46. During non-pumping conditions, a slight upward gradient is observed at the MS-46 location, while during pumping conditions a more substantial downward gradient is observed at this location. The full impacts of the pumping system should be acknowledged and the potential impact on the pilot test should be discussed in the Draft Report.

As noted in the following comments, the extraction system may have significant impacts on the migration of contaminants through ACP and into the pilot test area. Consequently, it does not appear appropriate to state that "geochemical and contaminant conditions within the pilot test area do not appear to be directly impacted by the extraction system." Revise the Draft Report to acknowledge the potential impact of the extraction system on the pilot test area.

5. **Section 2.4 Groundwater Quality Prior to Vegetable Oil Injection (Pages 2-11/2-12):** When discussing the higher concentrations of TCE in the central portion of ACP, the Draft Report indicates that isoconcentration maps of the shallow aquifer zone in the 1999 AMR show that "TCE concentrations are significantly lower northeast of East River Road than TCE concentrations present in the ACP." The Draft Report further states that "this zone of elevated concentrations generally corresponds to the location of the groundwater divide, which may represent a stagnation zone. This groundwater stagnation zone may allow elevated concentrations to exist in this area."

While the area of elevated concentrations in ACP has previously been thought to potentially result from an area of stagnation, more recent analyses suggests that this area of elevated concentrations may be/have been the result of contamination passing through the extraction system and migrating downgradient into the central portion of ACP. Recent analysis of vertical gradients in ACP, particularly in those areas upgradient to MS-46, indicate that this contamination may have been migrating not only through the shallow aquifer zone but also through the extraction system in the intermediate aquifer zone and subsequently may have been raised by the vertical gradients into the shallow zone. It is also important to note that high levels of contaminants remain evident in the intermediate zone northeast of the East River Road in potential source areas beneath the former manufacturing building. The drop in contaminant levels in ACP observed since the augmentation of the extraction system in 2001 appears to support this alternate explanation of contamination patterns in ACP.

Revise the Draft Report to acknowledge this alternate explanation for the patterns of contamination observed in ACP. The Draft Report should similarly use knowledge gained during the pilot study regarding groundwater flow in the study area, including estimates of groundwater velocity, to assess whether the study area is an area of hydraulic stagnation. If found to be an area of hydraulic stagnation, the ramification of this finding on the implementation of the vegetable oil technology should be further explored in the Draft Report.

6. **Section 2.5 Chlorinated Ethenes Over Time at Anoka County Park:** The Draft Report discusses the trends in TCE and Dichloroethene (DCE) concentration in ACP prior to and during the pilot test. Several concerns have been noted about this analysis of contaminant trends. The extraction system was upgraded in June, 2001, and this upgrade appears to have had significant impact on contaminant levels in ACP, particularly in the core area of the ACP plume (see the 2003 AMR). The analysis of contaminant trends prior to and during the pilot test should be focused on evaluating the potential impact of these upgrades in the extraction system on the contaminant trends upgradient from and in the pilot study area. The analysis currently included in the Draft Report presents data from wells located throughout the ACP and tends to average contaminant trends from these wells. However, contaminant levels are significantly less in the peripheral areas of the plume than the core area of the plume. Moreover, the upgrades to the extraction system were designed to address core areas of the plume, which appear to be largely upgradient from the initial pilot study area.

   The wells located in the core area of the plume, including upgradient and within the general downgradient area of the pilot study, include MS-36S, 18-S, MS-45, and 26-S. The data in the 2003 AMR clearly demonstrate that all of these wells have experienced significant declines in contaminant concentrations since the 2001 upgrade of the extraction system, both prior to and during the pilot test. As indicated in an earlier comment, contaminant trends in the intermediate zone in areas upgradient from the pilot study area may also influence contaminant trends in the shallow zone in the pilot study area. The data from well MS-36I demonstrates a dramatic drop in contaminant levels in the upgradient intermediate zone after implementation of the 2001 extraction system upgrade.

   Indicating that wells MS-45S and MS-46S were likely impacted by vegetable oil injection, the Draft Report has excluded the data from these wells from the evaluation of the data trends during pilot test. However, the contaminant trends observed in these wells during the pilot test appear consistent with the overall trends observed in the core area of the ACP plume. Based on the data presented, the cause for the decreases observed in these well are not clear and appear to require further evaluation.

   The analysis of contaminant trends presented in the Draft Report appears to dramatically underestimate the potential impact of the 2001 upgrade of the extraction system on contaminant trends in the Pilot Study Area. Revise the Draft Report to include a detailed analysis of contaminant trends in the core areas of the plume in ACP prior to and during the pilot test and to provide a more complete analysis of the impact of these trends on the interpretation of pilot test results.

7. **Section 4.1 Groundwater Flow:** Since the geochemical data obtained during the pilot test appears to indicate potentially significant variability in flow patterns in the test area. Revise the Draft Report to include an analysis of the boring data obtained during the installation of the pilot-test wells to determine if any significant geologic features can be identified that might influence flow patterns in the pilot-test area.

8. **Section 4.3 Pre-Injection Extent of Chlorinated Aliphatic Hydrocarbons in Groundwater (Page 2-24):** When discussing the initial distribution of TCE in groundwater, the Draft Report states that "this distribution of TCE concentrations is similar to the distribution of TCE concentration in soil and is (the) reciprocal to the distribution of TOC in soil." This statement appears counterintuitive. While high concentrations of TCE would be expected in soil at locations where groundwater concentrations are high, for any given concentration of TCE in groundwater, the concentration of TCE in soil should be higher in soils with a higher TOC. This is because the higher soil TOC provides for greater adsorption of TCE for any given concentration of TCE in groundwater.

Review of the groundwater quality data reported in Table 4-4 and the soil data presented in Table 4.3 indicates that the above statement is also not fully supported by the data. While this statement appears to correct for the data reported at PES-MW-6, where a high concentration of TCE in groundwater (6,200 ug/l) was observed along with a high concentration of TCE (710 ug/kg) and a relatively low TOC concentration (320 mg/kg) in soil. However, at PES MW-8 the highest concentration of TCE was measured in groundwater (6,700 ug/l), while a relatively low concentration of TCE (130 ug/kg) and high concentration of TOC (1,400 mg/kg) were measured in soil. At PES-MW-2 the groundwater concentration was initially relatively low at 2,100 ug/l, particularly relative to that at PES MW-8. However, the TCE and TOC concentrations in soil were 140 ug/kg and 1,200 mg/kg, respectively, which are very close to the soil concentrations observed at PES MW-8. Thus, the pattern between TCE concentrations in groundwater and soil and TOC in soil appears less certain than initially stated.

The Draft Report also states that "spatial distributions of TCE concentrations in soil and in groundwater correspond to observed changes in hydraulic conductivity, groundwater potentiometric surface gradients, and TOC concentrations." The meaning of this statement is unclear and the referenced correspondences should be more fully developed. The Draft Report continues by stating that "these data indicate that VOC migration downgradient through the pilot test area is being retarded and that this retardation may be related to increasing TOC content in soil near the river or changes in the groundwater migration related to changes in hydraulic conductivity." Although somewhat ambiguous, this statement appears to indicate that the contaminant concentration gradients observed within and downgradient of the pilot study area are due to the advancing contaminant front and it's failure to reach the river. However, given the high groundwater velocities observed in ACP and the length of time the contamination has likely been present in the environment, this does not appear likely.

Revise the Draft Report to include further analysis of the role adsorption is currently playing on contaminant migration in ACP and, particularly, in the pilot test area. The impact of adsorption on the migration patterns of contaminant and daughter products during biodegradation and the resulting consequence on data interpretation should be fully defined.

9. **Section 4.4.1 Chlorinated Ethenes Over Time (Page 4-29):** When discussing the significant decrease in TCE concentrations observed in MS-46S following vegetable oil injection, the Draft Report states that "this decrease indicates that this well was impacted by the vegetable oil activities, despite the fact that it is located approximately 20 feet upgradient of the injection wells." The Draft Report fails to provide adequate evidence that MW-46S was impacted by the vegetable oil injection. The TCE concentrations in this well dropped from 20,000 ug/l in November, 2001 before the injection of vegetable oil to 14,000 ug/l in February, 2002 after the injection. The TCE concentration at MW-46S subsequently dropped further to 5,600 ug/l by May, 2002. No discussion of the vegetable oil having spread this far upgradient in the text has been provided. Moreover, the geochemical data (Table 4.6) provides little evidence of the impact of vegetable oil in MS-46S, although geochemical impacts are readily observable in other wells impacted by the vegetable oil.

   The widespread reductions in TCE concentration observed in the core of the contaminant plume in ACP after the augmentation of the extraction system may be responsible, at least in part, for the reduction in TCE observed in MS-46S. The Draft Report should be revised to discuss the potential causes for the decreases in contamination observed in MS-46S. Unless a convincing demonstration can be made that the injection of vegetable oil is responsible for the reduction in contaminant concentrations, an acknowledgment that the pilot test may not be responsible for these decreases should be included in the Draft Report. This demonstration should clearly account for the lack of rebound in TCE concentrations in MS-46S after the initial period following the injection of vegetable oil.

   The drop in TCE concentrations in MS-45S following injection of vegetable has similarly been attributed to impacts of the injection of vegetable oil. The Draft Report should also discuss whether the decreases in contaminant concentrations observed in MS-45S are attributable to the injection of vegetable oil or acknowledge that these decreases in contaminant concentrations may be attributable to underlying trends in contaminant concentrations observed in ACP.

10. **Section 4.4.1 Chlorinated Ethenes Over Time (Pages 4-36 to 4-38):** The Draft Report provides an analysis of the average decrease of TCE in the pilot test area and contrasts this decrease with that observed in ACP outside the pilot test area. This discussion should be revised to more fully account for the decreasing contaminant trends occurring in the core of the plume in ACP, including the potential influence of these underlying trends on the decreases in contaminant concentration observed in MS-46S.

    Presentation of the total concentrations of volatile organic compounds (VOCs) expressed as molar concentrations at pilot test wells may be useful to demonstrate the extent to which the total mass of contaminants in the pilot study area remained constant during the test period. Such an analysis may help to demonstrate that the reductions in contaminant concentrations observed in many pilot test wells were not due to an underlying trend in contaminant mass in the pilot study area. Revise the Draft Report accordingly.

11. **Section 4.4.3 Chlorinated Aliphatic Hydrocarbons in Vegetable Oil (Page 4-41):** Based on the concentration of TCE measured in vegetable oil collected from PES-INJ-2 in February, 2002 and the changes in TCE concentrations observed in groundwater at this location before and after vegetable oil injection, the Draft Report indicates that the majority of TCE mass at this location was partitioned into the vegetable oil. While this appears to be a reasonable assumption, the Draft Report has also concluded that "these data also indicate that an additional 5,600 ug/l of TCE was added to the system," and that "this additional TCE mass was likely stripped out of the soil matrix by the vegetable oil and partitioned into the vegetable oil NAPL."' The basis for this statement is unclear. While TCE mass was likely stripped from the soil matrix, the estimate of an additional 5,600 ug/l that was added to the system does not appear to be well founded. The vegetable clearly shows the ability to concentrate contaminants above groundwater concentrations, but the actual volume of vegetable oil into which the contaminants were partitioned and the relative volume of water from which the TCE is removed are not known. Consequently, it does not appear possible to estimate the amount of mass that has been removed from the soil matrix. Revise the Draft Report to clarify this analysis or remove it from the text.

12. **Section 4.8 Summary of Enhanced Biodegradation (Page 4-80):** The Draft Report states that "increases in VC and ethene concentrations observed at monitoring well PES-MW-9 during 2002 indicate that TCE was being completely reductively dechlorinated to the reaction end product ethene at this location during this time period." Since there remained high levels of cis-1,2-DCE at PES-MW-9 during these periods, it appears more appropriate to indicate that a <u>limited amount</u> of TCE was being completely dechlorinated to the end reaction product ethene. Revise the Draft Report language accordingly.

13. **Section 4.8 Summary of Enhanced Biodegradation (Page 4-80):** When discussing the contaminant trends at PES-MW-9, the Draft Report states that "TCE concentrations increased and cis-1,2-DCE, VC and ethene concentrations decreased in December 2002 and April 2003," and that "this reversal in contaminant concentrations and molar fractions indicates that groundwater flow conditions changed in the vicinity of PES-MW-9." However, water level data do not appear to indicate a change in groundwater flow during this period, particularly during December 2002. Revise the Draft Report to further justify this statement or provide other explanations for the increases in TCE concentrations at PES-MW-9.

14. **Section 4.8 Summary of Enhanced Biodegradation:** Significant quantities of cis-1,2-DCE have been generated during the pilot test at a number of locations, including PES-MW-9. However, the fate of this daughter product and subsequent daughter products (i.e., vinyl chloride) has not been clearly established in the Draft Report. Discussions during the April 14, 2004 meeting indicated that a number of processes, abiotic as well as biotic, were available for the destruction of these compounds. Since concern has previously been expressed regarding the generation of vinyl chloride and its discharge to the river, the Draft Report should discuss in greater detail the potential fate of these daughter products.

The Draft Report has noted that significant amount of the daughter products have not been detected at the sentinel wells. Based on the apparent flow directions observed in the southeast portion of the pilot test area, it appears that flow directions away from the study area may be in a much more southerly direction than originally anticipated and that the sentinel wells may not be adequately placed to detect daughter products migrating from the pilot test area. Revise the Draft Report to acknowledge this potential deficiency in the sentinel monitoring well network.

15. **Section 4.8 Summary of Enhanced Biodegradation (Page 4-82):** The Draft Report indicates that the "data indicate that the lack of wide-spread reductive dechlorination at the ACP pilot test site is primarily a function of sub-optimal organic carbon distribution." The report further states that "dissolved phase organic carbon is not being transport to downgradient monitoring wells as rapidly as was expected," and that "the slow migration rates are likely a result of the low hydraulic gradient in the injection area and the transient groundwater flow reversals observed occasionally during the process monitoring activities." However, the assessment that slow groundwater flow is responsible for the failure of dissolve organic carbon to be transported seems inconsistent with the reduction of TCE levels in a number of downgradient wells, although there is little evidence that reductive dechlorination is occurring at these locations. This would appear to suggest that TCE levels are being reduced upgradient and that these volumes of groundwater with reduced TCE concentrations are migrating to the downgradient wells. If there is sufficient groundwater velocity to bring these reduced levels of TCE into downgradient areas, there may be some other reason for dissolved organic carbon not reaching these downgradient areas as well. Revise the Draft Report to discuss other potential causes for the failure for dissolved organic carbon to reach downgradient area.

16. **Section 4.10 Data Quality Objectives (Page 4-87):** The Draft Report indicates that "the pilot test project can be considered a complete success from the DQO standpoint." The Draft Report also indicates that, based on the DQOs previously established, the first step in evaluating the pilot test is to determine if "the mean concentration at monitoring wells PES-MW-1, PES-MW-6, or PES-MW-7 is below 1,000 ug/l for five consecutive sampling rounds." The Draft Report notes that this requirement is met at PES-MW-7. Although not stated in the report and not required by the DQOs, this requirement has clearly not been met at PES-MW-1 and PES-MW-6. The Draft Report indicates that TCE concentration reduction at PES-MW-7 represents a decline of 99.3%, with the TCE concentration dropping from 300 ug/l to 2.1 ug/l. This reduction does demonstrate that the pilot test was able to reduce significantly the relatively low concentrations of TCE initially found at this location. However, it must be noted that the DQOs would likely have been met at this location, even if the pilot test had not been conducted, since the TCE concentration was already below 1000 ug/l at this location before the start of the test. The DQOs were originally established based on the idea that concentrations of TCE representative of that found at MS-46S (18,000 ug/l) would be found throughout the study area and that the goal was to achieve a reduction of TCE concentrations from this level to below 1,000 ug/l.

Thus, while the DQOs have technically been met, these evaluation criteria do not appear to be particularly well suited for evaluating the conditions actually encountered during the test. It is recommended that while indicating that the DQOs have been met, the Draft Report should be revised to indicate that these evaluation criteria do not provide a good measure of the capability of the vegetable oil injection technology. Rather, the Draft Report should emphasize other measures of success when evaluating the pilot test.

17. **Section 5.1 Conclusions:** The conclusions present in the Draft Report should be revised as necessary after addressing the concerns and issues raised in the previous Specific Comments.

18. **Section 5.2 Recommendations:** Based on discussion at the April 14, 2004 NIROP Technical Team meeting, the recommendations included in the Draft Report should be revised to include only a recommendation for an expanded pilot test. The recommendations should identify the issues and data gaps that should be addressed during the expanded pilot test and include tentative plans for how these issues and data gaps can be addressed