TECHNICAL MEMORANDUM

August 2005

To: Dan Owens and Cliff Casey, NFESC; Venky Venkatesh, CH2M Hill Constructors, Inc.

From: Dan Griffiths and Bruce Henry, Parsons

Subject: Preliminary Results for the Anoka County Park Organic Substrate Addition Pilot Test, Fridley, Minnesota

---

This technical memorandum presents a summary of data collected during extended monitoring activities conducted at the vegetable oil injection pilot test during the Spring of 2005, as well as relevant historic pilot test data. This technical memorandum has been prepared for the Naval Facilities Engineering Command (NAVFAC), Southern Division, and CH2M Hill Constructors (CCI) by the Parsons Corporation (Parsons).

INTRODUCTION

During the reporting phase of this project it was determined that this pilot test was a success in that each of the data quality objectives (DQOs) were met and reductive dechlorination was enhanced in the vicinity of the vegetable oil injection area. However, it was also determined that vegetable-oil-derived organic carbon was not effectively distributed within the pilot test area and that complete reductive dechlorination was only induced in a relatively small area (Parsons, 2004).

The activities associated with the extended monitoring program, presented in the work plan addendum technical memorandum dated January 6th 2005 and presented in this technical memorandum, were designed to improve the characterization of the pilot test area and to address the data gaps identified in the final work plan addendum (Parsons, 2005).

EXTENDED MONITORING ACTIVITIES

Extended process monitoring activities at the vegetable oil pilot test site were conducted in accordance with the final work plan addendum (January 6th 2005), the Final Work Plan (Parsons, 2001a), final Quality Assurance Project Plan (QAPP), (Parsons, 2001b), and guidance provided by the United States Environmental Protection Agency (USEPA (1998)).

The extended process monitoring activities were conducted in three phases. The first phase consisted of a membrane interface probe (MIP) survey within the pilot test area to investigate the stratigraphy and vertical distribution of volatile organic compound (VOC) mass from the ground surface to a total depth of approximately 60 to 70 feet below ground surface (bgs). The second phase used the data generated during the MIP survey to place eight new monitoring wells and ten soil borings within approximately 100 feet of the injection area. The third phase began after the new monitoring well clusters are installed and consisted of a groundwater sampling event at the newly installed wells, existing pilot test wells, and selected existing monitoring wells located outside of the pilot test area. A second groundwater sampling event will be conducted approximately 6 months after the first event, in October 2005. The data collected during the field activities associated with the extending monitoring of the vegetable oil pilot test area are presented in the following subsections.

Membrane Interface Probe Survey

An MIP survey was conducted within the pilot test area in order to improve the characterization of the stratigraphy and distribution of VOCs in the subsurface. During the MIP survey it was determined that an area of relatively high VOC concentrations is present in the proximity of the pilot test area, and that this area of high chlorinated VOC concentrations extends further than expected to the south and west. Therefore, all of the contingency MIP borings and one additional MIP boring were installed for a total of 38 MIP points (Figure 1). In addition, it was discovered that the direct push equipment employed during the MIP survey was capable of drilling deeper than expected. Thus, select MIP borings were advanced to a maximum depth of 70 feet below ground surface (bgs) instead of the proposed maximum depth of 50-60 feet. This data indicates that the direct push drilling technology is a viable drilling method at Anoka County Park to depths of at least 70 feet.

During the course of the MIP survey, discrete groundwater samples were collected from the background MIP location and sixteen MIP locations drilled within or in close proximity to the injection area. A total of 45 discrete groundwater samples were collected from select vertical intervals corresponding to high and low chlorinated VOC concentrations and areas where high flame ionization detector (FID) readings were observed. The discrete groundwater samples were collected at each location using direct push discrete sampling equipment. Each sample was collected directly from the aquifer formation through the sampling point without purging a significant quantity of groundwater. These samples were analyzed for VOCs via USEPA Method 8260B, total organic carbon (TOC) via USEPA method SW9060, and methane, ethane, and ethene via Microseeps Internal standard operating procedure (SOP) AM-20GAX in order to qualitatively validate the MIP results. The data set generated from the analysis of these samples was used in conjunction with data generated during the MIP program and the soil sampling program to determine the extent of the area directly impacted by vegetable oil and to investigate the distribution of CAH reductive dechlorination products within the injection area. The completed MIP borings and discrete groundwater sampling results are summarized in Table 1.

Soil Boring Installations

A total of ten soil borings were installed as part of the extended monitoring activities related to the vegetable oil pilot test. Seven soil borings (PES-SB-1 through PES-SB-7) were advanced in the immediate vicinity of the three injection wells. These soil borings were used to collect stratigraphic, geochemical, mineralogical, and microbial data in the vicinity of each injection well and to determine the extent of the injection area. Three additional soil borings (PES-SB-8 through PES-SB-10) were installed immediately downgradient of the injection area in order to investigate anomalies in the geophysical data set generated by the United States Geological Survey (USGS). The completed soil boring installation activities are summarized in Table 2 and are presented in detail in the following subsections. Boring logs prepared during drilling are presented in Appendix A.

Monitoring Well Installations

A total of eight new monitoring wells were installed using hollow stem auger (HSA) drilling techniques during the extended monitoring program. One of the proposed monitoring wells (PES-MW-13A) is located approximately 55 feet upgradient of MS-46S and approximately 65 feet upgradient of the injection area (Figure 2). The data collected from this location is representative of soil and groundwater that have not been impacted by the injected vegetable oil and iron tracers. The remaining seven monitoring wells were installed south and downgradient from the injection area as shown on Figure 2. Proposed monitoring well clusters PES-MW-10, PES-MW-12, PES-MW-14 consist of two wells installed at two vertical intervals within the shallow drift aquifer (Figure 2), while monitoring wells PES-MW-11A and PES-MW-13A consist of single wells installed slightly below the bottom of the silt/clay unit (Figure 2). The new monitoring wells, with the exception of PES-MW-13A, were installed to investigate potential vegetable oil impacts in a more southerly direction from the injection area and to investigate the potential for vertical groundwater flow. The installation details associated with the new monitoring wells are summarized in Table 2.

Each monitoring well installed during the extended monitoring program was constructed of 2-inch inside diameter (ID) schedule 40 polyvinyl chloride (PVC) casing and 0.020-inch slot screen. Each monitoring well was installed with approximately 10 feet of factory slotted screen which was flush threaded to the appropriate length of solid casing. A filter pack consisting of clean size 10-20 silica sand was installed from the bottom of each borehole to approximately 2 feet above the top of the screen interval. A 2-foot thick pure bentonite seal was installed above the sand pack, and a concrete-bentonite sanitary seal was installed from the top of the bentonite seal to ground surface. The installation details associated with the new monitoring wells are summarized in Table 2.

During drilling and well installation activities, soil samples were collected from the screen interval of each proposed monitoring well and shipped to an offsite laboratory for analysis.

Membrane Interface Probe Survey Results

The MIP rig employed at Anoka County Park was provided and operated through a subcontract by KB Labs Incorporated. KB Labs' MIP rig was equipped with approximately 70 feet of direct push rod with a heating block on the bottom. As the MIP rod was advanced, a heating block at the tip of the probe heated the soil and groundwater in the immediate vicinity of the probe tip. As the heating block heated the soil and groundwater, the resultant "soil gas" was drawn through a membrane and into an inert gas loop where it was drawn through a series of detectors at ground surface. The detectors included an electron capture detector (ECD) to detect total chlorinated VOCs, a photoionization detector (PID) to detect total VOCs, and an FID to detect methane and less volatile organic compounds that are not detected by the PID. In addition, a dipole array was installed in the MIP probe which collected electrical conductivity data from the soil matrix. Using this suite of detectors, a complete vertical profile of relative soil grain size, total chlorinated and non-chlorinated VOC concentrations, and methane concentrations was generated for each MIP location. The MIP locations are depicted on Figure 1.

During the course of the MIP survey it was discovered that the soil conductivity logs that were being produced by the dipole array did not match up to soil boring logs collected during the installation of the pilot test system in 2001. After the new soil borings and monitoring wells were installed the soil conductivity profiles were compared to the newly generated boring logs and the historic logs. The newly generated boring logs matched the historic logs relatively well. However, the soil conductivity logs did not match the new or historic boring logs. Therefore, we conclude that the soil conductivity logs collected during the MIP survey do not represent stratigraphic conditions at the site and will not be used for any purpose.

The data collected during the MIP survey indicates that the concentration of total VOCs present beneath the pilot test area is insufficient to cause a deflection on the PID instrument associated with the MIP system. There were no PID detections in any of the profiles collected with the exceptions of MIP-31 and MIP-36. Therefore, the MIP discussion with regard to VOC concentrations will be based on data collected with the ECD. The MIP profiles are attached to this technical memorandum as Appendix A.

Electron Capture Detector Data

The ECD data collected during the MIP survey is summarized on Table 3, is depicted on Figure 5, and is presented in detail in Appendix A. The complete data set collected by KB labs was also provided under a separate cover (KB Labs, 2005). Review of the horizontal distribution of ECD response indicates that elevated concentrations of chlorinated VOCs are present throughout the pilot test area. Elevated concentrations of chlorinated ethenes were detected at all MIP locations, indicating that the VOC "hot spot" was not bounded in any direction during the MIP survey.

Review of the vertical distribution of ECD response indicates that at most MIP locations installed upgradient of PES-MW-10A/B, elevated concentrations of chlorinated solvents were present below approximately 28 to 30 feet bgs and above 40 to 42 feet bgs. The exceptions to this observation include MIP points MIP-3, MIP-6, MIP-10, MIP-11, and MIP-14. Downgradient of PES-MW-10A/B the ECD data collected at the majority of the MIP points indicate that elevated concentrations of chlorinated VOCs are present below a depth of approximately 35 feet bgs and do not extend below approximately 50 feet bgs. In some cases elevated concentrations of chlorinated VOCs extended below the bottom of the total advancement depth of the point. Therefore, the vertical distribution of elevated chlorinated VOC concentrations is not completely defined at these locations.

Immediately after the completion of the MIP survey, discrete groundwater samples were collected from direct push borings installed immediately adjacent to a selection of MIP bore holes. The discrete groundwater samples were collected in an effort to quantify the ECD and FID response data collected during the MIP survey. The ECD response and associated discrete sampling data are summarized in Table 4. Generally the ECD response for a given depth compares relatively well to the associated total chlorinated VOC concentration as reported by the discrete sampling results within each borehole, with the exception of results from MIP-5, MIP-8, and MIP-19. However, the correlation of ECD response to discrete sampling data does not hold up between boreholes as indicated by the variability in the correlation factor data presented on Table 4. These observations indicate that the ECD response data appears to be a useful tool to qualitatively determine the vertical distribution of chlorinated solvents within a particular borehole. However, the ECD data does not appear to be a very useful tool to determine the horizontal distribution of chlorinated VOC concentrations except in a very qualitative "presence-absence" way. Therefore, the distribution of ECD response data with respect to the size of the detections will not be discussed, as this data does not appear to correlate to changes in chlorinated VOC concentrations.

Flame Ionization Detector Data

The FID response data generated during the MIP survey (Table 4 and Appendix B) is representative of concentrations of methane and other less volatile organic compounds that are not detected by the PID or the ECD. Thus, FID response can be considered to be indicative to the presence of organic material in the subsurface because the presence of methane can be inferred to result from the biodegradation of organic matter. Organic material in the subsurface at the pilot site consists of a combination of naturally occurring organic material in the soil matrix as well as vegetable oil injected as part of the pilot test. Therefore, the FID data collected during the MIP survey is representative of both naturally occurring as well as vegetable oil derived organic carbon. However, vegetable oil was injected at relatively high concentration at this site so it was expected that the response to vegetable oil derived organic carbon would be much larger than the response to naturally derived organic carbon signature.

Relatively low FID detections in the range of approximately 1E+05 to 6E+05 microvolts (uV) were observed sporadically throughout the pilot test area at locations that are unlikely to be impacted by vegetable oil derived organic carbon (i.e., cross gradient points MIP-18 and MIP-36, as well as downgradient points MIP-27, MIP-32, and MIP-37). These observations indicate that the FID detector was detecting organic carbon that is likely to be naturally occurring, with a response of approximately 6E+05 uV. Within and downgradient from the injection area FID detections were much higher, ranging from approximately 1E+06 uV to 1E+07 uV, indicating that the vegetable oil derived organic carbon is responsible for an increase in FID response of approximately one to two orders of magnitude.

Relatively high FID detections were observed in a large area which includes the injection area and extends southwest as far down gradient as MIP-26 (Figure 6). This relatively large area corresponds roughly to the area of elevated TOC discussed in later sections (Figure 9). The coincidence of the area of elevated FID readings and the area of elevated TOC concentrations indicates that the FID was likely detecting dissolved phase organic carbon, dissolved methane, as well as non-aqueous phase vegetable oil. Thus, the area of elevated FID detections represents an area that is impacted by vegetable oil derived organic carbon, both directly and indirectly.

The vertical distribution of FID detections at all locations is highly heterogeneous. Within the un-impacted locations this heterogeneity indicates that naturally occurring organic carbon is present only within particular vertical intervals. For example, at MIP-36 (Appendix A) elevated FID readings are limited to two very narrow vertical intervals located at 28 feet and 30 feet bgs. Review of the boring log from PES-BG-2, located approximately 8 feet away, indicates that these vertical intervals consist of silty sand which is slightly finer than the fine to medium sand present above and below this vertical interval. This fine grained unit likely contains higher concentrations of naturally occurring organic carbon than the surrounding sands, which would result in a higher FID reading. Large ECD peaks are also present in the MIP-36 profile at the same depth intervals indicating that the fine grained unit contains elevated concentrations chlorinated VOCs as well as TOC. The heterogeneous distribution of FID peaks in borings within the injection area indicates that the injected vegetable oil also has a heterogeneous vertical distribution.

Soil Sampling Results

Continuous soil samples were collected from the soil borings and monitoring well borings from the ground surface to the bottom of each borehole. Boring logs were prepared by an experienced field geologist at each boring location. The boring logs compiled during the extended monitoring program are included as Appendix B.

A total of 36 soil samples were collected during drilling activities and analyzed for VOCs via USEPA method 8260B. Soil samples were collected from soil borings PES-SB-1, PES-SB-2, and PES-SB-3 to characterize the soil conditions in the immediate vicinity of the injection wells. At each soil boring location, subsurface soils impacted by vegetable oil were typically stained dark brown or black and smelled of degrading vegetable oil. At soil boring PES-SB-1 and PES-SB-3, the soil was heavily impacted by vegetable oil from a depth of approximately 33 feet bgs to 39 feet bgs and from 39 feet to 48 feet bgs, respectively. These impact intervals correspond to the closest injection well screen intervals (PES-INJ-01 and PES-INJ-03, respectively). At soil boring PES-SB-2, which was installed immediately adjacent to PES-INJ-02, vegetable oil impacts extended from just below the top of the PES-INJ-02 injection interval at 40 feet to 6 feet below the bottom of the PES-INJ-02 injection interval at 50 feet. At all locations vegetable oil impacts were more pronounced in coarser, more transmissive units, indicating that the injection fluids migrated predominantly through the more permeable sand units.

Soil borings PES-SB-4 and PES-SB-5, were drilled upgradient of PES-INJ-2 to define the upgradient edge of the injection area, while PES-SB-6, and PES-SB-7 were drilled down gradient of PES-INJ-2 to define the down gradient edge of the injection area. Evidence of vegetable oil impact was not observed in PES-SB-4 and PES-SB-5, indicating that the injected vegetable oil did not travel more than approximately 8 to 10 feet upgradient during or after injection. This conclusion is contradicted somewhat by the high FID detections at MIP-02 (installed approximately 25 feet upgradient of PES-SB-5). On the downgradient side of the injection area vegetable oil impacts were observed at PES-SB-6, PES-SB-7, PES-SB-8, and PES-SB-9 indicating that vegetable oil or high concentrations of vegetable oil derived organic carbon migrated as far down gradient as approximately 23 feet. Impacts were observed in these wells primarily as soil intervals with mild to moderate degrading vegetable oil odor. Impacts were observed at these downgradient locations as deep as approximately 55 feet bgs (PES-SB-9). Two intervals containing "weak to mild odor" were observed during drilling at PES-MW-10B at 50 feet bgs and 53 feet bgs. These observations may indicate that these depth intervals were impacted by vegetable oil or high concentrations of vegetable oil derived organic carbon. These observations indicate that during and potentially shortly after injection the vegetable oil or high concentrations of vegetable oil derived organic carbon continued to spread laterally along the coarser more transmissive units as far down gradient as approximately 23 to 25 feet. This data does not indicate that the injected vegetable oil spread vertically (upward or downward) to a significant extent.

The boring logs compiled during the drilling activities were combined with the historic boring logs and used to develop a fence diagram which depicts the stratigraphic data collected during drilling in three dimensions (Figure 3). Review of the boring log data and the fence diagram indicates that the stratigraphy beneath the pilot test site is relatively consistent on a large scale. The soil beneath the pilot test area consists predominantly of fine to medium sand and silty sand which extends from approximately 5 feet bgs to below the maximum drilling depth of 70 feet bgs.. At approximately 30 feet bgs there is a fine grained of unit of variable thickness which consists predominantly of silt and clay. This fine grained unit ranges in thickness from less than one foot to a maximum of approximately 6 feet and is continuous throughout the pilot test area. There are also a number of smaller, less continuous, fine grained units present beneath the pilot test area. In particular, there appears to be a relatively large, thin silt/clay unit present at a depth of approximately 60 feet beneath and downgradient from the injection area. It is likely that these fine grained units impact and therefore to some extent control groundwater flow characteristics locally within the pilot test area.

Total Organic Carbon Analyses in Soil

During drilling operations soil samples were collected from soil borings drilled within the injection area and from outside the injection area in order to determine the areal extent of soils impacted by vegetable oil and to compare the TOC content of impacted soils and un-impacted soils. The soil TOC results are summarized in Table 5. Soil TOC concentrations measured at the background boring PES-MW-13A ranged from approximately 330 mg/kg to approximately 830 mg/kg, indicating that there is naturally occurring organic carbon present within the soil matrix. This concentration range compares well with soil TOC data collected prior to the injection of the vegetable oil in 2001, indicating that PES-MW-13A has not been impacted by vegetable oil derived organic carbon.

TOC concentrations in soil collected within the injection area ranged from approximately 300 mg/kg to a maximum of 6,200 mg/kg. The high concentrations of TOC detected in the injection area were detected in vertical intervals that were visibly impacted by vegetable oil, indicating that significant vegetable oil derived organic carbon remains within the injection area to drive biological processes, including reductive dechlorination. TOC concentrations within the injection area vary widely between boreholes and even vertically within individual boreholes. This vertical and horizontal variation indicates that vegetable oil derived TOC is distributed heterogeneously within the injection area.

At locations PES-SB-7 and PES-MW-12B soil samples were collected from silty clay or clay units and analyzed for TOC (as well as a number of other parameters discussed in later sections). The silty clay unit sampled at PES-SB-7 was located at a depth of approximately 32 to 34 feet bgs, while the cohesive clay unit sampled at PES-MW-12B was located at 62 to 63 feet bgs. The clay units at both locations and depths contained high concentrations of TOC (2,900 mg/kg at PES-SB-7 and 5,900 mg/kg at PES-MW-12B). There is no evidence of vegetable oil impact between 32 and 34 feet bgs at PES-MW-7 and PES-MW-12B is located several hundred feet downgradient of the injection area and is thus unlikely to be impacted by vegetable oil. Thus, the high concentration of TOC present in the silt units at PES-SB-7 and PES-MW-12B likely to be naturally occurring. Groundwater samples were collected in close proximity to these sampling intervals (MIP-14 at 36 ft bgs for PES-SB-7 and MW-12B) and analyzed for TOC as well as a number of other parameters. TOC concentrations in groundwater at these locations were relatively low, below 8 mg/L in both cases, indicating that the high concentration of naturally occurring TOC present in the soil matrix is insoluble and thus not bioavailable to drive biological processes (including reductive dechlorination). This data indicates that these fine grained units are capable of absorbing significant amounts of contaminant mass and may serve as secondary sources of contaminant mass over time.

PLFA and Microbial Population Characterization Analyses in Soil

Biomass is represented by the total amount of phospholipid fatty acids (PLFA) present and provides a quantitative measure of the viable microbial biomass present. Elevated concentrations of biomass are an indicator of enhanced microbial activity and are an indirect indicator of changes in food supply (organic carbon) or changes in environmental conditions. The microbial population can also be identified through targeted gene detection analysis in order to determine if the microbial population present in a particular location is capable of dechlorinating chlorinated solvent mass and to what extent. A series of soil samples were collected from the injection area, upgradient of the injection area, and downgradient from the injection area in order to compare the microbial populations (both total population and which microbes are present) in each area. These samples were analyzed for total microbial biomass (PLFA) as well as targeted gene detection to determine the presence or absence of 4 phylogenic groups (Eubacteria, methanogens, sulfate and iron reducing bacteria, and methanotrophs); four bacterial genera that are known to be capable of dechlorinating chlorinated solvents (*Dehalococcoides* (DHC), *Desulfuromonas* (DSM), *Dehalobacter* (DHB), and *Desulfitobacterium* (DSB) and one additional genera that is known to dechlorinate tetrachloroethene (PCE) and trichloroethene (TCE) to cis-1,2-dichloroethene (DCE) (*Geobacter* (GEO)). In addition, two functional genes which identify particular species of DHC were identified and quantified. The BAV1 vinyl chloride reductase (BVC) functional gene is indicative of the species BAV1 which was isolated and identified by Frank Löffler's group at the Georgia Institute of Technology (He et. al., 2003) as a species of DHC that is capable of completely dechlorinating TCE to ethene. The second functional gene, also isolated and identified by Frank Löffler's group (He et. al., 2003), is TCE R-dase (TCER) which has been shown to be indicative of a DHC species that is capable of dechlorinating TCE completely. A third strain of methanotrophic bacteria was also identified and quantified through the analysis for soluble methane monooxygenase (sMMO). sMMO is an enzyme that is produced by methanotrophic bacteria when TCE is being broken down to non-toxic organic hypoxides through a destructive process called cometabolic oxidation (He et. al., 2003).

A total of 14 samples were collected and analyzed for targeted gene detection and PLFA, while an additional 9 samples were collected and analyzed for PLFA only. The PLFA and targeted gene detection analysis results are presented in Table 6. 11 of the 23 samples collected were impacted by vegetable oil or high concentrations of vegetable oil derived organic carbon as evidenced by visual and olfactory observations reported during drilling operations (Appendix B). The total biomass measured in the impacted samples was approximately two orders of magnitude higher than the total biomass measured in the un-impacted samples. The observed increase in microbial biomass is a result of an increase in microbial food supply supplied by the injected vegetable oil. The increased biomass is paralleled by increases in all of the identified phylogenic groups. Each phylogenic group increased by approximately one to four orders of magnitude with the largest increases observed in the sulfate/iron reducers and methanotrophs. This data indicates that the injected substrate was successful in promoting anaerobic microbial population development within and downgradient from the injection area.

DHC and DHB were positively identified in nearly all samples analyzed including both vegetable oil impacted and non-impacted samples. The population of DHC in the impacted samples was approximately one order of magnitude higher than the population measured in the non-impacted samples while DHB populations in the impacted samples were approximately two to three orders of magnitude higher than background. DSM was positively identified in only one sample (PES-SB-6). DSB was positively identified in approximately half of the samples analyzed and does not appear to be affected by the presence or absence of vegetable oil. GEO was also detected at concentrations near the method detection limit in the impacted samples but not in the un-impacted samples. This data indicates that several microbial strains that are known to be capable of dechlorinating VOC mass are present naturally in site soils and that the injected vegetable oil has been effective at increasing the populations of DHC, DHB, and to a lesser extent GEO. Thus, the microbial population within the pilot test area is capable of completely dechlorinating chlorinated VOC mass.

During the functional gene portion of the targeted gene detection analysis BVC was detected at low concentrations in nearly all of the impacted samples and in approximately one half of the un-impacted samples. TCER was also detected at low concentrations in three of the impacted samples and in only one of the un-impacted samples. sMMO was also detected in all but one of the impacted samples and in four of seven of the un-impacted samples. Moderate to high concentrations of sMMO (with respect to the un-impacted samples) were detected at locations PES-SB-1, PES-MW-7, and PES-MW-10B, indicating that it is likely that chlorinated solvent mass is being destroyed by methanotrophic bacteria through cometabolic oxidation at these locations.

During the April 2005 sampling event groundwater samples were collected from a selection of monitoring wells and submitted to Microbial Insights Inc. for targeted gene detection analysis. The results of the targeted gene detection in groundwater analyses are summarized in Table 6 for easy comparison to the soil results. Comparison of targeted gene detection results in water and soil from similar locations (e.g., PES-SB-2 to PES-INJ-2, PES-SB-7 to PES-MW-1, PES-MW-10B soil to PES-MW-10A water, PES-SB-4 to MS-46S, and PES-MW-10B soil to PES-MW-10B water) provides an insight into the relative representativeness of groundwater samples. Soil samples are considered to be most representative of the true microbial population present because the bulk of the microbial population grows on the soil matrix. Groundwater samples are generally considered to provide a good approximation of the microbial population and are generally preferred over soil samples due to the ease and low cost associated with groundwater sampling in comparison to soil sampling. However, review of Table 6 indicates that on this site groundwater samples are biased low and do not represent the microbial population present in the subsurface.

Volatile Organic Compound Analyses in Soil

A total of 36 soil samples were collected during drilling activities and analyzed for VOCs via US EPA method 8260B (Table 5). TCE, cis-1,2-DCE, trans-1,2-DCE, and acetone were the only VOCs that were detected at concentrations above the method detection limit. VOC concentrations varied widely across the site, both vertically and horizontally. TCE concentrations ranged from non detect to 7,700 μg/kg (PES-SB-2) while cis-1,2-DCE and trans-1,2-DCE concentrations ranged from non detect to 2,100 μg/kg and 91 μg/kg, respectively. Samples that were impacted by vegetable oil, as indicated by visual and olfactory inspection, contained substantial concentrations of cis-1,2-DCE, and in some cases trans-1,2-DCE, indicating that at least partial dechlorination is occurring.

VOC samples were collected from several intervals at locations PES-SB-1, PES-SB-4, PES-SB-7, PES-MW-10B, PES-MW-11A, PEs-MW-13A, and PES-MW-14B. At each location soil samples were collected from fine grained units, typically silty sands or clays, and coarser units, typically fine to medium sands, in an effort to determine which units contained more VOC mass. At all locations sampled the finer grained, lower permeability units contained higher concentrations of VOCs than the coarser grained units. For example, at PES-SB-7 a clay unit located at 32 to 34 feet bgs contained 2,100 μg/kg of TCE while a sand unit immediately below (34 to 36 feet bgs) contained only 50J μg/kg. This phenomena is repeated at PES-MW-10B where a silt unit at 36 to 42 feet bgs contains 1,600 μg/kg of TCE while a sand unit at 49 feet bgs contains no detectable concentrations of TCE. This data indicates that the fine grained silt/clay units contain more contaminant mass than the more transmissive sand units and will likely serve as secondary sources of contaminant mass for some time.

Aqueous and Mineral Intrinsic Bioremediation Assessment Analyses in Soil

Aqueous and Mineral Intrinsic Bioremediation Assessment (AMIBA) analyses consist of analyses for chromium extractable sulfides, acid extractable sulfides, weak acid extractable iron, strong acid extractable iron, weak and strong acid extractable manganese, and total oxidized iron (Kennedy *et al.*, 2000). This suite of analyses, in addition to bioavailable ferric iron and bioavailable manganese, is designed to assess the potential for a reductive dechlorination pathway known as biogeochemical reductive dechlorination (BiRD) and to assess the potential for abiotic degradation through mineralization. The BiRD process is termed "biogeochemical" because microbial processes are used to facilitate geochemical conditions that cause the precipitation of mineral ferrous iron monosulfide (FeS) in the aquifer matrix. The primary microbial processes that are necessary to produce FeS are iron reduction and sulfate reduction. In a normal aquifer system, both of these processes occur in the presence of sufficient organic carbon, ferric iron, and sulfate. These processes are occurring within the pilot test area due to the presence of vegetable-oil-derived organic carbon.

A total of 11 samples were collected for AMIBA analysis. 6 of the 11 samples collected were impacted by vegetable oil or high concentrations of vegetable oil derived organic carbon as evidenced by visual and olfactory inspection. Comparison of the impacted and non-impacted sample sets indicates that bioavailable iron, bioavailable manganese, and chromium extractable sulfide have been depleted slightly in the impacted samples. This data indicates that the impacted soil matrix has been depleted of bioavailable metals and sulfide, and therefore the capacity for abiotic degradation has been reduced slightly. However, the observed reduction in these species is relatively small in relation to the total mass present in the un-impacted samples. Therefore, the impacted soils' capacity to support abiotic degradation may remain relatively unchanged.

Review and comparison of all of the bioavailable iron and the strong acid extractable iron data is interesting and provides some insights into the relationship between the total mass of iron present in the soil (represented by strong acid extractable iron), and how much of that iron mass is accessible to the microbial community for use. In most of the samples collected strong acid extractable iron concentrations are one to nine times higher than the respective bioavailable iron concentration. This relationship is likely related to that fact that iron mineral dissolution is related to the surface area accessible to the microbial population and the microbial population present within a particular sample. It is also important to understand that the mass of bioavailable iron is rate dependant in that iron will continue to be stripped over time. Thus, as the time scale of the bioavailable iron analysis is extended, more of the total iron present in the soil matrix will become bioavailable. The time scale for the current bioavailable iron data set was 30 days. If the analysis time scale were extended for a much longer period of time most or all of the total iron present in the soil could become bioavailable. Therefore, the limiting factor on this site may be sulfide because the total sulfide mass in the soil matrix (as represented by chromium extractable sulfide) has been depleted by approximately 56% in the first 30 months following injection.

Groundwater Sampling Results

Site Hydrology

During the groundwater sampling event in April 2005 a round of groundwater elevation measurements was collected within the pilot test area as well as a number of monitoring wells installed outside of the pilot test area. The data collected during this round (Table 8) was used to develop a groundwater potentiometric surface map which is depicted on Figure 4. The groundwater mound in the park, historically known as the "stagnation zone", is clearly evident in the 2005 potentiometric surface map and continues to control groundwater flow in the pilot test area.

Groundwater elevation data collected at the newly installed monitoring wells (PES-MW-10A, PES-MW-11A, PES-MW-12A, PES-MW-13A, and PES-MW-14A) have resulted in the improvement of the definition of the groundwater potentiometric surface within the pilot test area. Groundwater flow is interpreted to be more southerly in and immediately downgradient from the injection area than previous interpretations. This more southerly flow appears to continue to monitoring wells PES-MW-9 and PES-MW-11A where groundwater flow appears to turn to a more westerly heading.

The reinterpretation of the groundwater potentiometric surface did impact interpreted groundwater flow direction. However, the slope of the groundwater potentiometric surface map remained similar to past interpretations. In April of 2005 the groundwater surface was relatively flat in the upgradient portion of the pilot test area (upgradient of monitoring well PES-MW-3) and in the downgradient portion of the pilot test area (downgradient of PES-MW-4. The groundwater surface between well PES-MW-3 and well PES-MW-4 slopes strongly to the south-southwest. This stair-step pattern in the groundwater surface is likely a result of the discontinuous silt unit that has been detected in the area during drilling operations (Figure 3).

Historically, vegetable oil thickness measurements have also been collected during each process monitoring round. Since injection measurable vegetable oil thicknesses have been detected routinely at PES-INJ-02 and PES-INJ-03 and sporadically at PES-INJ-01. During more recent sampling events the vegetable oil thickness measured in PES-INJ-3 has been greater than that measured in PES-INJ-1 and PES-INJ-2. During the Spring 2005 sampling event separate phase vegetable oil was not detected at PES-INJ-01 and PES-INJ-02, while the thickness at PES-INJ-03 was approximately 0.24 feet. The continuing decrease in measurable vegetable oil at PES-INJ-03 and the absence of measurable vegetable oil at PES-INJ-01 and PES-INJ-02 indicates that the vegetable oil is being gradually consumed.

Table 9 presents the results of pre- and post-injection aquifer testing and estimates of groundwater seepage velocity. The geometric mean for hydraulic conductivity values measured for PES-MW1 and the injection wells in the upgradient portion of the study area (upgradient of PES-MW-8 and PES-MW-9) was 177 feet per day (ft/day) (0.062 centimeters per second [cm/sec]). Hydraulic conductivity measurements conducted in wells PES-MW3, PES-MW-8, and PES-MW-9 indicate that a zone of low hydraulic conductivity is present downgradient of the immediate injection area. The geometric mean for hydraulic conductivity values measured at PES-MW-3, PES-MW-8, and PES-MW-9 was 29.6 ft/day (0.010 cm/sec). The only location tested downgradient from this zone of lower conductivity prior to injection was PES-CW1. The hydraulic conductivity calculated for PES-CW-1 was approximately 196 ft/day (0.069 cm/sec). Mean groundwater flow velocities, calculated from data collected prior to injection, ranged from approximately 438 feet per year (ft/yr) to 2,545 ft/yr.

Comparison of the pre-injection aquifer testing data with the post-injection aquifer testing data (Table 9) indicates that values of hydraulic conductivity calculated immediately after injection for the injection wells was approximately an order of magnitude lower than pre-injection values of hydraulic conductivity for these same wells. This decrease in hydraulic conductivity was likely due to the presence of vegetable oil within the aquifer matrix that effectively lowers the relative permeability of the aquifer matrix.

Values of hydraulic conductivity calculated from data collected 1 year after injection are similar to those calculated from the pre-injection testing round. This indicates that the decrease in hydraulic conductivity observed immediately after injection was transient, and that the hydraulic conductivity of the aquifer matrix in the vicinity of the injection wells (PES-MW-1) has returned to baseline conditions. This may be due to a lowering of residual oil saturation due to degradation and/or migration and dispersion of the vegetable oil.

A second post-injection round of slug testing was conducted during the April 2003 process monitoring event. Slug test data collected in April indicate that the hydraulic conductivity within the injection wells is very low relative to the baseline sampling event. This decrease in hydraulic conductivity within the injection wells is due to the presence of vegetable oil within the well casings and within the aquifer matrix surrounding the wells. The low hydraulic conductivities measured within the injection wells is also likely due to microbial growth (biofouling) within and around the injection wells. Immediately downgradient from the injection area (PES-MW-1, PES-MW-6, and PES-MW-7) hydraulic conductivities measured in April 2003 are similar to those measured during the baseline event (Table 9). These data indicates that the decrease in hydraulic conductivity is limited to the area immediately surrounding the injection wells.

Six of the new monitoring wells were installed in two well clusters (PES-MW-10A/B, PES-MW-12A/B, and PES-MW-14A/B) in order to determine if vertical groundwater flow is a significant factor within the pilot test area. The vertical hydraulic gradient was calculated at each monitoring well cluster by dividing the difference in head by the vertical interval between the wells within each cluster. The vertical hydraulic gradient at monitoring well clusters PES-MW-10 and PES-MW-14 were both weak (approximately 0.004 ft/ft) and upward indicating that there may be a small component of upward flow in the vicinity of these well clusters. The vertical gradient at cluster PES-MW-12 was very small (0.002 ft/ft) and in the downward direction.

Volatile Organic Compound Analyses in Groundwater

Groundwater VOC data is the primary line of evidence in determining the success of the vegetable oil pilot test. During the first extended monitoring program process monitoring round all of the original pilot test monitoring wells, the eight newly installed monitoring wells, and seven monitoring wells outside of the pilot test area were sampled for VOCs. Table 10 presents the latest round of VOC data as well as historic data for the previously sampled monitoring wells.

Review of the entire VOC data set indicates that TCE remains the most commonly detected contaminant across the site and that TCE is typically present at greater concentration than any other contaminant compound within each monitoring well. TCE concentrations have been decreasing at all of the wells (except for the newly installed wells) since 2002. *cis*-1,2-DCE, *trans*-1,2-DCE, 1,1-DCE, and 1,1-DCA have also been detected routinely during the last 30 months at much lower concentrations than TCE. VC, acetone, and 2-butanone have also been detected sporadically both historically and during the most recent sampling event in the Spring of 2005.

TCE concentrations detected during the baseline sampling event, conducted prior to vegetable oil injection, are depicted on Figure 7. Review of groundwater analytical data (summarized in Table 10) from the baseline sampling event in November 2001 indicates that four contaminants were detected at concentrations above associated method detection limits: PCE, TCE, *cis*-1,2-DCE, and *trans*-1,2-DCE. PCE was detected at only one location (GWMS-47S) at a low concentration of 0.92 micrograms per liter (ug/L). TCE was detected at elevated concentrations at all wells within the pilot test area, except GWMS-27S, with a maximum concentration of 20,000 ug/L detected at location MS-46S (see Figure 1 for well locations). TCE concentrations were generally highest (>1,000 µg/L in most cases) in the upgradient portions of the pilot test area, east of PES-MW-4. TCE concentrations detected in the downgradient portions of the pilot test area were significantly lower, generally below 300 µg/L, with the exception of PES-CW-1 (630 ug/L). *cis*-1,2-DCE, a breakdown product of TCE, was detected at most locations at concentrations significantly less than TCE. This data suggests that limited degradation of TCE to *cis*-1,2-DCE occurred naturally at the site prior to vegetable oil injection.

Review of groundwater analytical data (Table 10) collected after vegetable oil injection indicates that TCE concentrations detected in groundwater have been variable over time, but generally have declined at the three injection wells (PES-INJ-1, PES-INJ-2, and PES-INJ-3) and at all of the pilot test wells with the exception of GMW-27S. At the majority of these wells TCE concentrations increased initially, typically peaking in the May or August 2002 sampling rounds, then decreased through April 2005. TCE concentrations detected during the most recent sampling event in April of 2005 are depicted on Figure 8. Comparison of the pre-injection plume map presented in Figure 7 to the most recent plume map presented in Figure 8 indicates that TCE concentrations have decreased substantially since injection, with the largest decreases observed in and downgradient from the injection area.

During the course of the vegetable oil pilot test TCE concentrations have decreased at monitoring wells located outside of the pilot test area as well as within the pilot test area, indicating that TCE mass is being removed from the system through other means unrelated to the injected vegetable oil (e.g., the extraction system, other natural attenuation mechanisms). Table 11 summarizes changes in TCE and total DCE (cis-1,2-DCE plus trans-1,2-DCE) concentrations at select monitoring wells installed close to the pilot test area but outside of the pilot test area (Table 11A) as well as changes in TCE and total DCE concentrations at monitoring wells installed inside the pilot test area. Review of Tables 11A and 11B indicates that TCE concentrations within the pilot test area decreased much more rapidly than TCE concentrations outside of the pilot test area as indicated by a much more negative average slope within the pilot test area. During the same time period DCE concentrations increased within the pilot test area while DCE concentrations decreased slightly outside of the pilot test area, indicating that more DCE was being produced within the pilot test area, likely as a result of partial reductive dechlorination. These observations indicate that the vegetable oil pilot test has been effective at removing TCE mass from the pilot test area. However, this simple trend analysis does not give any indication with regard to how the TCE mass was removed. It is likely that the observed TCE reductions are due to a combination of biotic mechanisms (biotically mediated reductive dechlorination and cometabolic oxidation) and abiotic mechanisms (interaction with mineral species, dilution, and dispersion).

2-butanone and acetone have been detected sporadically at elevated concentrations during all of the process monitoring events in several wells including PES-INJ-1, PES-INJ-2, PES-INJ-3, PES-MW-6, PES-MW-7, PES-MW-8, and PES-MW-9. Concentrations of both analytes were relatively low during the first round of process monitoring with a maximum concentration of 490 µg/L for 2-butanone and 240 µg/L for acetone. During later process monitoring rounds concentrations of 2-butanone and acetone were highly variable and in some cases relatively high. However, 2-butanone and acetone have never been detected at concentrations approaching the MPCA Health

Risk Limits of 4,000 µg/L for 2-butanone and 700 µg/L for acetone outside of the injection area and monitoring wells PES-MW-7 and PES-MW-9.

VC was not detected at concentrations above the method detection limit in any of the contingency wells (PES-CW1, PES-CW2, PES-CW3, GWMS-47S), or the new downgradient monitoring well cluster PES-MW-12A/B, during the most recent process monitoring event.

Geochemical Analyses in Groundwater

Biodegradation of organic carbon, whether natural or anthropogenic, brings about measurable changes in the chemistry of groundwater in the affected area. Concentrations of compounds used as electron acceptors (e.g., dissolved oxygen [DO], nitrate, sulfate, and carbon dioxide) are depleted, and byproducts of electron acceptor reduction (e.g., carbon dioxide, ferrous iron, sulfide, reduced manganese, and methane) are elevated. By measuring these changes, it is possible to evaluate what biological processes are occurring at a particular site. The geochemical data collected during the course of the pilot test is presented in Table 12.

During the Spring 2005 sampling event TOC concentrations sufficient to support reductive dechlorination (>20 milligrams per liter (mg/L) (USEPA, 1998)) were detected at the injection wells and at monitoring wells PES-MW-4, PES-MW-7, PES-MW-10A, and PES-MW-14A. The TOC data set collected from the monitoring wells during the Spring 2005 sampling round was combined with the TOC data set collected during the discrete sampling program (also in the Spring of 2005) and used to develop a TOC contour map (Figure 9). The TOC data depicted on Figure 9 indicates that there is a relatively large area of elevated TOC present to the south and southwest of the injection area. Within the relatively large area impacted by elevated (>10 mg/L) TOC concentrations is a smaller core of highly elevated TOC concentrations (>50 mg/L) which extends as far down gradient as PES-MW-4 and PES-MW-14A. TOC concentrations within this area are present at concentrations sufficient to drive reductive dechlorination (USEPA, 1998). The TOC mass depicted on Figure 9 is most likely related to and derived from the vegetable oil injected as part of this pilot test. Comparison of the TOC plume map depicted in Figure 9 with the TCE plume map depicted in Figure 8 indicates that the area of high TOC concentration in Figure 9 roughly corresponds to the area of low TCE concentrations (<50 µg/L) in Figure 8.

At monitoring locations where TOC concentrations are elevated (the injection wells, PES-MW-1, PES-MW-4, PES-MW-7, PES-MW-10A, and PES-MW-14A) geochemical conditions are moderately to strongly reducing as indicated by the presence of elevated concentrations ferrous iron, reduced manganese, sulfide, and methane. The presence of these reduced species indicates that iron reduction, manganese reduction, sulfate reduction and methanogenesis are occurring at, or in close proximity to, these locations. These reducing conditions are conducive to anaerobic biological processes including anaerobic reductive dechlorination.

Ethane and ethene concentrations present in wells known to be un-impacted by vegetable oil (MS-27S, MS-47S, PES-CW-1, PES-CW-2, PES-CW-3) range up to approximately 35 nanograms per liter (ng/L) and 50 ng/L, respectively. During the Spring 2005 sampling event ethane concentrations at least twice the concentration measured in non-impacted wells (70 ng/L) were detected in the injection wells and in monitoring wells MS-45S, MS-46S, PES-MW-1, PES-MW-7, PES-MW-10A, PES-MW-11A, PES-MW-12B, PES-MW-14A, and PES-MW-14B. During the same sampling event ethene concentrations at least twice the concentration measured in un-impacted wells (100 ng/L) were detected in the injection wells and in monitoring wells PES-MW-1, PES-MW-6, PES-MW-10A, PES-MW-12B, PES-MW-14A, and PES-MW-14B. This data indicates that complete reductive dechlorination may be occurring at these locations or immediately upgradient of these locations (in the case of PES-MW-1 and PES-MW-6).

Carbon Isotope Fractionation Analysis of VOCs and Carbon Dioxide

The carbon isotope fractionation data is currently unavailable. This data set will be addressed after the second process monitoring event, currently scheduled for October 2005, has been completed.

Groundwater Sampling Results from MS-53PC

Monitoring well MS-53PC was redeveloped and one groundwater sample collected as recommended in the August 2003 Report (CCI, 2003). In April of 2005, the TOC concentration in MS-53 PC was 110 mg/L and the total VFA concentration was 792 mg/L (Table 12). Background concentrations of TOC as measured during the baseline event were below 5 mg/L and VFA concentrations measured at wells upgradient of the injection system are below 4 mg/L. Therefore, the high concentrations of TOC and VFAs measured at MS-53PC indicate that this well was impacted with vegetable oil during injection. However, TCE was the only VOC detected in MS-53PC in April 2005 and it was detected at a concentration of 0.83J µg/L, which is lower than the TCE concentration detected during the June 2003 sampling event. The concentration of TCE detected in MS-53-PC during the June 2003 sampling event was 2.1 and 1.19 µg/L in the screened interval. This suggests that, although monitoring well MS-53PC was impacted during the vegetable oil injection, the TCE concentration at this well did not increase. No further action is recommended for monitoring well MS-53PC.

Summary

During the Spring 2005 field program a total of 38 MIP points were installed with 48 discrete groundwater samples collected to confirm or further investigate the data collected during the MIP program. After the MIP program was complete 8 new wells and 10 new soil borings were installed to investigate the soil conditions within and downgradient from the injection area to improve the definition of groundwater flow conditions in the pilot test area and to investigate geochemical and VOC conditions in the area south of the injection wells. Following the completion of the drilling program a full round of groundwater sampling was conducted.

During the course of the MIP program it was found that direct push drilling is well suited for drilling activities at Anoka County Park. The direct push rig deployed in support of this project was capable of reaching depths of up to approximately 75 feet below ground surface and was limited by the supply of drilling rod and not by the capabilities of the rig. It is also likely small diameter monitoring wells could be installed in addition to the MIP work, soil sampling, and discrete groundwater sampling conducted during this project. Small diameter monitoring wells could be installed in lieu of standard monitoring wells during future drilling programs at a fraction of the cost due to cost savings related to decreased mobilization and drilling costs, decreased investigation derived waste production, and decreased well material costs.

Groundwater elevation data collected during the 2005 program from the existing pilot test wells, the newly installed pilot test wells, and a selection of wells installed outside of the pilot test area indicates that groundwater flow near the injection area is more southerly than previously thought. As a result, the effects of the injected vegetable oil are migrating with groundwater flow in a more south-southwest direction. This newly interpreted groundwater flow regime is supported by the TOC plume map presented on Figure 9 and the Spring 2005 plume map presented on Figure 8. The groundwater elevation data collected in 2005 from the newly installed monitoring well clusters also indicates that there is the potential for upward vertical groundwater flow at wells PES-MW-10 and PES-MW-14, and downward groundwater flow at PES-MW-12.

The ECD data collected during the MIP survey indicates that chlorinated VOC mass is present in the subsurface between approximately 28 feet and 42 feet bgs in the upgradient portion of the pilot test area (upgradient of PES-MW-10) and between approximately 35 feet and 50 feet bgs downgradient of PES-MW-10. This distribution was confirmed by discrete groundwater sampling conducted immediately after the completion of the MIP program. The VOC in soil data collected during the drilling program further indicates that VOC concentrations in the finer grained, less transmissive units are significantly higher than VOC concentrations present in the coarser grained, more transmissive units. This data indicates that the majority of contaminant mass present in the subsurface soils is present in the fine grained silt-clay units, not in the sand units. Thus, any remedial strategies implemented in this area should be targeted to the finer grained units present between approximately 30 feet and 50 feet bgs where the majority of the contaminant mass resides. In addition, groundwater flow and contaminant migration within the fine grained units are likely to be controlled by diffusion based mechanics as apposed to the more permeable units where advective flow mechanics likely control contaminant migration. As a result, the success of any remedial option chosen for application within this area will be dependant upon the rate at which contaminant mass diffuses out of the fine grained units.

The TOC in soil data and observations collected during the drilling program indicate that the injected vegetable oil was distributed heterogeneously both vertically and horizontally within the injection area. TOC concentrations in soil detected within the injection area ranged from approximately 2,000 to 6,000 mg/kg, indicating that significant vegetable derived organic carbon mass is remains in the system to drive biological degradation processes. TOC data collected in groundwater during the discrete sampling program and during the groundwater sampling program indicates that a relatively large area of elevated TOC concentrations is present around the injection area and extends approximately 80 feet to the south-southwest. TOC concentrations in this area are high enough to support reductive dechlorination (>20 mg/L (USEPA, 1998)). Geochemical conditions within this area (the injection wells, PES-MW-1, PES-MW-4, PES-MW-7, PES-MW-10A, and PES-MW-14A) are indicative of anaerobic geochemical conditions capable of supporting reductive dechlorination. The TOC data also indicates that monitoring well MS-53PC was inadvertently impacted by vegetable oil during injection activities in 2001.

During targeted gene detection analysis of soil samples collected during the 2005 program indicates that DHC and DHB were positively identified in nearly all samples analyzed including both vegetable oil impacted and un-impacted samples. The population of DHC in the impacted samples was approximately one order of magnitude higher than the population measured in the non-impacted samples, while DHB populations in the impacted samples were approximately two to three orders of magnitude higher than background. Dechlorinating bacteria DSB, DSM, and GEO were also positively identified at lower concentrations. Thus, the microbial population within the pilot test area is capable of completely dechlorinating chlorinated VOC mass. In addition, moderate to high concentrations of sMMO (with respect to the un-impacted samples) were detected at locations PES-SB-1, PES-MW-7, and PES-MW-10B, indicating that it is likely that chlorinated solvent mass is being destroyed by methanotrophic bacteria through cometabolic oxidation at these locations. This data indicates that several microbial strains that are known to be capable of dechlorinating chlorinated VOC mass are present naturally in site soils, that the injected vegetable oil has been effective at increasing the populations of DHC, DHB, and to a lesser extent GEO. The injected vegetable oil has also been successful in promoting contaminant mass destruction through cometabolic oxidation. Samples of groundwater were also collected for targeted gene detection analysis. Comparison of the targeted gene detection data collected in soil and in groundwater indicates that the analysis of groundwater from this site does not adequately represent the microbial population in the subsurface.

A total of 11 samples were collected for AMIBA analysis during the 2005 drilling program. Comparison of the impacted and un-impacted sample sets indicates that bioavailable iron, bioavailable manganese, and chromium extractable sulfide have been depleted slightly in the impacted samples. This data indicates that the impacted soil matrix has been depleted of bioavailable metals and sulfide and therefore the capacity for abiotic degradation has been reduced slightly. However, the observed reduction in these species is relatively small in relation to the total mass present in the un-impacted samples. Therefore, the impacted soils' capacity to support abiotic degradation remains relatively unchanged.

Groundwater VOC data collected during the Spring 2005 sampling round indicate that VOC concentrations continued to decrease both within and outside of the pilot test area. Comparison of the pre-injection TCE plume map presented on Figure 7 and the Spring 2005 TCE plume map presented on Figure 8 indicates that TCE concentrations decreased most dramatically within and down gradient from the pilot test area. This observation indicates that the vegetable oil pilot has been successful in enhancing VOC mass destruction. Review of the VOC data presented in Table 10 indicates that at locations were adequate TOC is present partial, potentially complete, reductive dechlorination is occurring. Elevated ethane and ethene concentrations at these locations further indicates that complete reductive dechlorination may be occurring.

Recommendations

Parsons recommends that the Fall 2005 sampling event be collected as scheduled in order to continue to document the effectiveness of the pilot system: It is also recommended that the following changes be made to the Fall 2005 sampling program:

- Delete the microbial population characterization sampling planned for the Fall 2005 sampling event. Data collected during the Spring 2005 event indicates that targeted gene detection data collected from groundwater is not representative of the microbial population present.
- Delete the PLFA sampling planned for the Fall 2005 sampling event. It has been well established that the injected vegetable oil is continuing to be successful in promoting microbial population development over the long term. The value of continuing to establish this fact is not commensurate with the significant analysis costs associated with these analyses.

After the Fall 2005 sampling event is complete the pilot test assessment report will be updated to include the 2005 sampling data and finalized (including the incorporation of the comments/responses submitted on the draft report in 2004).

During the coming months the NIROP team will be required to make a series of decisions regarding the future of remedial activities at Anoka County Park. The vegetable oil pilot test has been successful in increasing enhancing the destruction of chlorinated solvent mass in the subsurface and has thus been successful in reducing the overall toxicity of the groundwater plume. Therefore, Parsons recommends that organic substrate addition in general and vegetable oil injection specifically be considered as a future remedial option at this site.

Data collected during the most recent round of field activities indicates that the majority of the contaminant mass remaining in the subsurface beneath the park is located in the fine grained silt/clay units and not in the more transmissive sand units. As a result, the remedial time frame and effectiveness associated with any remedy (including organic substrate addition) will be dependant upon the rate at which the contaminant mass diffuses out of the silt/clay units and into the transmissive sand units where it can be removed or destroyed. Therefore, it is unlikely that any remedial technology will be successful in accelerating the time it will take to clean up the site. As a result Parsons recommends that future remedial activities at Anoka County Park be designed to reduce the potential impact to receptors and therefore reduce the environmental risk associated with the contaminant mass remaining in the subsurface instead of attempting to remove or destroy all of the remaining contaminant mass. There are several remedial technologies, in addition to natural attenuation, that could be deployed to the site to manage the environmental risk posed by the site including organic substrate addition, permeable reactive barriers, and injectable zero valent iron. Parsons also suggests that the NIROP team limit future remedial activities at Anoka County Park to defined contaminant hot spots instead of attempting to treat large areas (for example attempting to treat an area within a particular interpreted VOC concentration contour). The control or elimination of contaminant hot spots will allow the environmental risk associated with the site to be reduced most significantly and at much lower cost.

REFERENCES

Bouwer, E.J., 1994. Bioremediation of chlorinated solvents using alternate electron acceptors. In: *Handbook of Bioremediation*. CRC Press, Boca Raton, FL.

CH2M Hill Constructors Incorporated (CCI), 2002. *Project Completion Report (Revision 00), Pilot –Scale Study to Enhance In-Situ Bioremediation of Chlorinated Solvents via Vegetable Oil Injection at Anoka County Riverfront Park, Naval Industrial Reserve Ordnance Plant Fridley*. January.

Chapelle, F.H., 1993. *Ground-Water Microbiology and Geochemistry*: John Wiley & Sons, Inc., New York, 424 p.

He, J., Ritalahti, K. M., Aiello, M. R., Löffler, F. E., 2003. Complete Detoxification by an Anaerobic Enrichment Culture and Identification of the Reductively Dechlorinating Population as a Dehalococcoides Species. *Applied and Environmental Microbiology,* February, 2003, , p. 996-1003.

Karickhoff, S.W., Brown, D.S., and Scott, T.A., 1979. Sorption of Hydrophobic Pollutants on Natural Sediments. *Water Resour. Res.*, 13:241-248.

Karickhoff, S.W., 1981. Semi-empirical Estimation of Sorption of Hydrophobic Pollutants on Natural Sediments and Soils: *Chemosphere*, 10:833-846.

Kennedy, L., Everett, J., and Gonzales, J., 2000. *Aqueous and Mineral Intrinsic Bioremediation Assessment (AMIBA) Protocol.*

Lyman, W.J., Reidy, P.J., and Levy, B., 1992. *Mobility and Degradation of Organic Contaminants in Subsurface Environments*: C.K. Smoley, Chelsea, MI, 395 p.

Parsons, 2001a. *Final Work Plan for Field Application to Enhance In-Situ Bioremediation of Chlorinated Solvents via Vegetable Oil Injection at the Naval Industrial Reserve Plant (NIROP) Fridley, Minnesota*. September.

Parsons, 2001b. *Final Quality Assurance Project Plan for Field Application to Enhance In-Situ Bioremediation of Chlorinated Solvents Via Vegetable Oil Injection at The Naval Industrial Reserve Ordnance Plant (NIROP), Fridley, Minnesota.* September.

Parsons, 2004. *Draft Report for a Field Application to Enhance In-Situ Bioremediation of Chlorinated Solvents via Vegetable Oil Injection at Naval Industrial Ordnance Plant Fridley, Minnesota.*

Parsons, 2005. *Addendum to the Final Work Plan for Field Application to Enhance In-Situ Bioremediation of Chlorinated Solvents via Vegetable Oil Injection at the Naval Industrial Reserve Plant (NIROP) Fridley, Minnesota.* January.

Song, D.L., Conrad. M.E., Sorenson ,K.S., and Alverez-Cohen, L. 2002. Stable Carbon Isotope Fractionation During Enhanced In-Situ Bioremediation of Trichloroethene: *Environmental Science and Technology,* vol. 36, No. 10, p. 2262-2268.

US Environmental Protection Agency (USEPA), 1998. *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater*: EPA/600/R-98/128, September; http://www.epa.gov/ada/reports.html.

Vogel, T.M., C.S. Criddle, and P.L. McCarty, 1987. Transformations of halogenated aliphatic compounds. *Environmental Science and Technology* 22:722-736.

TABLES

TABLE 1
SUMMARY OF MEMBRANE INTERFACE PROBE POINT INSTALLATIONS
NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
ANOKA COUNTY PARK
FRIDLEY, MINNESOTA

Well/Borehole Identification	Well/Boring Diameter (Inches)	Total Depth (feet bgs)[a/]	Ground Surface Elevation (feet amsl)[b/]	Elevation Top of Casing (feet amsl)	Survey Northing (State Plane)	Survey Easting (State Plane)
MIP-1	1	60	NM[d/]	NM	1,077,426.77	2,810,933.36
MIP-2	1	60	NM	NM	1,077,392.94	2,810,924.37
MIP-3	1	60	NM	NM	1,077,386.69	2,810,892.06
MIP-4	1	55	NM	NM	1,077,389.93	2,810,890.64
MIP-5	1	60	NM	NM	1,077,393.87	2,810,889.35
MIP-6	1	60	NM	NM	1,077,385.27	2,810,882.59
MIP-7	1	74	NM	NM	1,077,387.07	2,810,908.80
MIP-8	1	60	NM	NM	1,077,382.04	2,810,914.14
MIP-9	1	61	NM	NM	1,077,378.44	2,810,910.70
MIP-10	1	60	NM	NM	1,077,374.97	2,810,906.82
MIP-11	1	60	NM	NM	1,077,393.04	2,810,910.18
MIP-12	1	60	NM	NM	1,077,378.63	2,810,925.62
MIP-13	1	70	NM	NM	1,077,367.15	2,810,898.56
MIP-14	1	62	NM	NM	1,077,364.96	2,810,894.05
MIP-15	1	60	NM	NM	1,077,354.34	2,810,904.24
MIP-16	1	60	NM	NM	1,077,348.53	2,810,893.98
MIP-17	1	60	NM	NM	1,077,351.98	2,810,908.44
MIP-18	1	60	NM	NM	1,077,378.73	2,810,935.81
MIP-19	1	60	NM	NM	1,077,340.37	2,810,897.87
MIP-20	1	60	NM	NM	1,077,322.76	2,810,900.43
MIP-21	1	70	NM	NM	1,077,314.20	2,810,903.44
MIP-22	1	60	NM	NM	1,077,215.88	2,810,882.20
MIP-23	1	70	NM	NM	1,077,347.80	2,810,907.97
MIP-24	1	60	NM	NM	1,077,343.98	2,810,907.95
MIP-25	1	60	NM	NM	1,077,323.60	2,810,884.91
MIP-26	1	60	NM	NM	1,077,308.01	2,810,878.27
MIP-27	1	60	NM	NM	1,077,292.13	2,810,865.27
MIP-28	1	60	NM	NM	1,077,383.47	2,810,925.54
MIP-29	1	60	NM	NM	1,077,258.88	2,810,896.58
MIP-30	1	60	NM	NM	1,077,281.18	2,810,903.57
MIP-31	1	67	NM	NM	1,077,311.17	2,810,911.70
MIP-32	1	62	NM	NM	1,077,305.95	2,810,929.81
MIP-33	1	60	NM	NM	1,077,345.89	2,810,925.22
MIP-34	1	60	NM	NM	1,077,354.24	2,810,924.29
MIP-35	1	66	NM	NM	1,077,213.64	2,810,866.11
MIP-36	1	60	NM	NM	1,077,377.46	2,810,925.30
MIP-37	1	67	NM	NM	1,077,271.25	2,810,921.46
MIP-38	1	61	NM	NM	1,077,308.49	2,810,952.02

[a/] feet bgs indicates depth in feet below ground surface.

[b/] feet amsl indicates elevation in feet above mean sea level.

[c/] NA indicates data not available.

[d/] NM indicates elevation not measured.

TABLE 2
SUMMARY OF MONITORING WELL AND SOIL BORING CONSTRUCTION
NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
ANOKA COUNTY PARK
FRIDLEY, MINNESOTA

Well/Borehole Identification	Completion Date	Well/Boring Diameter (Inches)	Screened Interval/TD (feet bgs)[a/]	Ground Surface Elevation (feet amsl)[b/]	Elevation Top of Casing (feet amsl)	Survey Northing (State Plane)	Survey Easting (State Plane)
Newly Installed Monitoring Wells							
PES-MW-10A	4/1/2005	2/8	45.0 - 55.0	NM[d/]	832.17	1,077,342.33	2,810,904.47
PES-MW-10B	3/31/2005	2/8	65.0 - 75.0	NM	832.11	1,077,345.35	2,810,906.36
PES-MW-11A	3/29/2005	2/8	45.0 - 55.0	NM	832.28	1,077,320.34	2,810,900.39
PES-MW-12A	4/5/2005	2/8	35.0 - 45.0	NM	833.89	1,077,205.43	2,810,881.86
PES-MW-12B	4/5/2005	2/8	55.0 - 65.0	NM	833.80	1,077,208.68	2,810,882.56
PES-MW-13A	3/28/2005	2/8	35.0 - 45.0	NM	832.15	1,077,420.00	2,810,927.99
PES-MW-14A	4/4/2005	2/8	45.0 - 55.0	NM	831.74	1,077,291.98	2,810,872.98
PES-MW-14B	4/4/2005	2/8	65.0 - 75.0	NM	831.84	1,077,295.69	2,810,871.97
Newly Installed Soil Borings							
PES-SB-1	8/29/2000	NA/8	60	NM	NA	1,077,385.69	2,810,895.57
PES-SB-2	8/29/2000	NA/8	60	NM	NA	1,077,373.21	2,810,905.91
PES-SB-3	9/7/2000	NA/8	60	NM	NA	1,077,359.27	2,810,907.97
PES-SB-4	9/7/2000	NA/8	60	NM	NA	1,077,379.96	2,810,914.05
PES-SB-5	9/9/2000	NA/8	60	NM	NA	1,077,376.71	2,810,909.98
PES-SB-6	9/7/2000	NA/8	60	NM	NA	1,077,368.49	2,810,898.43
PES-SB-7	9/7/2000	NA/8	60	NM	NA	1,077,365.37	2,810,894.23
PES-SB-8	9/9/2000	NA/8	60	NM	NA	1,077,357.14	2,810,883.76
PES-SB-9	9/9/2000	NA/8	60	NM	NA	1,077,357.62	2,810,895.39
PES-SB-10	9/9/2000	NA/8	60	NM	NA	1,077,353.26	2,810,903.79

[a/] feet bgs indicates depth in feet below ground surface.

[b/] feet amsl indicates elevation in feet above mean sea level.

[c/] NA indicates data not available.

[d/] NM indicates elevation not measured.

TABLE 3
SUMMARY OF MIP SURVEY DATA
NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
ANOKA COUNTY PARK
FRIDLEY, MINNESOTA

Location	Depth Range (ft bgs)[a/]	Peak depth(s) (ft bgs)	peak hit (uV)[b/]	FID range (ft bgs)	FID peak depth (ft bgs)	FID peak (uV)
MIP Points Upgradient of MPES-MW-10A/B						
MIP-01	30.5-49.0	32.0-36.0	3.50E+05	NA[c/]	NA	ND[d/]
MIP-02	27.0-47.0	33.5	1.20E+06	26.7-28.5	26.5	1.80E+06
		36.0	2.50E+05		27.0	2.20E+06
MIP-03	29.5-59.5	39.0	3.90E+05	30.5-32.5	31.0	8.00E+06
		42.0	3.00E+05			
		45.0	3.20E+05			
		51.0	2.80E+05			
MIP-04	38.0-53.0	32.5	4.00E+05	NA	NA	ND
		35.0	3.50E+05			
		37.5	5.20E+05			
MIP-05	28.5-49.0	30.0	1.80E+06	30.0-32.0	30.0	4.80E+05
		32.5	8.00E+05			
MIP-06	34.5-TD (60) [e/]	37.0	3.00E+05	31.0-34.0	32.0	1.50E+06
		48.0	3.90E+05		33.0	9.00E+05
		54.0	3.00E+05			
MIP-07	27.5-46.0	27.5	8.00E+05	27.5	27.5	1.80E+05
		31.0	7.00E+05			
MIP-08	28.5-TD (60)	37.0	1.00E+06	31.0	31.0	4.00E+05
		39.0	1.00E+06			
		41.0	9.00E+05			
MIP-09	28.5-50.0	31.0	1.00E+06	NA	NA	ND
		36.0	8.00E+05			
MIP-10	36.0-52.0	41.0	2.00E+05	32.0	32.0	5.50E+05
		43.0	2.00E+05			
		50.0	1.50E+05			
MIP-11	28.5-TD (60)	44.0	7.00E+05	NA	NA	ND
		51.5	1.00E+06			
		56.5	6.00E+05			
		59.0	6.00E+05			
MIP-12	27.0-40.0	27.0	1.00E+06	NA	NA	ND
		35.0	3.50E+06			
MIP-13	31.0-51.0	33.0	1.70E+06	31.0-50.5	47.5	6.00E+06
					51.0	5.50E+06
MIP-14	29.5-TD (62)	36.0	5.00E+05	32.0-54.0	32.0	6.00E+05
		49.0	4.00E+05		38.0	6.00E+05
		58.0	5.00E+05		49.0	2.80E+06
					54.0	8.00E+05
MIP-15	30.5-42.0	36.0	1.60E+06	54.0-57.0	54.0	5.00E+06
					56.0	3.00E+06
MIP-16	30.5-42.0	34.0	1.50E+06	34.0-56.0	34.0	5.00E+05
		36.0	2.30E+06		53.0	2.00E+06
					56.0	3.00E+05
MIP-17	30.0-52.5	32.5	8.00E+05	NA	NA	ND
		39.0	7.00E+05			
		42.0	6.00E+05			
MIP-18	26.5-48.0	29.0	7.00E+05	28.0	28.0	1.50E+05
		33.5	4.00E+05			
		37.0	4.00E+05			
MIP-23	30.0-48.0	35.5	2.50E+06	NA	NA	ND
		40.0	2.00E+06			
MIP-28	28.0-TD (60)	35.0	6.00E+05	53.0-54.0	53.5	1.00E+05
		42.0	5.50E+05			
MIP-33	28.0-46.0	28.0	1.50E+06	NA	NA	ND
		35.5	7.50E+05			
		41.0	5.00E+05			

TABLE 3
SUMMARY OF MIP SURVEY DATA
NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
ANOKA COUNTY PARK
FRIDLEY, MINNESOTA

MIP-34	27.0-43.5	28.5	1.30E+06	NA	NA	ND
		33.0	7.50E+05			
MIP-36	27.5-33.0	28.5	8.00E+06	27.5-30.0	28.0	6.00E+05
		30.5	5.50E+06		30.0	6.00E+05
		32.0	2.00E+06			
MIP Points Down Gradient of MPES-MW-10A/B						
MIP-19	31.0-TD (60)	34.0	6.00E+05	38.0-54.0	42.5	4.00E+06
		38.0	9.50E+05		44.5	7.00E+06
		44.5	8.00E+05		49.0	2.00E+06
		48.0	9.00E+05		53.0	4.50E+06
		55.0	4.00E+05			
		58.0	8.00E+05			
MIP-20	31.0-58.0	34.0	4.50E+05	55.5-57.0	56.0	7.50E+06
		42.0	7.50E+05		57.0	3.00E+06
		58.0	3.50E+05			
MIP-21	31.5-52.5	35.0	6.00E+05	47.5-58.0	55.0	8.50E+06
		40.0	1.00E+06		56.0	1.10E+07
		42.5	1.80E+06		57.5	5.00E+06
		47.0	1.00E+06			
MIP-22	33.0-TD (60)	41.0	3.00E+05	NA	NA	ND
		47.0	3.00E+05			
		59.0	6.00E+05			
MIP-24	31.0-48.0	34.0	1.20E+06	47.5-55	48.0	8.00E+05
		36.0	1.70E+06		52.5	2.10E+06
		39.0	1.20E+06		53.5	1.60E+06
					55.0	9.00E+05
MIP-25	31.0-TD (60)	34.0	3.20E+05	39.0-52.0	40.0	2.00E+05
		39.0	3.80E+05		44.0	1.55E+05
		48.0	2.50E+05		49.0	2.00E+05
		56.0	2.00E+05		52.0	3.00E+05
MIP-26	31.0-51.0	35.0	5.80E+05	54.5-55.5	55.0	8.00E+06
MIP-27	31.0-54.0	35.0	4.00E+05	35.0-41.0	38.5	1.50E+06
		37.0	4.20E+05	50.0-57.5	57.0	2.10E+05
		46.0	3.00E+05			
MIP-29	44.0-59.0	49.0	7.00E+05	NA	NA	ND
		55.0	5.50E+05			
MIP-30	35, 38.0-58.0	35.0	5.00E+05	42.0-45.0	44.0	7.00E+05
		47.0	3.20E+06			
MIP-31	33.0-57.0	43.0	4.50E+06	NA	NA	ND
		45.0	4.00E+06			
		48.0	2.00E+06			
MIP-32	31.5-56.0	40.0	5.00E+06	35.0, 40.0, 46.5	35.0	1.90E+05
		47.0	4.00E+06		40.0	2.00E+05
					46.5	1.80E+05
MIP-35	43-TD (66)	43.0	2.00E+05	NA	NA	ND
		50.0	2.80E+05			
		57.0	3.20E+05			
		63.0	4.50E+05			
		66.0	3.50E+05			
MIP-37	38.0-62.5	47.0	6.00E+05	39.5-46.5	44.0	4.50E+05
		51.0	5.00E+05			
MIP-38	40.0-TD (61)	41.0	3.00E+05	NA	NA	ND
		43.0	3.70E+05			
		45.0	9.00E+05			
		48.0	7.50E+05			
		53.0	5.00E+05			

a/ ft bgs - feet below ground surface
b/ uV = microvolts
c/ NA = not applicable
d/ ND = not detected
e/ TD = total depth

TABLE 4
SUMMARY OF MIP AND DISCRETE GROUNDWATER SAMPLING DATA
NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
ANOKA COUNTY PARK
FRIDLEY, MINNESOTA

Sample Location	Date	Sampling Depth (ft bgs)	ECD Response (uV)	Correlation Factor (unitless)	Total Cl VOCs (µg/L)	PCE[a] (µg/L)[b]	TCE[a] (µg/L)	*cis*-1,2-DCE[a] (µg/L)	*trans*-1,2-DCE[a] (µg/L)	Vinyl Chloride (µg/L)	FID Response (uV)	TOC Concentration (mg/L)	Methane (µg/L)	Ethene (µg/L)	Ethane (µg/L)
MIP-01	14-Mar-05	30.0	3.00E+05	149	2,007	0.45 U	1,900	49	51	0.52 J	ND	4.6	NA	NA	NA
		50.0	3.00E+05	1279	235	0.45 U	220	6.6	3.2	0.18 U	ND	3.9	NA	NA	NA
MIP-03	14-Mar-05	31.0	1.56E+05	233	671	0.90 U	38	610	12	3.4	8.00E+06	420	NA	NA	NA
		39.0	3.42E+05	291	1,174	2.2 U	940	170	44	0.9 U	ND	14	NA	NA	NA
		43.0	2.93E+05	439	667	1.1 U	630	13	14	0.45 U	ND	4.8	NA	NA	NA
MIP-04	14-Mar-05	38.0	4.00E+05	277	1,444	2.2 U	1300	65	59	0.90 U	ND	4.4	NA	NA	NA
	14-Mar-05	43.0	3.20E+05	389	822	0.45 U	790	13	14	0.18 U	ND	4.7	NA	NA	NA
	15-Mar-05	50.0	2.00E+05	434	460	0.90 U	430	16	6.2	0.36 U	ND	10	26	2.9	3.0
MIP-05	15-Mar-05	30.0	1.00E+06	1679	596	0.45 U	520	40	31	0.18 U	4.00E+05	1.7	2.7	0.36	0.55
		40.0	3.61E+05	396	912	0.90 U	860	19	25	0.36 U	ND	1.7	9.3	0.85	0.75
MIP-08	17-Mar-05	31.0	3.00E+05	187	1,607	9 U	1,400	58	68	3.6 U	4.00E+05	3.2	20	12	9.4
		35.0	4.50E+05	263	1,710	9 U	1,500	60	69	3.6 U	ND	3.1	13	6.0	5.8
		41.0	8.00E+05	783	1,022	4.5 U	920	32	29	1.8 U	ND	1.7	9.4	4.9	4.6
		48.0	5.50E+05	1202	458	4.5 U	400	9.6	7.4	1.8 U	ND	1.9	15	7.0	7.8
MIP-09	17-Mar-05	31.0	1.00E+06	596	1,678	2.2 U	1,500	79	81	0.9 U	ND	2.9	13	2.2	1.9
		36.0	8.00E+05	421	1,899	4.5 U	1,700	74	84	1.8 U	ND	2.3	13	5.0	3.7
		45.0	2.50E+05	526	476	2.2 U	440	9.9	7.6	0.9 U	ND	2.7	8.2	0.55	0.89
MIP-10	17-Mar-05	32.0	ND	None	310	1.1 U	280	10	9.8	0.45 U	5.00E+05	2.4	83	0.24	0.36
		43.0	2.50E+05	341	733	2.2 U	680	17	18	0.9 U	ND	3.1	15	1.6	1.6
		48.0	ND	None	425	0.90 U	400	9.6	7.4	0.36 U	ND	150	14000	1.4	0.53
MIP-13	16-Mar-05	33.5	2.00E+06	2494	802	0.45 U	170	590	41	0.51 J	ND	3.0	4900	9.4	7.6
		43.0	2.50E+05	310	807	0.45 U	160	630	14	2.2	ND	37	11000	0.90	0.49
		47.5	2.00E+05	801	250	0.45 U	4.5	240	3.8	0.96 J	6.00E+06	130	20000	2.7	1.5
MIP-14	16-Mar-05	36.0	4.50E+05	300	1,499	0.45 U	120	1,300	66	6.5	ND	7.2	14000	15	11
		42.0	1.00E+05	145	688	2.2 U	630	25	15	0.9 U	ND	1.8	4300	0.56	0.47
		46.0	3.50E+05	1076	325	1.1 U	300	10	4.7	0.45 U	ND	2.0	70	15	16
		49.0	4.00E+05	1607	249	0.45 U	180	62	2.4	0.18 U	2.50E+06	3.2	660	4.6	4.9
MIP-15	17-Mar-05	36.0	1.50E+06	579	2,589	11 U	2,300	99	89	4.5 U	ND	3.2	53	0.41	0.52
		42.0	2.50E+05	370	675	2.2 U	630	15	12	0.9 U	ND	3.1	1900	5.1	4.4
		54.0	ND	None	158	0.45 U	19	130	1.7	3.1 J	5.00E+06	170	30000	4.9	8.5
MIP-16	15-Mar-05	36.0	2.00E+06	1887	1,060	0.45 U	850	150	54	0.4 J	ND	2.2	3100	13	8.3
		45.0	ND	None	323	0.45 U	280	33	4.9	0.20 J	2.50E+05	2.3	7000	13	14
		53.0	ND	None	135	0.45 U	71	57	2.3	0.18 U	2.00E+06	4.6	1700	3	3.5
MIP-17	15-Mar-05	39.0	7.50E+05	386	1,941	0.45 U	1,800	66	67	0.53 J	ND	1.7	15	13	5.2
		42.0	6.00E+05	915	656	0.45 U	620	14	12	0.90 U	ND	2.3	560	12	12
		46.0	3.50E+05	897	390	0.45 U	370	8.6	6.5	0.18 U	ND	2.4	230	3.7	3.9
		50.0	ND	None	227	0.45 U	200	19	3.6	0.18 U	ND	3.8	7.5	1.1	1.0
MIP-19	15-Mar-05	38.0	9.50E+05	766	1,240	0.45 U	250	930	50	2.4	7.00E+05	5.8	18000	21	15
		42.0	2.00E+05	322	621	0.45 U	17	580	18	0.59 J	2.00E+06	4.3	20000	3.6	2.8
		47.0	5.00E+05	2670	187	0.45 U	8.4	170	4.0	0.97 J	ND	16	28000	6	7.3
		52.0	2.00E+05	733	273	0.45 U	23	240	4.8	0.93 J	4.00E+06	5.6	17000	14	18
MIP-21	15-Mar-05	43.0	1.80E+06	935	1,926	4.50 U	1,500	330	55	1.8 U	ND	1.9	1900	72	37
		56.0	ND	None	151	0.77 J	130	14	1.7	0.18 U	1.00E+07	3.9	30	7.2	7.8
MIP-23	15-Mar-05	36.0	2.50E+06	1427	1,752	0.45 U	1,400	240	85	1.8 U	ND	0.8	5000	24	6.7
MIP-24	16-Mar-05	36.5	1.00E+06	516	1,939	0.45 U	1,800	62	69	0.97 J	ND	1.7	110	7.8	5.6
		53.0	ND	None	179	0.45 U	12	160	1.8	1.4	2.00E+06	230	19000	0.14	0.05
MIP-31	16-Mar-05	43.0	4.00E+06	3460	1,156	0.45 U	1,100	24	26	0.23 J	ND	2.6	39	1.3	1.4
MIP-32	16-Mar-05	40.0	1.00E+06	873	1,145	0.45 U	1,100	20	17	1.8 U	2.00E+05	18	39	48	47

[a] PCE = tetrachloroethene; TCE = trichloroethene; DCE = dichloroethene; TCA = trichloroethane; DCA = dichloroethane.

[b] µg/L = micrograms per liter.

[c] U = Analyte was not detected at a concentration above the method detection limit.

[d] J = Analyte was detected at a concentration above the method detection limit and below the reporting limit.

S:\ES\WP\PROJECTS\739484\July05 Tech memo tables.xls

TABLE 5
SUMMARY OF SOIL ANALYTICAL DATA
NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
ANOKA COUNTY PARK
FRIDLEY, MINNESOTA

Sample Location	Sample Date	Sample Depth (feet bgs)[a]	Stratigraphy	Total Organic Carbon (mg/kg)[d]	TCE[b] (µg/kg)[c]	*cis*-1,2-DCE[b] (µg/kg)	*trans*-1,2-DCE (µg/kg)	Vinyl Chloride (µg/kg)	1,2-DCA[b] (µg/kg)	Carbon Tetrachloride (µg/kg)	Acetone (µg/kg)	2-Butanone (µg/kg)	Bromomethane (µg/kg)
PES-SB-1	16-Mar-05	32 - 35	Cohesive silt, mild odor, staining	**410**	**220**	**100**	17 U	17 U	24 U	19 U	67 U	84 U	29 U
	16-Mar-05	35 - 36	Cohesive Silt, mild odor, staining	**830**	**510**	**490**	17 U	17 U	24 U	19 U	67 U	84 U	29 U
	16-Mar-05	37 - 38	Sandy Silt, mild odor, staining	**330**	**80**	**2,100**	**83**	17 U	24 U	19 U	69 U	87 U	29 U
PES-SB-2	15-Mar-05	37 - 38	Sandy silt, strong odor, heavy staining	**6,200**	**7,700**	**850**	**56 J**[e]	17 U	23 U	20 U	69 U	87 U	19 U
PES-SB-3	14-Mar-05	42	Non-plastic silt with fine sand, moderate odor, staining	**1,700**	**2,400**	**610**	**75**	17 U	24 U	19 U	67 U	84 U	19 U
PES-SB-4	24-Mar-05	30	Sandy silt, no odor, no staining	**480 J**	**1,000**	22 U	**19 J**	16 U	24 U	19 U	65 U	81 U	28 U
	24-Mar-05	31	Sandy Silt, no odor, no staining	**3,700**	**710**	23 U	17 U	17 U	24 U	19 U	66 U	83 U	28 U
	24-Mar-05	42 - 44	Fine sand, no odor, no staining	**160 J**	**110**	24 U	17 U	17 U	23 U	20 U	69 U	87 U	29 U
PES-SB-5	7-Apr-05	42 - 44	Fine - medium sand, no odor, no staining	**230 J**	**77**	24 U	17 U	17 U	25 U	20 U	**130 J**	87 U	29 U
PES-SB-6	7-Apr-05	36 - 38	Fine sand, strong odor	**550**	23 U	**43 J**	17 U	17 U	24 U	19 U	66 U	84 U	28 U
PES-SB-7	23-Mar-05	32 - 34	Tight clay with medium sand	**2,800**	**2,100**	**57 J**	**91**	18 U	26 U	20 U	71 U	90 U	30 U
	7-Apr-05	34 - 36	Cohesive Sandy Silt, no odor	**340 J**	**50 J**	**210**	**18 U**	18 U	26 U	20 U	70 U	88 U	30 U
	3-Mar-05	46 - 48	Find sand, strong odor	**300 J**	24 U	24 U	18 U	18 U	25 U	20 U	70 U	88 U	30 U
PES-SB-8	17-Mar-05	46	Silt, no odor, some staining	**280**	NA	NA	NA	NA	NA	NA	NA	NA	NA
	17-Mar-05	48 - 50	Fine Sand and Silt, mild odor	**230 J**	**81**	24 U	17 U	17 U	25 U	19 U	68 U	85 U	19 U
	17-Mar-05	51	Fine Sand and Silt, no odor	**280 J**	NA	NA	NA	NA	NA	NA	NA	NA	NA
	17-Mar-05	56	Fine - coarse sand, no odor	**330 J**	NA	NA	NA	NA	NA	NA	NA	NA	NA
PES-SB-9	7-Apr-05	34 - 36	Fine sand with silt, mild-strong odor	**350 J**	**85**	**150**	17 U	17 U	25 U	19 U	67 U	85 U	29 U
	21-Mar-05	46	Fine - medium sand with silt, mild odor, weak staining	**1,200**	NA	NA	NA	NA	NA	NA	NA	NA	NA
	21-Mar-05	51	Silty sand, mild odor	**210 J**	NA	NA	NA	NA	NA	NA	NA	NA	NA
	21-Mar-05	56	Fine - coarse silty sand, mild odor	**350 J**	NA	NA	NA	NA	NA	NA	NA	NA	NA
PES-SB-10	22-Mar-05	51	Fine sand, no odor	**290 J**	NA	NA	NA	NA	NA	NA	NA	NA	NA
	22-Mar-05	56	Fine - medium sand, no odor	**240 J**	NA	NA	NA	NA	NA	NA	NA	NA	NA
PES-MW-10B	31-Mar-05	36 - 38	sandy silt, no odor	**610**	**1,600**	22 U	**25 J**	16 U	23 U	18 U	64 U	81 U	27 U
	31-Mar-05	40 - 42	sandy silt, no odor	**1,000**	**1,600**	23 U	**24 J**	16 U	24 U	19 U	65 U	82 U	28 U
	31-Mar-05	49 - 50	fine sand, no odor	**370 J**	24 U	24 U	17 U	17 U	25 U	20 U	69 U	87 U	29 U
	31-Mar-05	70 - 71	Fine - medium sand, no odor	**220 J**	24 U	24 U	17 U	17 U	25 U	20 U	68 U	85 U	29 U
PES-MW-11A	29-Mar-05	42 - 44	Sandy silt, no odor	**470 J**	**1,800**	22 U	**26 J**	16 U	23 U	18 U	64 U	81 U	27 U
	29-Mar-05	48 - 50	fine sand, no odor	**310 J**	**100**	24 U	17 U	17 U	25 U	20 U	69 U	87 U	30 U
PES-MW-12B	5-Apr-05	62 - 63	Cohesive tight clay, no odor.	**5,900**	**190**	25 U	18 U	18 U	26 U	20 U	**140 J**	89 U	30 U
PES-MW-13A	28-Mar-05	26 [f]	Sandy silt, no odor	**610**	**200**	22 U	16 U	16 U	23 U	18 U	64 U	80 U	27 U
	28-Mar-05	27	sandy silt, no odor	**460 J**	**89**	22 U	17 U	16 U	23 U	18 U	64 U	81 U	27 U
	28-Mar-05	42	Fine sand, no odor	**330 J**	**59**	23 U	17 U	17 U	24 U	19 U	66 U	84 U	28 U
PES-MW-14B	4-Apr-05	40 - 42	Sandy silt, no odor	**580**	**220**	**130**	16 U	16 U	23 U	18 U	63 U	79 U	27 U
	4-Apr-05	42	Sandy silt, no odor	**510**	**200**	**250**	**22 J**	16 U	23 U	18 U	64 U	81 U	27 U
	4-Apr-05	68 - 70	Fine sand, no odor	**370 J**	23 U	23 U	17 U	17 U	24 U	19 U	**360**	84 U	28 U

[a] feet bgs = feet below ground surface.

[b] TCE = trichloroethene; DCE = dichloroethene; DCA = dichloroethane.

[c] µg/kg = micrograms per kilogram.

[d] mg/kg = milligrams per kilogram.

[e] J indicates that the analyte was detected at a concentration above the method detection limit but below the reporting limit resulting in an estimated value.

TABLE 6
SUMMARY OF PLFA AND TARGETED GENE DETECTION DATA IN SOIL AND GROUNDWATER
NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
ANOKA COUNTY PARK
FRIDLEY, MINNESOTA

Sample Location	Sample Date	Sample Depth (feet bgs)[a]	Stratigraphic Classification	Evidence of Organic Carbon Impact	Total Organic Carbon (mg/kg)[b]	Dechlorinating Bacteria: DHC[c] (cells/gram)[d]	Dechlorinating Bacteria: DSM[c] (cells/gram)	Dechlorinating Bacteria: DHB[c] (cells/gram)	Dechlorinating Bacteria: DSB[c] (cells/gram)	Geobacter (cells/gram)	DHC Functional Genes: BVC[c] (cells/gram)	DHC Functional Genes: TCER[c] (cells/gram)	sMMO[c] (cells/gram)	Phylogenic Groups: Eubacteria (cells/gram)	Phylogenic Groups: Methanogens (cells/gram)	Phylogenic Groups: Sulfate+Iron Reducers (cells/gram)	Phylogenic Groups: Methanotrophs (cells/gram)	Total Biomass (cells/gram)
Soil Samples Impacted by Vegetable Oil																		
PES-SB-1	16-Mar-05	32-35	Silt	Mild Odor	410	2.00E+04	<1.75E+03 [e]	1.64E+07	5.32E+08	7.77E+03	4.33E+01 J	<8.76E+02	3.76E+05	4.73E+08	3.11E+07	7.92E+06	2.13E+09	1.21E+08
PES-SB-2	15-Mar-05	37-38	F-M Sand	Strong Odor	6,200	9.76E+04	<1.70E+03	2.73E+07	<1.70E+03	6.70E+02	2.47E+03	3.01E+02 J	7.36E+02	2.26E+09	1.09E+04	1.48E+06	4.98E+09	1.29E+07
PES-SB-3	14-Mar-05	42	Silty Fine Sand	Moderate Odor, Staining	1,700	1.20E+03	<1.82E+03	4.47E+07	<1.82E+03	<1.37E+03	2.19E+01 J	2.40E+02 J	1.23E+03 J	1.62E+09	6.61E+06	3.50E+07	7.95E+09	1.09E+08
PES-SB-6	23-Mar-05	36-38	Fine Sand	Strong Odor	550	1.25E+04	1.24E+03 J [f]	2.94E+07	8.30E+07	1.40E+03	1.19E+02 J	4.40E+03	1.08E+01 J	8.36E+08	4.31E+05	6.08E+05	2.95E+09	1.58E+08
PES-SB-7	23-Mar-05	46-48	Fine Sand	Strong Odor	300 J	6.48E+04	<1.59E+03	9.08E+07	3.25E+06	1.44E+02 J	4.94E+02 J	<7.96E+02	1.55E+07	2.84E+09	5.21E+06	7.96E+05	3.77E+10	1.93E+08
PES-SB-9	21-Mar-05	46	Silty Fine Sand	Moderate Odor, Staining	1,200	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.83E+08
PES-SB-9	21-Mar-05	51	Silty Fine Sand	Mild Odor	210 J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.21E+07
PES-SB-9	21-Mar-05	56	F-C Sand	Mild Odor	350 J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.02E+07
PES-SB-10	22-Mar-05	46	Fine Sand	Strong Odor	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.60E+08
PES-MW-10B	31-Mar-05	49-50	Fine Sand	Mild Odor	370 J	<9.98E+02	<2.00E+03	1.78E+03 J	5.58E+06	7.11E+02	<9.98E+02	<9.98E+02	2.40E+08	1.13E+09	6.04E+08	3.99E+06	3.25E+08	2.45E+08
PES-SB-3	14-Mar-05	32	Sandy Silt	Very Mild Odor	NA	2.45E+04	<1.69E+03	6.41E+04	<1.69E+03	1.26E+03	2.11E+02 J	<8.43E+02	<1.69E+03	6.67E+06	<1.69E+03	<1.29E+03	1.39E+05	4.52E+05
Soil Samples Un-Impacted by Vegetable Oil																		
PES-SB-4	24-Mar-05	42-44	Fine Sand	None	160 J	<4.0E+02	<7.99E+02	4.99E+04	1.24E+05	<6.00E+02	<4.00E+02	<4.00E+02	<7.99E+02	7.43E+07	4.05E+04	<6.00E+02	3.46E+05	1.98E+06
PES-SB-5	25-Mar-05	42-44	F-m Sand	None	230 J	4.17E+03	<1.54E+03	1.04E+05	<1.54E+03	<1.15E+03	1.55E+01 J	<7.69E+02	<1.54E+03	5.81E+07	<1.54E+03	<1.15E+03	3.42E+05	5.30E+05
PES-SB-8	17-Mar-05	46	Silty Fine Sand	None	280	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.37E+05
PES-SB-8	17-Mar-05	51	Fine Sand and Silt	None	280 J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	6.26E+05
PES-SB-8	17-Mar-05	56	F-C Sand	None	330 J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.11E+05
PES-SB-10	22-Mar-05	51	Fine sand	None	290 J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.49E+08
PES-SB-10	22-Mar-05	56	F-M Sand	None	240 J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	7.98E+06
PES-MW-10B	31-Mar-05	70-71	F-M Sand	None	220 J	1.38E+03	<1.97E+03	1.06E+05	5.14E+06	<1.48E+03	<9.84E+02	<9.84E+02	6.61E+05	3.14E+08	6.89E+05	<1.48E+03	1.03E+07	1.53E+06
PES-MW-11A	29-Mar-05	48-50	Fine Sand	None	310 J	1.38E+03	<8.71E+02	6.83E+05	4.03E+06	4.88E+00 J	<4.36E+02	5.46E+02	1.44E+01 J	4.60E+08	6.74E+05	<6.53E+02	3.66E+07	7.50E+05
PES-MW-12B	5-Apr-05	62-63	Tight Clay	None	5,900	6.24E+07	<1.83E+03	5.90E+04	4.27E+05	<1.38E+03	<9.17E+02	<9.17E+02	9.34E+02	2.43E+08	9.08E+04	1.94E+02 J	3.38E+05	6.11E+05
PES-MW-14B	4-Apr-05	68-70	Fine Sand	None	370 J	2.04E+06	<1.90E+03	1.97E+04	1.41E+07	<1.43E+03	6.57E+02 J	<9.51E+02	1.03E+04	3.55E+08	4.62E+06	<1.43E+03	6.27E+06	7.54E+05
PES-MW-13A	28-Mar-05	42	Fine Sand	None	330 J	5.54E+04	<1.46E+03	1.84E+05	<1.46E+03	<1.09E+03	3.99E+01 J	<7.28E+02	<1.46E+03	3.54E+05	<1.46E+03	<1.09E+03	3.85E+05	1.26E+05
Groundwater Samples Impacted by Vegetable Oil																		
PES-INJ-02	19-Apr-05	40.0 - 50.0	NA	NA	2,400	<2.5E-01	<5.0E-01	9.82E+02	3.69E+04	<3.75E-01	<2.50E-01	<2.50E-01	1.65E+02	2.54E+05	3.87E+03	<3.75E-01	6.58E+03	7.14E+06
PES-MW-10A	15-Apr-05	45.0 - 55.0	NA	NA	190	<2.5E-01	<5.0E-01	2.87E+04	1.68E+05	5.85E+00	<2.50E-01	<2.50E-01	<5.0E-01	7.46E+07	2.23E+05	1.22E+04	1.36E+06	3.18E+06
PES-MW-14A	12-Apr-05	55.0 - 65.0	NA	NA	50	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.33E+05
Groundwater Samples Un-Impacted by Vegetable Oil																		
18S	18-Apr-05	27.8 - 37.8	NA	NA	3.8	<2.5E-01	<5.0E-01	1.34E+04	1.20E+05	<3.75E-01	<2.50E-01	<2.50E-01	<5.0E-01	3.34E+06	3.09E+03	1.09E+02	5.76E+05	2.47E+04
26S	15-Apr-05	30.0 - 40.0	NA	NA	2.2	<2.5E-01	<5.0E-01	4.13E+02	6.23E+03	<3.75E-01	<2.50E-01	<2.50E-01	<5.0E-01	1.16E+05	2.42E+03	<3.75E-01	2.61E+03	1.28E+04
GWMS-46S	18-Apr-05	24.0 - 34.0	NA	NA	3.7	<2.5E-01	<5.0E-01	1.52E+03	1.85E+04	3.86E-02 J	<2.50E-01	<2.50E-01	<5.0E-01	2.75E+06	4.75E+03	3.29E+01	4.18E+04	3.64E+03
PES-MW-1	15-Apr-05	35.0 - 45.0	NA	NA	3.0	<2.5E-01	<5.0E-01	3.11E+04	2.24E+05	8.61E-01	<2.50E-01	<2.50E-01	1.52E+04	1.05E+08	1.34E+05	3.19E+04	1.03E+06	1.13E+05
PES-MW-6	15-Apr-05	35.0 - 45.0	NA	NA	2.6	3.23E+00	<5.0E-01	3.16E+04	1.81E+05	8.61E-01	<2.50E-01	<2.50E-01	<5.0E-01	9.03E+07	1.02E+05	1.14E+04	1.16E+06	6.93E+04
PES-MW-7	15-Apr-05	40.0 - 50.0	NA	NA	29	4.79E+00	1.84E+00	1.87E+04	2.09E+05	2.68E+00	<2.50E-01	<2.50E-01	<5.0E-01	9.77E+05	2.21E+05	1.85E+03	7.27E+05	4.03E+05
PES-MW-9	13-Apr-05	30.0 - 40.0	NA	NA	3.6	4.19E+00	<5.0E-01	1.49E+03	9.34E+04	<3.75E-01	<2.50E-01	<2.50E-01	<5.0E-01	6.34E+07	7.08E+03	3.46E+01	1.78E+04	2.06E+04
PES-MW-10B	14-Apr-05	65.0 - 75.0	NA	NA	3.3	8.95E-01	<5.0E-01	4.31E+02	9.99E+02	<3.75E-01	<2.50E-01	<2.50E-01	<5.0E-01	2.55E+05	6.60E+03	<3.75E-01	2.33E+04	2.88E+04
PES-MW-12A	12-Apr-05	35.0 - 45.0	NA	NA	6.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.12E+05

[a] feet bgs = feet below ground surface.

[b] mg/kg = micrograms per kilogram

[c] DHC = Dehalococcoides; DSM = Desulfuromonas; DHB = Dehalobacter; DSB = Desulfitobacterium; BVC = BAV-1 VC R-Dase; TCER = TCE R-Dase; sMMO = Soluble Methane Monooxygenase

[d] cell/gram = live microbial cells per gram of soi

[e] <1.75E+03 indicates that the analyte was not detected above the indicated method detection limit

[f] J indicates that the analyte was detected at a concentration above the method detection limit but below the reporting limit resulting in an estimated valu

TABLE 7
SUMMARY OF AQUEOUS AND MINERALOGICAL INTRINSIC BIOREMEDIATION ASSESSMENT RESULTS
NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
ANOKA COUNTY PARK
FRIDLEY, MINNESOTA

Sample Location	Sample Date	Sample Depth (feet bgs)[a/]	Stratigraphic Classification	Evidence of Organic Carbon Impact	Total Organic Carbon (mg/kg)[d/]	$BAFe^{3+}$ [b/] (mg/kg)[c/]	WAEFe [b/] (mg/kg)	SAEFe [b/] (mg/kg)	$O\text{-}Fe^{total}$ [b/] (mg/kg)	BAMn [b/] (mg/kg)	WAEMn [b/] (mg/kg)	SAEMn [b/] (mg/kg)	AVS [b/] (mg/kg)	CES [b/] (mg/kg)
Samples Impacted by Vegetable Oil														
PES-SB-1	16-Mar-05	35	Silt	Mild Odor	**410**	**423**	**550**	**540**	<5.9	**15.6**	<100	<200	**1,600**	**6300**
PES-SB-2	15-Mar-05	38	F-M Sand	Strong Odor	**6,200**	**1,430**	**250**	**4,400**	**100**	**41.5**	<100	<200	**1,300**	**2,200**
PES-SB-3	14-Mar-05	42	Silty Fine Sand	Strong Odor, staining	**1,700**	**1,040**	**150**	**5,800**	<5.8	**4.5**	<100	<200	<1200	**1,500**
PES-SB-3	14-Mar-05	60	Silty Fine Sand	Mild Odor	NA	<6.0	**150**	**1,960**	<6.0	**1,890**	<100	<200	**1,200**	**1,900**
PES-SB-9	21-Mar-05	36	Silty Fine Sand	Moderate Odor	**350 J**	**929**	**600**	**6,500**	<5.8	**1.6**	<100	<200	<1200	**1400**
PES-SB-10	22-Mar-05	46	Fine Sand	Strong Odor	NA	**1,540**	**1,100**	**7,000**	**7.4**	**12.1**	<100	<200	<1200	**3200**
					Average Concentrations	**1,072** [g/]	**467**	**4,367**	**11.6**	**15** [g/]	<100	<200	**983**	**2,750**
Samples Un-Impacted by Vegetable Oil														
PES-SB-1	16-Mar-05	56	Silty Fine Sand	None	NA	**1,100**	**150**	**7,900**	**282**	**114**	<100	<200	**2,200**	**11,000**
PES-SB-2	15-Mar-05	60	Fine Sand	None	NA	**990**	**150**	**4,700**	<6.0	**12.0**	<100	<200	**1,300**	**1,800**
PES-SB-4	24-Mar-05	44	Fine Sand	None	**160 J**	**544**	**200**	**5,000**	<6.0	**20.3**	<100	<200	<1200	**4,100**
PES-SB-4	24-Mar-05	54	Fine Sand	None	NA	**1,020**	**150**	**1,800**	<6.1	**29.7**	<100	**7,000**	<1200	**14,000**
PES-SB-8	17-Mar-05	50	Silty Fine Sand	None	**230 J**	**2,920**	**300**	**2,700**	**656**	**96.2**	<100	<200	<1200	<1200
					Average Concentrations	**1,315**	**190**	**4,420**	**124**	**54**	<100	<200 [g/]	**1,060**	**6300**

[a/] feet bgs = feet below ground surface.

[b/] $BAFe^{3+}$ = bioavailable ferric iron; $WAEFe^{3+}$ = weak acid extractable ferric iron; $SAEFe^{3+}$ = strong acid extractable ferric iron; $WAEFe^{2+}$ = weak acid extractable ferrous iron;
$SAEFe^{2+}$ = strong acid extractable ferrous iron; $O\text{-}Fe^{total}$ = total oxidized iron; BAMn = bioavailable manganese; WAEMn = weak acid manganese; SAEMn = strong acid extractable manganese;
AVS = acid volatile sulfide; CES = chromium extractable sulfide.

[c/] mg/kg = micrograms per kilogram.

[d/] <25 indicates that the analyte was not detected above the indicated method detection limit.

[f/] J indicates that the analyte was detected at a concentration above the method detection limit but below the reporting limit resulting in an estimated value.

[g/] One value that is significantly different from the population was discluded from this calculation.

TABLE 8
SUMMARY OF GROUNDWATER ELEVATION DATA
NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
ANOKA COUNTY PARK
FRIDLEY, MINNESOTA

Well/Borehole Identification	Date	Elevation Datum (Feet amsl)[a]	Depth to Water (Feet btoc)[b]	Depth to Oil (Feet btoc)	Groundwater Elevation[c] (Feet amsl)
MONITORING WELLS					
18-S	11-Apr-05	833.86	25.53	N.E. [e]	808.33
26-S	11-Apr-05	834.06	25.98	N.E.	808.08
GWMS-27S	11-Apr-05	832.74	27.35	N.E.	805.39
GWMS-45S	11-Apr-05	832.13	24.10	N.E.	808.03
GWMS-46S	11-Apr-05	831.67	24.41	N.E.	807.26
GWMS-47S	11-Apr-05	834.83	30.47	N.E.	804.36
GWMS-49S	11-Apr-05	834.16	N.M. [d]	N.E.	N.M.
MWW-13	11-Apr-05	833.33	28.53	N.E.	804.80
PES-MW-1	11-Apr-05	832.49	24.66	N.E.	807.83
PES-MW-2	11-Apr-05	832.41	24.66	N.E.	807.75
PES-MW-3	11-Apr-05	832.80	25.72	N.E.	807.08
PES-MW-4	11-Apr-05	832.57	27.91	N.E.	804.66
PES-MW-5	11-Apr-05	832.60	27.94	N.E.	804.66
PES-MW-6	11-Apr-05	832.41	24.63	N.E.	807.78
PES-MW-7	11-Apr-05	832.58	24.81	N.E.	807.77
PES-MW-8	11-Apr-05	832.64	25.00	N.E.	807.64
PES-MW-9	11-Apr-05	832.85	25.18	N.E.	807.67
PES-MW-10A	11-Apr-05	832.17	24.47	N.E.	807.70
PES-MW-10B	11-Apr-05	832.11	24.33	N.E.	807.78
PES-MW-11A	11-Apr-05	832.28	24.04	N.E.	808.24
PES-MW-12A	11-Apr-05	833.89	29.53	N.E.	804.36
PES-MW-12B	11-Apr-05	833.80	29.48	N.E.	804.32
PES-MW-13A	11-Apr-05	832.15	24.17	N.E.	807.98
PES-MW-14A	11-Apr-05	831.74	24.25	N.E.	807.49
PES-MW-14B	11-Apr-05	831.84	24.28	N.E.	807.56
PES-CW-1	11-Apr-05	832.01	27.17	N.E.	804.84
PES-CW-2	11-Apr-05	833.02	28.25	N.E.	804.77
PES-CW-3	11-Apr-05	835.47	30.89	N.E.	804.58
PES-BG-1	11-Apr-05	832.75	24.87	N.E.	807.88
PES-BG-2	11-Apr-05	832.73	24.91	N.E.	807.82
PES-BG-3	11-Apr-05	832.56	24.72	N.E.	807.84
INJECTION WELLS					
PES-INJ-1	11-Apr-05	832.42	24.64	N.E.	807.78
PES-INJ-2	11-Apr-05	832.87	25.14	N.E.	807.73
PES-INJ-3	11-Apr-05	832.71	25.28	25.04	807.65

[a] Feet amsl indicates elevation in feet above mean sea level.
[b] Feet btoc indicates depth in feet below top of casing.
[c] Water elevations corrected for presence of oil using a specific gravity of 0.92.
[d] N.M. = not measured. [e] N.E. = not encountered.

TABLE 9
PRE- AND POST-INJECTION HYDRAULIC CONDUCTIVITIES AND AVERAGE GROUNDWATER VELOCITIES
NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
ANOKA COUNTY PARK
FRIDLEY, MINNESOTA

Monitoring Well	Test Date	Rising or Falling Test	Screened Interval (ft bgs)[a]	Casing Inside Diameter (inches)	Static Water Level (feet btoc)	Hydraulic Conductivity (K) (ft/day)[b]	(cm/sec)[c]	(gpd/ft²)[d]	Estimated Effective Porosity	Hydraulic Gradient (ft/ft)[e]	Maximum Groundwater Velocity (ft/yr)[f]
Pre-Injection Slug Tests in the Injection Area											
PES-INJ-1	12/7/01	Both	35-45	3.0	28.37	210	7.43E-02	1,574	0.25	0.002	522
PES-INJ-2	12/7/01	Both	30-40	3.0	28.84	221	7.79E-02	1,651	0.25	0.002	548
PES-INJ-3	12/7/01	Both	40-50	3.0	28.73	254	8.96E-02	1,898	0.25	0.002	630
PES-MW-1	12/7/01	Both	35-45	2.0	28.55	177	6.23E-02	1,321	0.25	0.002	438
GEOMETRIC MEAN						**214**	**7.54E-02**	**1,597**	**0.25**	**0.00**	**530**
Pre-Injection Slug Tests Down Gradient From the Injection Area											
PES-MW-3	12/6/01	Both	35-45	2.0	29.66	23	8.15E-03	173	0.25	0.059	1,988
PES-MW-4	12/6/01	Both	30-40	2.0	31.20	14	5.03E-03	107	0.25	0.059	1,228
PES-MW-8	12/7/01	Both	30-40	2.0	28.70	78	2.77E-02	587	0.25	0.059	6,754
GEOMETRIC MEAN						**30**	**1.04E-02**	**221**	**0.25**	**0.059**	**2,545**
PES-CW-1	12/6/01	Both	30-40	2.0	31.38	**196**	**6.92E-02**	**1,467**	**0.25**	**0.002**	**572**
December 2002 Post-Injection Slug Tests in the Injection Area											
PES-INJ-1	12/14/02	Both	35-45	3.0	28.73	11	3.87E-03	82	0.25	0.002	27
PES-INJ-2	12/14/02	Rise	30-40	3.0	28.82	7.9	2.79E-03	59	0.25	0.002	20
PES-INJ-3	12/14/02	Both	40-50	3.0	28.73	13	4.59E-03	97	0.25	0.002	32
GEOMETRIC MEAN						**10**	**3.67E-03**	**78**	**0.25**	**0.002**	**26**
December 2002 Post-Injection Slug Tests Down Gradient From the Injection Area											
PES-MW-1	12/16/02	Rise	35-45	2.0	26.67	83	2.93E-02	622	0.25	0.041	4,974
PES-MW-6	12/16/02	Rise	35-45	2.0	26.60	70	2.46E-02	522	0.25	0.041	4,179
PES-MW-7	12/16/02	Rise	35-45	2.0	26.79	110	3.87E-02	820	0.25	0.041	6,560
GEOMETRIC MEAN						**86**	**3.04E-02**	**643**	**0.25**	**0.04**	**5,147**
April 2003 Post-Injection Slug Tests in the Injection Area											
PES-INJ-1	4/5/03	Both	35-45	3.0	27.73	1.0	3.39E-04	7.2	0.25	0.002	2.4
PES-INJ-2	4/4/03	Both	40-50	3.0	28.23	8.4	2.96E-03	63	0.25	0.002	21
GEOMETRIC MEAN						**2.8**	**1.00E-03**	**21**	**0.25**	**0.00**	**7.0**
April 2003 Post-Injection Slug Tests Down Gradient From the Injection Area											
PES-MW-1	4/4/03	Both	35-45	2.0	27.77	124	4.36E-02	925	0.25	0.041	7,399
PES-MW-6	4/4/03	Both	35-45	2.0	27.71	68	2.40E-02	509	0.25	0.041	4,071
PES-MW-7	12/16/02	Both	35-45	2.0	26.79	85	2.99E-02	633	0.25	0.041	5,069
GEOMETRIC MEAN						**86**	**3.04E-02**	**644**	**0.25**	**0.041**	**5,156**
August 2003 Post-Injection Slug Tests in the Injection Area											
PES-INJ-1	8/28/03	Both	35-45	3.0	27.73	0.3	9.00E-05	1.9	0.25	0.002	0.6
PES-INJ-2	8/27/03	Both	40-50	3.0	28.23	2.7	9.60E-04	20	0.25	0.002	6.8
GEOMETRIC MEAN FOR POST-INJECTION TESTS						**0.8**	**2.94E-04**	**6.2**	**0.25**	**0.00**	**2.1**
August 2003 Post-Injection Slug Tests Down Gradient From the Injection Area											
PES-MW-1	8/27/03	Both	35-45	2.0	27.77	94	3.31E-02	702	0.25	0.020	2,741
PES-MW-6	8/27/03	Both	35-45	2.0	27.71	94	3.32E-02	704	0.25	0.023	3,159
PES-MW-7	8/27/03	Both	35-45	2.0	26.79	66	2.34E-02	496	0.25	0.012	1,161
GEOMETRIC MEAN FOR POST-INJECTION TESTS						**81**	**2.87E-02**	**607**	**0.25**	**0.018**	**2,094**

[a] ft bgs = feet below ground surface.
[b] ft/day = feet per day.
[c] cm/sec = centimeters per second.
[d] gpd/ft² = gallons per day per square foot.
[e] ft/ft = foot per foot.
[f] ft/yr = feet per year.
[g] Pre-injection mean calculations are for wells upgradient of PES-MW8 and PES-MW9.
[h] Pre-injection mean calculations are for wells PES-MW3, PES-MW8, and PES-MW9.
[i] Pre-injection calculations are for well PES-CW1.

TABLE 10

SUMMARY OF VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER

NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY

ANOKA COUNTY PARK

FRIDLEY, MINNESOTA

Sample Location	Date	PCE[a] (μg/L)[b]	TCE[a] (μg/L)	*cis-* 1,2-DCE[a] (μg/L)	*trans* 1,2-DCE[a] (μg/L)	1,1-DCE[a] (μg/L)	Vinyl Chloride (μg/L)	1,1,1-TCA[a] (μg/L)	1,1-DCA[a] (μg/L)	1,2-DCA[a] (μg/L)	Carbon Tetrachloride (μg/L)	Chloroform (μg/L)	Bromodichloro-methane (μg/L)	2-Butanone (μg/L)	Acetone (μg/L)	Benzene (μg/L)	Toluene (μg/L)
MONITORING WELLS																	
18-S	4/18/2005	0.45 U	400	96	27	0.87 J	0.37 J	0.90 U	0.89 J	0.36 U	0.49 U	0.37 U	0.56 U	4.3 U	39	0.41 U	0.67 U
MS-26S	4/15/2005	0.63 J	230	48	2.7	0.61 J	0.18 U	0.90 U	0.75 U	0.36 U	0.49 U	0.37 U	0.56 U	4.3 U	2.3 U	0.41 U	0.67 U
GWMS-27S	12-Nov-01	0.39 U[c]	0.44 U	0.99 U	0.38 U	0.47 U	0.17 U	0.53 U	0.47 U	0.52 U	0.54 U	0.47 U	0.42 U	1.0 U	3.3	12	0.42 U
	11-Feb-02	0.39 U	0.76 J[d]	2.4	0.38 U	0.47 U	0.17 U	0.53 U	0.47 U	0.52 U	0.54 U	0.47 U	0.42 U	1.0 U	1.6 U	0.44 U	0.42 U
	21-May-02	0.39 U	89	12	0.97	0.47 U	0.17 U	0.53 U	1.2	0.52 U	0.54 U	0.47 U	0.42 U	1.0 U	1.6 U	0.44 U	0.42 U
	26-Aug-02	0.39 U	170	50	5.1	0.62 J	0.17 U	0.53 U	0.62 J	0.52 U	0.54 U	0.47 U	0.42 U	1.0 U	1.6 U	0.44 U	0.42 U
	9-Dec-02	0.25 U	54	33	0.99 J	0.58 J	0.30 U	0.23 U	0.94 J	0.34 U	0.29 U	0.19 U	0.32 U	0.86 U	2.0 U	0.20 U	0.22 U
	7-Apr-03	0.24 U	140 J	10	1.5	0.22 U	0.17 U	0.23 U	0.20 U	0.17 U	0.25 U	0.19 U	0.11 U	0.86 U	2.0 U	0.11 U	0.11 U
	18-Aug-03	0.30 J	290	45	6.4	0.22 U	0.17 U	0.23 U	0.2 U	0.17 U	0.25 U	0.19 U	0.11 U	0.86 U	23	0.11 U	0.11 U
MS-36S	22-Apr-05	0.45 U	21	270	51	0.57 U	1.7	0.90 U	0.75 U	0.36 U	0.49 U	0.37 U	0.56 U	4.3 U	2.3 U	0.41 U	0.67 U
MS-44S	18-Apr-05	0.45 U	77	19	2.3	0.57 U	0.18 U	0.90 U	0.75 U	0.36 U	0.49 U	0.37 U	0.56 U	4.3 U	4.0 J	0.41 U	0.67 U
GWMS-45S	18-Apr-05	0.45 U	180	550	62	2.3	0.28 J	0.90 U	1.5	0.36 U	0.49 U	0.37 U	0.56 U	4.3 U	5.7	0.41 U	0.67 U
GWMS-46S	19-Nov-01	78 U	20,000	200 U	200	94 U	34 U	110 U	94 U	0.52 U	0.54 U	0.47 U	0.42 U	210 U	330 U	88 U	84 U
	18-Feb-02	39 U	14,000	120	140	47 U	17 U	53 U	47 U	52 U	54 U	47 U	42 U	100 U	160 U	44 U	42 U
	22-May-02	1.9 U	5,600	55	61	4.6	0.85 U	2.6 U	2.3 U	2.6 U	2.7 U	2.3 U	2.1 U	5.2 U	8.2 U	2.2 U	2.1 U
	28-Aug-02	0.78 U	4,900	29	29	2.5	0.92 J	1.1 U	0.94 U	1.0 U	1.1 U	0.94 U	0.8 U	2.1 U	5.0 J	0.88 U	0.84 U
	11-Dec-02	1.2 U	7,200	65	73	6.4	1.5 U	1.2 U	1.0 U	1.7 U	1.4 U	0.95 U	1.6 U	4.3 U	10 U	1.0 U	1.1 U
	9-Apr-03	0.24 U	2,600	24	32	2.6	0.6 J	0.23 U	1.0	0.17 U	0.25 U	0.19 U	0.32 U	0.86 U	2.0 U	0.11 U	0.11 U
	20-Aug-03	0.24 U	4,500	57	85	3.5	1.3 J	0.23 U	1.8	0.17 U	0.25 U	0.19 U	0.11 U	0.86 U	2.0 U	0.11 U	0.11 U
	18-Apr-05	0.45 U	1,700	55	51	1.7	0.45 J	0.90 U	1.8	0.36 U	0.49 U	0.37 U	0.56 U	4.3 U	2.3 U	0.41 U	0.67 U
GWMS-47S	14-Nov-01	0.92	44	22	1.1	0.47 U	0.17 U	0.53 U	0.89	0.52 U	0.54 U	0.47 U	0.42 U	1.0 U	1.6 U	0.44 U	0.42 U
	12-Feb-02	1.1 J	180	9.9	2.1	0.94 U	0.34 U	1.1 U	0.94 U	1.0 U	1.1 U	0.94 U	0.84 U	2.1 U	3.3 U	0.88 U	0.84 U
	21-May-02	0.60	220	9.3	3.3	0.50	0.17 U	0.53 U	1.1	0.52 U	0.54 U	0.47 U	0.42 U	1.0 U	1.6 U	0.44 U	0.42 U
	26-Aug-02	0.39 U	120	6.6	3.3	0.47 U	0.17 U	0.53 U	0.47 U	0.52 U	0.54 U	0.47 U	0.42 U	1.0 U	1.6 U	0.44 U	0.42 U
	10-Dec-02	0.64 J	62 U	25	1.4	0.26 U	0.30 U	0.23 U	0.20 U	0.34 U	0.29 U	0.19 U	0.32 U	0.86 U	2.0 U	0.20 U	0.22 U
	8-Apr-03	1.5	66 U	20	1.4 U	0.22 U	0.17 U	0.23 U	0.20 U	0.17 U	0.25 U	0.19 U	0.32 U	0.86 U	2.0 U	0.11 U	0.11 U
	19-Aug-03	1.1	57	14	1.2	0.22 U	0.17 U	0.23 U	0.20 U	0.17 U	0.25 U	0.19 U	0.11 U	0.86 U	2.0 U	0.11 U	0.11 U
	11-Apr-05	0.87 J	42	4.1	0.89 U	0.57 U	0.18 U	0.90 U	0.75 U	0.36 U	0.49 U	0.37 U	0.56 U	4.3 U	2.3 U	0.41 U	0.67 U
MS-53PC	11-Apr-05	0.45 U	0.83 J	0.83 U	0.19 U	0.75 U	0.18 U	0.90 U	0.75 U	0.36 U	0.49 U	0.37 U	0.56 U	4.3 U	2.7 U	0.41 U	0.67 U
PES-MW-1	16-Nov-01	3.9 U	1,100	14	15	4.7 U	1.7 U	5.3 U	4.7 U	5.2 U	5.40 U	4.7 U	4.2 U	10 U	16 U	4.4 U	4.2 U
	15-Feb-02	7.8 U	1,100	20 U	20 J	9.4 U	3.4 U	11 U	9.4 U	10 U	11 U	9.4 U	8.4 U	21 U	33 U	8.8 U	8.4 U
	22-May-02	0.78 U	3,200	450	75	4.5	0.34 U	1.1 U	1.6	1.0 U	1.1 U	0.94 U	0.84 U	2.1 U	3.3 U	0.88 U	0.84 U
	28-Aug-02	0.39 U	2,600	630	39	3.8	1.3 J	0.53 U	1.5	0.52 U	0.54 U	0.47 U	0.42 U	12 U	8.2 U	0.44 U	0.42 U
	12-Dec-02	0.50 U	1,700	230	26	2.5	0.6 U	0.46 U	1.4 J	0.68 U	0.58 U	0.38 U	0.64 U	1.7 U	1.0 U	0.40 U	4.1
	10-Apr-03	0.24 U	1,300	370	30	2.0	0.17 U	0.23 U	1.2	0.17 U	0.25 U	0.19 U	0.32 U	0.86 U	2.0 U	0.11 U	0.11 U
	21-Aug-03	0.24 U	1,200	1100	79	3.2	1.4 J	0.23 U	2.3	0.17 U	0.25 U	0.19 U	0.11 U	0.86 U	2.0 U	0.11 U	0.11 U
	15-Apr-05	0.45 U	380	210	16	0.99 J	0.18 U	0.90 U	1.0	0.36 U	0.49 U	0.37 U	0.56 U	4.30 U	2.5 J	0.41 U	0.67 U
PES-MW-2	15-Nov-01	7.8 U	2,100	22	27	9.4 U	3.4 U	11 U	9.4 U	10 U	11 U	9.4 U	8.4 U	21 U	33 U	8.8 U	8.4 U
	14-Feb-02	20 U	3,600	50 U	68	23 U	8.5 U	26 U	23 U	26 U	27 U	23 U	21 U	52 U	82 U	22 U	21 U
	22-May-02	0.78 U	2,200	62	39	3.1	0.59	1.1 U	1.7	1.0 U	1.1 U	0.94 U	0.84 U	2.1 U	9.3	0.88 U	0.84 U
	28-Aug-02	0.78 U	3,200	21	26	2.0 J	0.34 U	1.1 U	1.3 J	1.0 U	1.1 U	0.94 U	0.84 U	2.1 U	3.3 U	0.88 U	0.84 U
	11-Dec-02	0.50 U	2,600	24	32	3.0	0.60 U	0.5 U	1.4 J	0.68 U	0.58 U	0.38 U	0.64 U	1.7 U	4.0 U	0.40 U	0.44 U
	9-Apr-03	0.24 U	2,900	46	55	2.7	0.53 J	0.23 U	1.6	0.17 U	0.25 U	0.19 U	0.32 U	0.86 U	2.0 U	0.11 U	0.11 U
	20-Aug-03	0.24 U	2,000	27	57	2.2	0.39 J	0.23 U	2.0	0.17 U	0.25 U	0.19 U	0.11 U	0.86 U	2.0 U	0.11 U	0.11 U
	14-Apr-05	0.45 U	930	45	18	1.5	0.18 U	0.90 U	0.93 J	0.36 U	0.49 U	0.37 U	0.56 U	4.3 U	2.3 U	0.41 U	0.67 U
PES-MW-3	14-Nov-01	20 U	5,000	73	110	23 U	8.5 U	26 U	23 U	26 U	27 U	23 U	21 U	52 U	82 U	22 U	21 U
	13-Feb-02	20 U	6,100	120	170	23 U	8.5 U	26 U	23 U	26 U	27 U	23 U	21 U	52 U	82 U	22 U	21 U
	21-May-02	1.9 U	6,200	220	160	5.3	0.85 U	2.6 U	2.3 U	2.6 U	2.7 U	2.3 U	2.1 U	5.2 U	8.2 U	2.2 U	2.1 U
	27-Aug-02	1.9 U	5,900	390	95	4.7 J	2.2 J	2.6 U	2.3 U	2.6 U	2.7 U	2.3 U	2.1 U	5.2 U	8.2 U	2.2 U	2.1 U
	10-Dec-02	1.2 U	5,000	260	120	5.7	1.5 U	1.2 U	1.0 U	1.7 U	1.4 U	0.95 U	1.6 U	4.3 U	10 U	1.0 U	1.1 U
	8-Apr-03	0.24 U	3,800	300	130	3.7	1.1 J	0.2 U	2.3	0.17 U	0.25 U	0.19 U	0.32 U	0.86 U	2.0 U	0.11 U	0.11 U
	20-Aug-03	0.24 U	2,400	320	110	3.0	0.90 J	0.23 U	2.8	0.17 U	0.25 U	0.19 U	0.11 U	0.86 U	2.0 U	0.11 U	0.11 U
	14-Apr-05	0.45 U	830	170	51	1.8	0.34 J	0.90 U	1.4	0.36 U	0.49 U	0.37 U	0.56 U	4.3 U	2.3 U	0.41 U	0.67 U
PES-MW-4	14-Nov-01	7.8 U	3,300	83	120	9.4 U	3.4 U	11 U	9.4 U	10 U	11 U	9.4 U	8.4 U	21 U	33 U	8.8 U	8.4 U
	12-Feb-02	7.8 U	3,300	88	110	9.4 U	3.4 U	11 U	9.4 U	10 U	11 U	9.4 U	8.4 U	21 U	33 U	8.8 U	8.4 U
	21-May-02	0.78 U	4,200	140	190	4.1	0.34 U	1.1 U	3.5	1.0 U	1.1 U	0.94 U	0.84 U	2.1 U	3.3 U	0.88 U	0.84 U
	27-Aug-02	0.78 U	3,100	56	67	2.2	0.34 U	1.1 U	1.7 J	1.0 U	1.1 U	0.94 U	0.84 U	2.1 U	3.3 U	0.88 U	0.84 U
	10-Dec-02	0.50 U	2,100	72	82	2.6	0.60 U	0.46 U	1.9 J	0.68 U	0.58 U	0.38 U	0.64 U	1.7 U	4.0 U	0.40 U	0.44 U
	8-Apr-03	0.24 U	2,300	80	100	2.1	0.17 U	0.23 U	0.17 U	0.17 U	0.25 U	0.19 U	0.32 U	0.86 U	2.0 U	0.11 U	0.11 U

TABLE 10

SUMMARY OF VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER

NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY

ANOKA COUNTY PARK

FRIDLEY, MINNESOTA

Sample Location	Date	PCE[a/] (µg/L)[b/]	TCE[a/] (µg/L)	*cis-* 1,2-DCE[a/] (µg/L)	*trans* 1,2-DCE[a/] (µg/L)	1,1-DCE[a/] (µg/L)	Vinyl Chloride (µg/L)	1,1,1-TCA[a/] (µg/L)	1,1-DCA[a/] (µg/L)	1,2-DCA[a/] (µg/L)	Carbon Tetrachloride (µg/L)	Chloroform (µg/L)	Bromodichloro -methane (µg/L)	2-Butanone (µg/L)	Acetone (µg/L)	Benzene (µg/L)	Toluene (µg/L)
	19-Aug-03	0.73 J	2,600	130	160	2.8	0.86 J	0.23 U	3.2	0.17 U	0.25 U	0.19 U	0.11 U	0.86 U	2.0 U	0.11 U	0.11 U
	12-Apr-05	0.45 U	820	200	86	1.5	0.33 J	0.90 U	2.2	0.36 U	0.49 U	0.37 U	0.56 U	4.30 U	180	0.41 U	0.67 U
PES-MW-5	14-Nov-01	0.39 U	75	29	1.8	0.47 U	0.17 U	0.53 U	0.76	0.52 U	0.54 U	0.47 U	0.42 U	1.0 U	1.6 U	0.44 U	0.42 U
	12-Feb-02	0.39 U	77	32	2.1	0.47 U	0.17 U	0.53 U	0.74 J	0.52 U	0.54 U	0.47 U	0.42 U	1.0 U	1.6 U	0.44 U	0.42 U
	21-May-02	0.39 U	82	34	1.8	0.47 U	0.17 U	0.53 U	0.67	0.52 U	0.54 U	0.47 U	0.42 U	1.0 U	1.6 U	0.44 U	0.42 U
	27-Aug-02	0.39 U	1,000	21	21	1.0	0.17 U	0.53 U	0.47 U	0.52 U	0.54 U	0.47 U	0.42 U	1.0 U	1.6 U	0.44 U	0.42 U
	10-Dec-02	0.25 U	120 U	94	4.4	0.26 U	0.3 U	0.23 U	2.8	0.34 U	0.29 U	0.19 U	0.32 U	0.86 U	2.0 U	0.20 U	0.22 U
	8-Apr-03	0.24 U	780	53	17	0.22 U	0.17 U	0.23 U	0.97 J	0.17 U	0.25 U	0.19 U	0.32 U	0.86 U	2.0 U	0.11 U	0.11 U
	19-Aug-03	0.28 J	880	28	30	1.7	0.17 U	0.23 U	0.20 U	0.17 U	0.25 U	0.19 U	0.11 U	0.86 U	2.0 U	0.11 U	0.11 U
	12-Apr-05	0.45 U	38	8.7	0.92 J	0.57 U	0.18 U	0.90 U	0.75 U	0.36 U	0.49 U	0.37 U	0.56 U	4.3 U	9.1	0.41 U	0.73*J
PES-MW-6	15-Nov-01	20 U	6,200	88	140	23 U	8.5 U	26 U	23 U	26 U	27 U	23 U	21 U	52 U	82 U	22 U	21 U
	15-Feb-02	20 U	5,800	100	150	23 U	8.5 U	26 U	23 U	26 U	27 U	23 U	21 U	52 U	82 U	22 U	4.2 U
	23-May-02	1.9 U	5,100	84	130	3.2	1.7	2.6 U	2.3 U	2.6 U	2.7 U	2.3 U	2.1 U	5.2 U	8.2 U	2.2 U	2.1 U
	28-Aug-02	1.9 U	6,600	87	83	3.2 J	1.4 J	2.6 U	2.3 U	2.6 U	2.7 U	2.3 U	2.1 U	5.2 U	17 J	2.2 U	2.1 U
	12-Dec-02	0.50 U	3,800	240	71	3.9	0.60 U	0.46 U	1.6 J	0.68 U	0.58 U	0.38 U	0.64 U	1.7 U	4.0 U	0.4 U	0.44 U
	10-Apr-03	0.24 U	3,000	180	100	2.7	0.77 J	0.23 U	2.5	0.17 U	0.25 U	0.19 U	0.32 U	0.86 U	2.0 U	0.1 U	0.11 U
	21-Aug-03	0.24 U	2,000	97	61	2.8	0.59 J	0.23 U	2.1	0.17 U	0.25 U	0.19 U	0.11 U	0.86 U	2.0 U	0.11 U	0.11 U
	15-Apr-05	0.45 U	700	170	27	1.7	0.27 J	0.90 U	0.87 J	0.36 U	0.49 U	0.37 U	0.91 U	4.3 U	2.3 U	0.41 U	0.67 U
PES-MW-7	16-Nov-01	0.78 U	300	5.2	0.78 U	0.94 U	0.34 U	1.1 U	0.94 U	1.0 U	1.1 U	0.94 U	0.84 U	2.1 U	3.3 U	0.88 U	0.84 U
	14-Feb-02	1.9 U	540	7.9	7.4	2.3 U	0.85 U	2.6 U	2.3 U	2.6 U	2.7 U	2.3 U	2.1 U	74	8.2 U	2.2 U	2.1 U
	22-May-02	0.39 U	980	14	18	2.2	0.36	0.53 U	1.6	0.52 U	0.54 U	0.47 U	0.42 U	130	340	0.44 U	0.42 U
	28-Aug-02	0.48 J	1,300	65	11	2.1	0.42 J	0.53 U	0.98 J	0.52 U	0.54 U	0.47 U	0.42 U	66	55	0.44 U	0.42 U
	12-Dec-02	0.25 U	350 J	180	8.3	2.0	0.53 U	0.23 U	1.0	0.34 U	0.29 U	0.19 U	0.32 U	320	2.0 U	0.20 U	4.5
	10-Apr-03	0.24 U	12 U	270	5.5	0.99 J	0.69 J	0.23 U	0.2 U	0.17 U	0.25 U	0.19 U	0.32 U	1,800	65	0.11 U	0.11 U
	21-Aug-03	0.24 U	2.1	410	7.2	0.22 U	0.90 J	0.23 U	0.2 U	0.17 U	0.25 U	0.19 U	0.11 U	89	14	0.11 U	0.11 U
	15-Apr-05	0.45 U	4.1	130	4.7	0.57 U	0.29 J	0.90 U	0.89 J	0.36 U	0.49 U	0.37 U	0.56 U	4.3 U	4.9 J	0.41 U	0.67 U
PES-MW-8	15-Nov-01	20 U	6,700	160	220	23 U	8.5 U	26 U	23 U	26 U	27 U	23 U	21 U	10 U	82 U	22 U	21 U
	14-Feb-02	20 U	4,700	150	200	23 U	8.5 U	26 U	23 U	26 U	27 U	23 U	21 U	10 U	82 U	22 U	21 U
	22-May-02	1.9 U	5,400	180	210	4.8	2.2	2.6 U	4.0	2.6 U	2.7 U	23 U	2.1 U	5.2 U	8.2 U	2.2 U	2.1 U
	27-Aug-02	1.9 U	5,700	130	130	4.0 J	1.8 J	2.6 U	3.8 J	2.6 U	2.7 U	2.3 U	2.1 U	5.2 U	19 J	2.2 U	2.1 U
	12-Dec-02	1.2 U	5,500	70	73	1.3 U	1.5 U	1.2 U	1.0 U	1.7 U	1.4 U	0.95 U	1.6 U	4.3 U	10 U	1.0 U	1.1 U
	9-Apr-03	0.2 U	3,000	120	130	3.0	0.81 J	0.23 U	2.8	0.17 U	0.25 U	0.19 U	0.32 U	0.86 U	2.0 U	0.11 U	0.11 U
	21-Aug-03	0.32 J	2,200	76	.96	3.3	0.17 U	0.23 U	1.9	0.17 U	0.25 U	0.19 U	0.11 U	0.86 U	2.0 U	0.11 U	0.11 U
	14-Apr-05	0.45 U	1,100	90	57	1.6	0.34 J	0.90 U	1.5	0.36 U	0.49 U	0.37 U	0.56 U	4.3 U	2.3 U	0.41 U	0.67 U
PES-MW-9	15-Nov-01	3.9 U	1,400	15	20	4.7 U	1.7 U	5.3 U	4.7 U	5.2 U	5.4 U	4.7 U	4.2 U	52 U	16 U	4.4 U	0.42 U
	13-Feb-02	3.9 U	1,300	17	20	4.7 U	1.7 U	5.3 U	4.7 U	5.2 U	5.4 U	4.7 U	4.2 U	52 U	16 U	4.4 U	4.2 U
	22-May-02	0.78 U	410	1,800	63	8.2	1.2	1.1 U	1.5	1.0 U	1.1 U	0.94 U	0.84 U	91	150	0.88 U	0.84 U
	27-Aug-02	1.9 U	120	3,000	67	9.6	12	2.6 U	2.3 U	2.6 U	2.7 U	2.30 U	2.1 U	290	180	2.2 U	2.1 U
	11-Dec-02	0.50 U	20 U	1,500	33	6.8	5.7	0.46 U	0.4 U	0.68 U	0.58 U	0.38 U	0.64 U	180	68	0.4 U	0.44 U
	9-Apr-03	0.24 U	2,300	180	42	2.7	0.17 U	0.23 U	1.3	0.17 U	0.25 U	0.19 U	0.32 U	0.86 U	2.0 U	0.11 U	0.11 U
	20-Aug-03	0.24 U	2,200	370	110	3.2	0.71 J	0.23 U	2.8	0.17 U	0.25 U	0.19 U	0.11 U	0.86 U	2.0 U	0.11 U	0.11 U
	13-Apr-05	2.20 U	490	270	30	1.0	0.90 U	4.5 U	0.77 J	1.8 U	2.40 U	1.8 U	2.8 U	22 U	12 U	2.0 U	3.4 U
PES-CW-1	13-Nov-01	1.9 U	630	12	7.5	2.3 U	0.85 U	2.6 U	2.3 U	2.6 U	2.7 U	2.3 U	2.1 U	5.2 U	8.2 U	2.2 U	2.1 U
	11-Feb-02	0.78 U	170	9.5	2.4	0.94 U	0.34 U	1.1 U	0.94 U	1.0 U	1.1 U	0.94 U	0.84 U	2.1 U	3.3 U	0.88 U	0.84 U
	20-May-02	0.39 U	170	8.2	2.3	0.47 U	0.17 U	0.53 U	0.86	0.52 U	0.54 U	0.47 U	0.42 U	1.0 U	1.6 U	0.44 U	0.42 U
	26-Aug-02	0.89 J	61	39	3.8	0.47 U	0.17 U	0.53 U	0.65 J	0.52 U	0.54 U	0.47 U	0.42 U	1.0 U	1.6 U	0.44 U	0.42 U
	9-Dec-02	0.53 J	250 J	9.6	2.9	0.67 J	0.30 U	0.23 U	0.99 J	0.34 U	0.29 U	0.19 U	0.32 U	0.86 U	2.0 U	0.20 U	0.22 U
	7-Apr-03	1.5	54	9.6	0.93 J	0.22 U	0.17 U	0.23 U	0.20 U	0.17 U	0.25 U	0.19 U	0.32 U	0.86 U	2.0 U	0.11 U	0.11 U
	18-Aug-03	2.0	67	8.9	0.97 J	0.22 U	0.17 U	0.23 U	0.20 U	0.17 U	0.25 U	0.19 U	0.11 U	0.86 U	2.0 U	0.11 U	0.11 U
PES-CW-2	13-Nov-01	1.9 U	290	7.3	1.9 U	2.3 U	0.85 U	2.6 U	2.3 U	2.3 U	2.7 U	2.3 U	2.1 U	5.2 U	8.2 U	2.2 U	2.1 U
	11-Feb-02	0.78 U	350	9.0	4.8	0.94 U	0.34 U	1.1 U	0.94 U	1.0 U	1.1 U	0.94 U	0.84 U	2.1 U	3.3 U	0.88 U	0.84 U
	20-May-02	0.39 U	210	7.0	2.1	0.71	0.17 U	0.53 U	1.4	0.52 U	0.54 U	0.47 U	0.42 U	1.0 U	1.6 U	0.44 U	0.42 U
	26-Aug-02	0.39 U	200	14	3.7	0.47 J	0.17 U	0.53 U	0.73 J	0.52 U	0.54 U	0.47 U	0.42 U	1.0 U	1.6 U	0.44 U	0.42 U
	9-Dec-02	0.25 U	230 J	6.4	1.5	0.26 U	0.30 U	0.23 U	1.0 U	0.34 U	0.29 U	0.19 U	0.32 U	0.86 U	2.0 U	0.20 U	0.22 U
	7-Apr-03	0.75 J	100	11	1.1	0.22 U	0.17 U	0.23 U	0.2 U	0.17 U	0.25 U	0.19 U	0.32 U	0.86 U	2.0 U	0.11 U	0.75 J
	19-Aug-03	1.3	87	14	1.5	0.22 U	0.17 U	0.23 U	0.2 U	0.17 U	0.25 U	0.19 U	0.11 U	0.86 U	2.0 U	0.11 U	0.11 U
	11-Apr-05	0.45 U	110	4.9	0.89 U	0.57 U	0.18 U	0.90 U	0.75 U	0.36 U	0.49 U	0.37 U	0.56 U	4.3 U	12	0.41 U	0.67 U
PES-CW-3	13-Nov-01	0.78 U	240	5.7	0.76 U	0.94 U	0.34 U	1.1 U	0.94 U	1.0 U	1.1 U	0.94 U	0.84 U	2.1 U	3.3 U	0.88 U	0.84 U
	12-Feb-02	0.78 U	330	6.5	2.3	0.94 U	0.34 U	1.1 U	0.94 U	1.0 U	1.1 U	0.94 U	0.84 U	2.1 U	3.3 U	0.88 U	0.84 U
	20-May-02	0.39 U	200	7.0	1.3	0.77	0.17 U	0.53 U	1.4	0.52 U	0.54 U	0.47 U	0.42 U	1.0 U	1.6 U	0.44 U	0.42 U

TABLE 10

SUMMARY OF VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER

NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY

ANOKA COUNTY PARK

FRIDLEY, MINNESOTA

Sample Location	Date	PCE[a] (µg/L)[b]	TCE[a] (µg/L)	*cis*- 1,2-DCE[a] (µg/L)	*trans* 1,2-DCE[a] (µg/L)	1,1-DCE[a] (µg/L)	Vinyl Chloride (µg/L)	1,1,1-TCA[a] (µg/L)	1,1-DCA[a] (µg/L)	1,2-DCA[a] (µg/L)	Carbon Tetrachloride (µg/L)	Chloroform (µg/L)	Bromodichloro -methane (µg/L)	2-Butanone (µg/L)	Acetone (µg/L)	Benzene (µg/L)	Toluene (µg/L)
	26-Aug-02	0.39 U	230	5.8	2.9	0.47 U	0.17 U	0.53 U	0.88 J	0.52 U	0.54 U	0.47 U	0.42 U	1.0 U	1.6 U	0.44 U	0.42 U
	10-Dec-02	0.25 U	220 J	6.0	0.98 J	0.58 J	0.30 U	0.23 U	1.0	0.34 U	0.29 U	0.19 U	0.32 U	0.86 U	2.0 U	0.20 U	0.22 U
	8-Apr-03	0.24 U	190 U	4.7 U	0.25 U	0.22 U	0.17 U	0.23 U	0.72 J	0.17 U	0.25 U	0.19 U	0.32 U	0.86 U	2.0 U	0.11 U	0.11 U
	19-Aug-03	0.24 U	160	8.6	1.2	0.22 U	0.17 U	0.23 U	0.76 J	0.17 U	0.25 U	0.19 U	0.11 U	0.86 U	2.0 U	0.11 U	0.11 U
	11-Apr-05	0.45 U	120	4.5	0.89 U	0.57 U	0.18 U	0.90 U	0.75 U	0.36 U	0.49 U	0.37 U	0.56 U	4.3 U	2.3 U	0.41 U	0.67 U
PES-MW-10A	15-Apr-05	0.45 U	6.8	180	4.8	0.57 U	0.67 J	0.90 U	0.75 U	0.36 U	0.49 U	0.37 U	0.56 U	870	66	0.41 U	0.67 U
PES-MW-10B	14-Apr-05	3.5	48	3.7	0.89 U	0.57 U	0.18 U	0.90 U	0.83 J	0.36 U	0.49 U	0.37 U	0.56 U	4.3 U	2.4 J	0.41 U	0.67 U
PES-MW-11A	13-Apr-05	0.45 U	100	110	6.5	0.57 U	0.18 U	0.90 U	1.1	0.36 U	0.49 U	0.37 U	0.56 U	4.3 U	3.7 J	0.41 U	0.67 U
PES-MW-12A	12-Apr-05	0.45 U	80	20	3.0	0.57 U	0.18 U	0.90 U	0.75 U	0.36 U	0.49 U	1.3	0.56 U	11	24	0.41 U	0.79 J
PES-MW-12B	20-Apr-05	1.1 U	330	22	8.7	1.4 U	0.45 U	2.2 U	1.9 U	1.9 U	1.2 U	0.92 U	1.4 U	11 U	5.8 U	1.0 U	1.7 U
PES-MW-13A	22-Apr-05	0.45 U	380	8.1	6.2	0.57 U	0.18 U	0.90 U	1.2	0.36 U	0.49 U	0.37 U	0.56 U	4.3 U	2.3 U	0.41 U	0.67 U
PES-MW-14A	12-Apr-05	0.45 U	87	490	25	1.0	0.85 J	0.90 U	0.81 J	0.36 U	0.49 U	1.8	0.56 U	4.3 U	190	0.41 U	0.74 J
PES-MW-14B	20-Apr-05	0.45 U	110	1.3	5.6	0.57 U	0.18 U	0.90 U	1.4	0.36 U	0.49 U	0.38 J	0.56 U	4.3 U	3.1 J	0.41 U	0.67 U
INJECTION WELLS																	
PES-INJ-1	19-Nov-01	3.9 U	1,400	16	20	4.7 U	1.7 U	5.3 U	4.7 U	5.2 U	5.4 U	4.7 U	4.2 U	10 U	16 U	4.4 U	4.2 U
	18-Feb-02	3.9 U	70	15	3.8 U	4.7 U	1.7 U	5.3 U	4.7 U	5.2 U	5.4 U	4.7 U	4.2 U	340	16 U	4.4 U	4.2 U
	23-May-02	0.39 U	47	13	2.7	0.47 U	0.17 U	0.53 U	0.47 U	0.52 U	0.54 U	0.47 U	0.42 U	420	360	0.44 U	1.1
	29-Aug-02	0.39 U	29	9.6	2.3	0.47 U	0.17 U	0.53 U	0.47 U	0.52 U	0.54 U	0.47 U	0.42 U	370	270	0.44 U	0.42 U
	13-Dec-02	0.25 U	37 J	19	2.6	0.64	0.83	0.23 U	0.20 U	0.34 U	0.29 U	0.19 U	0.32 U	360	130	0.20 U	0.7 U
	10-Apr-03	0.24 U	66	16	2.0	0.22 U	0.63 J	0.23 U	0.22 U	0.17 U	0.25 U	0.19 U	0.32 U	320	66	0.11 U	0.11 U
	22-Aug-03	0.24 U	20	17	1.8	0.22 U	0.7 J	0.23 U	0.2 U	0.17 U	0.25 U	0.19 U	0.11 U	450	170	0.11 U	0.9 J
	19-Apr-05	1.80 U	10	11	3.6 U	2.30 U	0.72 U	3.60 U	3.0 U	1.40 U	2.00 U	1.50 U	2.20 U	1,900	640	1.60 U	2.7 U
PES-INJ-2	19-Nov-01	1.90 U	630	8.6	7.9	2.3 U	0.85 U	2.6 U	2.3 U	2.6 U	2.7 U	2.3 U	2.1 U	5.2 U	8.2 U	2.2 U	2.1 U
	15-Feb-02	3.9 U	45	9.90 U	3.8 U	4.7 U	1.7 U	5.3 U	4.7 U	5.2 U	5.4 U	4.7 U	4.2 U	390	16 U	4.4 U	4.2 U
Veg. Oil	12-Feb-02	1,100 U	6,200	680 U	850 U	800 U	1,000 U	480 U	620 U	800 U	610 U	670 U	660 U	940 U	650 U	590 U	2,000 J
	23-May-02	0.39 U	25	3.8	2.9	0.47 U	0.17 U	0.53 U	0.47 U	0.52 U	0.54 U	0.47 U	0.42 U	670	150	0.44 U	0.45
	29-Aug-02	0.39 U	16	3.4	2.4	0.47 U	0.17 U	0.53 U	0.47 U	0.52 U	0.54 U	0.47 U	0.42 U	590	160	0.44 U	0.42 U
	13-Dec-02	0.25 U	18 J	3.4	2.7	0.34 U	0.30 U	0.23 U	0.20 U	0.34 U	0.34 U	0.19 U	0.32 U	1,200	320	0.20 U	9.4
	11-Apr-03	0.24 U	16	3.1	2.2	0.22 U	0.17 U	0.23 U	0.20 U	0.17 U	0.25 U	0.19 U	0.32 U	870	92	0.11 U	3.8
	22-Aug-03	0.24 U	13	3.0	2.1	0.22 U	0.17 U	0.23 U	0.2 U	0.17 U	0.25 U	0.19 U	0.11 U	1,100	170	0.11 U	2.4
	19-Apr-05	0.45 U	14	2.9	1.9	0.57 U	0.18 U	0.90 U	0.75 U	0.36 U	0.49 U	0.37 U	0.56 U	820	150	0.41 U	1.1
PES-INJ-3	16-Nov-01	3.9 U	760	9.9 U	9.1	4.7 U	1.7 U	5.3 U	4.7 U	5.2 U	5.4 U	4.7 U	4.2 U	10 U	16 U	4.4 U	4.2 U
	18-Feb-02	3.9 U	29	9.9 U	3.8 U	4.7 U	1.7 U	5.3 U	4.7 U	5.2 U	5.4 U	4.7 U	4.2 U	490	240	4.4 U	4.2 U
Veg. Oil	12-Feb-02	1,100 U	7,800	680 U	850 U	800 U	1,000 U	480 U	620 U	720 U	610 U	670 U	660 U	940 U	650 U	590 U	770 U
	23-May-02	0.39 U	21	3.7	0.39 U	0.47 U	0.17 U	0.53 U	0.47 U	0.52 U	0.54 U	0.47 U	0.42 U	770	610	0.44 U	0.42 U
	29-Aug-02	3.90 U	10	9.9 U	3.8 U	4.7 U	1.7 U	5.3 U	4.7 U	5.2 U	5.4 U	4.7 U	4.2 U	440	710	4.4 U	4.2 U
Veg. Oil	29-Aug-02	570 U	4,900	550 U	560 U	620 U	940 U	520 U	530 U	610 U	610 U	540 U	470 U	3,300	2,800	470 U	640 U
	13-Dec-02	0.25 U	12 J	3.8	2.8	0.26 U	0.30 U	0.23 U	0.20 U	0.34 U	0.29 U	0.19 U	0.32 U	560	680	0.20 U	0.22 U
Veg. Oil	9-Dec-02	1,100 U	3,500	680 U	850 U	800 U	1,000 U	480 U	620 U	720 U	610 U	670 U	660 U	4,000	1,600 J	590 U	4,800
	11-Apr-03	0.24 U	9.8	3.1	2.2	0.22 U	0.17 U	0.23 U	0.20 U	0.17 U	0.25 U	0.19 U	0.32 U	900	400	0.11 U	0.11 U
	22-Aug-03	0.24 U	10	3.5	2.4	0.22 U	0.17 U	0.23 U	0.2 U	0.17 U	0.25 U	0.19 U	0.11 U	1,200	470	0.11 U	0.11 U
	19-Apr-05	0.45 U	8.7	3.3	1.9	0.57 U	0.18 U	0.90 U	0.75 U	0.36 U	0.49 U	0.37 U	0.56 U	960	480	0.41 U	0.67 U
PRE-INJECTION OIL SAMPLES																	
PES-INJ-2A-OIL	11-Dec-02	1,000 U	920 U	670 U	840 U	790 U	1,000 U	470 U	610 U	710 U	600 U	650 U	650 U	880 U	640 U	580 U	750 U
PES-INJ-2-OIL	11-Dec-02	1,000 U	950 U	670 U	840 U	790 U	1,000 U	470 U	610 U	710 U	600 U	650 U	650 U	900 U	640 U	580 U	750 U

[a] PCE = tetrachloroethene; TCE = trichloroethene; DCE = dichloroethene; TCA = trichloroethane; DCA = dichloroethane.

[b] µg/L = micrograms per liter.

[c] U = Analyte was not detected at a concentration above the method detection limit.

[d] J = Analyte was detected at a concentration above the method detection limit and below the reporting limit.

TABLE 11A
VOC CONCENTRATION CHANGES AT LOCATIONS OUTSIDE OF THE PILOT TEST AREA
NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
ANOKA COUNTY PARK
FRIDLEY, MINNESOTA

Well Location	TCE Concentration (µg/L)[a] November-01	TCE Concentration (µg/L)[a] September 04, April 05	Slope	Percent Reduction	1,2-DCE (cis+trans) Concentration (µg/L) November-01	1,2-DCE (cis+trans) Concentration (µg/L) September 04, April 05	Slope	Percent Reduction
17-S	29	3.1	-0.7	89%	8.2	0.3	-0.2	96%
18-S	1,000	400	-17	60%	330	123	-6.0	63%
19-S	91	120	0.8	-32%	8.9	8.5	0.0	4%
26-S	1,100	230	-25	79%	170	51	-3.4	70%
27-S	73	21	-1.5	71%	19	29	0.3	-53%
36-S	790	21	-22	97%	390	321	-2.0	18%
41-S	53	64	0.3	-21%	1.5	55	1.6	-3587%
43-S	170	190	0.6	-12%	1.6	39	1.1	-2338%
44-S	82	77	-0.1	6%	2.2	21	0.6	-868%
45-S	1,700	180	-44	89%	270	612	9.9	-127%
46-S	20,000	1,700	-529	92%	200	106	-2.7	47%
		Average	-58	47%		Average	-0.1	-6.

TABLE 11B
VOC CONCENTRATION CHANGES AT LOCATIONS INSIDE THE PILOT TEST AREA
NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
ANOKA COUNTY PARK
FRIDLEY, MINNESOTA

Well Location	TCE[a] Concentration (µg/L)[b] November-01	TCE[a] Concentration (µg/L)[b] April-05	Slope	Percent Reduction	1,2-DCE[a] (cis+trans) Concentration (µg/L) November-01	1,2-DCE[a] (cis+trans) Concentration (µg/L) April-05	Slope	Percent Reduction
PES-MW-1	1,100	380	-47	65%	29	226	13	-679%
PES-MW-2	2,100	930	-76	56%	49	63	0.9	-29%
PES-MW-3	5,000	830	-270	83%	183	221	2	-21%
PES-MW-4	3,300	820	-161	75%	203	286	5.4	-41%
PES-MW-5	75	38	-2	49%	31	10	-1.4	69%
PES-MW-6	6,200	700	-356	89%	228	197	-2.0	14%
PES-MW-7	300	4.1	-19	99%	6.0	135	8	-2158%
PES-MW-8	6,700	1,100	-362	84%	380	147	-15	61%
PES-MW-9	1,400	490	-59	65%	35	300	17	-757%
		Average	-152	74%		Average	3	-4

[a] TCE = trichloroethene; DCE = dichloroethene

[b] µg/L = micrograms per liter.

Note: Data presented on this table represents well locations installed in the shallow draft aquifer and in close proximity to the vegetable oil pilot test area that were not impacted by the vegetable oil pilot test.

TABLE 12
SUMMARY OF GROUNDWATER GEOCHEMICAL DATA
NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
ANOKA COUNTY PARK
FRIDLEY, MINNESOTA

Sample Location	Sample Date	Methane (µg/L)[a]	Ethane (µg/L)	Ethene (µg/L)	TOC[b] (mg/L)[d]	Dissolved Oxygen (mg/L)	Dissolved Hydrogen (nM)[e]	Nitrate (mg/L)	Nitrite (mg/L)	Ferrous Iron (mg/L)	Manganese (mg/L)	Sulfate (mg/L)	Sulfide (mg/L)	Ammonia (mg/L)	Total Alkalinity (mg/L)	Carbon Dioxide (mg/L)	Chloride (mg/L)	Redox Potential (mV)[e]	pH (SU)[e]	Temperature (°C)[e]	Specific Conductivity (µs/cm)[b]
MONITORING WELLS																					
18-S	4/18/2005	NM[b]	NM	NM	3.8	R[b]	NM	NM	NM	1.44	2.0	180	0.01	NM	NM	35	NM	-87	7.49	11.9	1,238
MS-26S	4/15/2005	NM	NM	NM	2.2	R	NM	NM	NM	0.19	0.9	160	0.06	NM	NM	25	NM	-96	7.52	12.8	1,309
MS-27S	12-Nov-01	46 J[c]	1.6 U	1.4 U	3.7	0.34	Na[f]	<0.2[b]	<0.2	0.05	0.1	19	<0.01	0.12	119	1.25	20	-123	9.81	12.5	1,136
	11-Feb-02	36	1.6 U	1.4 U	1.4	0.02	Na	<0.13	<0.077	0.22	<0.6	43	0.02	0.06	163	18	75	-371	8.06	11.4	575
	21-May-02	2.0 U	1.6 U	1.4 U	<1.7	0.33	3.3	<0.13	<0.077	0.90	<0.6	170	0.02	0.02	340	35	55	-315	7.00	10.8	1,068
	26-Aug-02	2.7 J	1.6 U	1.4 U	9.9	0.06	2.2	<0.13	<0.077	0.83	<0.6	170	<0.01	0.01	425	60	70	-85	6.36	12.8	1,052
	9-Dec-02	4.3	0.064	0.036	16	0.26	3.0	<0.057	<0.018	0.73	<0.6	170	<0.01	0.05	357	45	60	60	7.17	9.8	645
	7-Apr-03	2.6	0.022	0.023	2.8	0.23	5.2	<0.058	<0.018	0.82	<0.6	150	0.03	0.01	272	30	60	-77	7.24	10.4	1,011
	18-Aug-03	4.5	0.033	0.056	1.2 J	1.34	2.4	<0.058	<0.018	0.86	1.1	140	0.01	0.02	340	55	75	-47	NM	15.4	142
MS-36S	22-Apr-05	NM	NM	NM	3.4	R	NM	NM	NM	0.05	0.1	60	0.51	NM	NM	15	NM	-184	8.18	15.1	1,538
MS-44S	18-Apr-05	NM	NM	NM	0.4	R	NM	NM	NM	0.17	2.2	170	<0.01	NM	NM	25	NM	-50	7.07	11.5	1,380
GWMS-45S	18-Apr-05	20	0.095	0.071	7.0	R	NM	NM	NM	1.08	1.4	160	0.06	NM	NM	25	NM	-94	7.59	11.2	1,130
GWMS-46S	19-Nov-01	2.0 U	1.6 U	1.4 U	1.8	0.57	Na	<0.2	<0.2	2.2	1.9	210	0.01	0.07	391	50	15	-82	7.04	10.1	1,134
	18-Feb-02	2.0 U	1.6 U	1.4 U	3.6	0.96	Na	<0.13	<0.077	1.9	1.0	340	0.01	0.09	85	10	25	-276	6.95	10.7	1,048
	22-May-02	2.0 U	1.6 U	1.4 U	2.3	<0.01	1.1	<0.13	<0.077	1.4	1.4	180	<0.01	0.08	323	30	55	-276	7.30	13.1	1,132
	28-Aug-02	6.0	1.6 U	1.4 U	10	<0.01	2.0	<0.13	<0.077	1.2	1.3	170	0.01	0.06	340	40	50	-229	7.13	12.9	1,045
	11-Dec-02	2.0 U	0.014	0.069	18	0.12	1.2	<0.057	<0.018	1.7	1.1	210	<0.01	0.09	357	35	40	R	7.37	10.0	564
	9-Apr-03	4.2	0.007	0.030	1.0 J	1.52	1.6	<0.058	<0.018	1.7	1.8	190	0.01	0.09	323	35	45	-58	7.31	10.6	1,137
	20-Aug-03	18	0.010	0.046	<1.0	3.9	1.8	<0.058	<0.018	2.4	1.9	190	0.01	0.07	306	35	45	-95	7.18	16.3	1,094
	18-Apr-05	30	0.071	0.080	3.7	R	NM	NM	NM	1.1	2.0	210	<0.01	NM	NM	25	NM	-115	7.45	12.0	1,132
GWMS-47S	14-Nov-01	2.0 U	1.6 U	1.4 U	1.7	1.7	Na	1.3	<0.2	<0.01	1.8	70	0.13	<0.01	459	134	50	115	6.82	12.9	1,102
	12-Feb-02	2.0 U	1.6 U	1.4 U	1.6	8.8	Na	<0.13	<0.077	<0.01	<0.6	160	<0.01	<0.01	442	50	65	-14	7.21	10.7	1,092
	21-May-02	2.0 U	1.6 U	1.4 U	<1.1	6.1	2.6	0.59	<0.077	0.01	<0.6	140	<0.01	0.01	340	35	50	-31	7.10	12.0	1,078
	26-Aug-02	2.0 U	1.6 U	1.4 U	11	3.7	3.0	0.45	<0.077	0.04	<0.6	100	0.03	0.03	340	45	55	149	6.94	13.9	1,054
	10-Dec-02	2.0 U	0.007	0.013	38	2.4	3.1	2.5	<0.018	<0.01	<0.6	111	<0.01	<0.01	476	65	95	265	7.09	10.4	818
	8-Apr-03	0.32	0.005 U	0.010	1.1	1.0	1.8	1.1	<0.018	0.02	<0.6	170	<0.01	0.02	442	40	75	112	7.02	9.9	1,283
	19-Aug-03	0.46	0.006 U	0.001 U	1 J	2.3	3.2	1.1	<0.018	0.00	0.6	100	<0.01	<0.01	408	65	95	208	6.88	20.9	1,227
	11-Apr-05	NM	NM	NM	3.8	R	NM	NM	NM	0.04	<0.6	170	0.01	NM	NM	65	NM	16	7.11	11.6	1,405
MS-53PC	11-Apr-05	NM	NM	NM	110	NA	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NA	NA	NA	NA
PES-MW-1	16-Nov-01	2.0 U	1.6 U	1.4 U	1.0	1.3	Na	<0.2	<0.2	0.02	0.6	100	<0.01	0.03	255	15	55	-50	8.29	11.0	873
	15-Feb-02	2.0 U	1.6 U	1.4 U	30	1.1	Na	<0.13	<0.077	0.91	1.2	290	0.18	0.04	408	40	50	-324	7.25	10.5	1,032
	22-May-02	2.9	1.6 U	1.4 U	3	<0.01	2.3	<0.13	<0.077	0.37	0.6	200	0.02	0.05	374	40	45	-245	7.40	11.9	1,217
	28-Aug-02	170	1.6 U	1.4 U	14	<0.01	2.1	<0.13	<0.077	1.3	1.1	140	0.18	0.06	357	50	55	-299	7.06	12.8	1,084
	12-Dec-02	380	0.014	0.079	12	R	3.9	<0.057	<0.018	1.2	0.6	200	0.16	0.05	425	45	45	R	7.42	10.6	R
	10-Apr-03	2,000	0.002 J	0.050	< 1.0	1.23	1.7	<0.058	<0.018	3.0	1.6	180	<0.01	0.07	374	45	50	-241	7.30	11.7	1,154
	21-Aug-03	0.16	0.004 J	0.013	1.4 J	0.49	1.5	<0.058	<0.018	2.4	1.9	160	0.52	0.05	374	45	50	-164	7.28	14.3	1,098
	15-Apr-05	4,600	0.095	0.120	3.0	R	NM	NM	NM	3.1	7.6	220	0.09	NM	NM	35	NM	-132	7.23	11.6	1,158
PES-MW-2	15-Nov-01	2.0 U	1.6 U	1.4 U	1.7	0.39	Na	0.2	<0.2	0.17	<0.6	190	<0.01	0.09	1,700	50	60	-185	11.66	11.5	1,181
	14-Feb-02	2.0 U	1.6 U	1.4 U	3.2	0.74	Na	<0.13	<0.077	0.04	<0.6	340	<0.01	0.05	340	25	50	-188	7.82	10.3	1,005
	22-May-02	2.0 U	1.6 U	1.4 U	2.5	0.07	1.8	<0.13	<0.077	0.03	<0.6	230	0.02	0.06	323	30	45	-160	7.40	13.8	1,139
	28-Aug-02	2.5 J	1.6 U	1.4 U	12	0.19	2.9	<0.13	<0.077	0.11	1.2	220	0.08	0.06	340	45	45	-176	6.98	12.7	1,091
	11-Dec-02	150	0.008	0.054	6.5	0.03	1.4	<0.057	<0.018	0.02	0.6	200	0.01	0.07	374	30	40	R	7.45	10.3	589
	9-Apr-03	1,700	0.001 U	0.025	< 1.0	1.60	1.3	<0.058	<0.018	0.04	1.5	230	0.01	0.07	347	30	45	-26	7.37	10.8	1,180
	20-Aug-03	0.3	0.007	0.023	1.0 J	0.48	1.8	<0.058	<0.018	0.02	1.5	210	<0.01	0.03	340	30	55	-1	7.27	15.6	1,095
	14-Apr-05	11	0.022	0.070	1.9	R	NM	NM	NM	0.03	1.1	200	0.01	NM	NM	35	NM	-57	7.29	11.5	1,071
PES-MW-3	14-Nov-01	2.0 U	1.6 U	1.4 U	1.6	0.35	Na	<0.2	<0.2	0.48	0.9	150	<0.01	0.02	340	40	45	-76	7.05	12.1	1,078
	13-Feb-02	2.0 U	1.6 U	1.4 U	0.2	0.46	Na	<0.13	<0.077	1.3	1.4	200	<0.01	0.05	391	40	45	-288	7.09	10.3	1,092
	21-May-02	2.0 U	1.6 U	1.4 U	2.9	0.12	1.4	<0.13	<0.077	1.8	0.8	200	0.03	0.06	391	45	55	-311	7.30	12.8	1,151
	27-Aug-02	4.4	1.6 U	1.4 U	13	<0.01	2.0	<0.13	<0.077	2.1	1.5	150	0.04	0.08	374	65	55	-136	6.81	12.5	1,106
	10-Dec-02	210	0.020	0.081	24	R	1.5	<0.057	<0.018	2.1	0.8	220	0.14	0.09	425	35	50	-60	7.35	10.6	727
	8-Apr-03	1,700	0.005 U	0.007	2.0 J	4.91	1.9	<0.058	<0.018	2.7	0.8	190	0.04	0.09	408	35	55	-100	7.29	10.8	1,178
	20-Aug-03	1.3	0.012	0.026	2.6 J	1.2	3.4	<0.058	<0.018	2.0	1.9	200	0.12	0.04	357	50	55	-93	7.07	17.8	1,134
	14-Apr-05	88	0.038	0.065	1.6	R	NM	NM	NM	2.4	1.4	180	0.02	NM	NM	40	NM	-86	7.09	11.4	1,106
PES-MW-4	14-Nov-01	2.0 U	1.6 U	1.4 U	Na	1.3	Na	<0.2	<0.2	<0.01	0.9	230	<0.01	0.02	374	55	70	-48	7.12	12.1	1,115
	12-Feb-02	2.0 U	1.6 U	1.4 U	1.3	3.0	Na	<0.13	<0.077	0.11	0.7	120	<0.01	0.03	408	35	65	-133	7.38	9.0	1,045
	21-May-02	2.0 U	1.6 U	1.4 U	2.0	1.2	2.9	0.18	<0.077	0.13	<0.6	180	<0.01	0.03	357	40	65	-129	7.10	13.1	1,123
	27-Aug-02	2.0 U	1.3 U	1.4 U	10	0.12	3.8	<0.13	<0.077	0.04	<0.6	200	0.08	0.05	340	60	70	6	6.62	12.2	1,083

TABLE 12
SUMMARY OF GROUNDWATER GEOCHEMICAL DATA
NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
ANOKA COUNTY PARK
FRIDLEY, MINNESOTA

Sample Location	Sample Date	Methane (µg/L)	Ethane (µg/L)	Ethene (µg/L)	TOC (mg/L)	Dissolved Oxygen (mg/L)	Dissolved Hydrogen (nM)	Nitrate (mg/L)	Nitrite (mg/L)	Ferrous Iron (mg/L)	Manganese (mg/L)	Sulfate (mg/L)	Sulfide (mg/L)	Ammonia (mg/L)	Total Alkalinity (mg/L)	Carbon Dioxide (mg/L)	Chloride (mg/L)	Redox Potential (mV)	pH (SU)	Temperature (°C)	Specific Conductivity (µs/cm)
	10-Dec-02	2.0 U	0.018	0.068	15	R	1.6	0.56	<0.018	0.31	<0.6	180	<0.01	0.07	408	35	65	20	7.30	10.7	740
	8-Apr-03	0.42	0.008	0.025	1.7 J	3.16	1.6	<0.058	<0.018	0.39	0.6	190	<0.01	0.05	340	30	60	4	7.28	10.6	1,133
	19-Aug-03	2.6	0.019	0.082	1.2 J	0.87	1.4	<0.058	<0.018	0.26	1.9	90	0.01	0.11	340	35	60	-47	7.07	20.5	1,087
	12-Apr-05	5.8	0.056	0.085	51	R	NM	NM	NM	0.46	1.4	180	0.20	NM	NM	50	NM	15	7.20	10.2	941
PES-MW-5	14-Nov-01	2.0 U	1.6 U	1.4 U	1.6	1.4	Na	0.58	<0.2	0.02	<0.6	120	<0.01	<0.01	422	85	105	104	6.80	11.7	1,279
	12-Feb-02	2.0 U	1.6 U	1.4 U	1.7	3.8	Na	<0.13	<0.077	0.04	<0.6	90	0.02	0.01	561	70	120	-64	7.04	10.1	1,241
	21-May-02	2.0 U	1.6 U	1.4 U	1.8	0.7	2.3	0.28	<0.077	0.01	<0.6	130	<0.01	<0.01	459	70	100	-65	6.90	13.1	1,266
	27-Aug-02	2.0 U	1.6 U	1.4 U	12	5.5	2.1	0.26	<0.077	<0.01	<0.6	120	<0.01	<0.01	202	50	80	197	6.17	11.9	1,011
	10-Dec-02	2.0 U	0.008	0.009	23	2.5	1.4	<0.057	<0.018	0.02	<0.6	111	<0.01	0.02	442	60	95	240	7.08	10.5	828
	8-Apr-03	0.04	0.005 U	0.009	< 1.0	3.3	1.9	0.87	< 0.018	0.06	<0.6	150	<0.01	<0.01	408	60	105	131	7.08	10.6	1,367
	19-Aug-03	0.1	0.015	0.026	<1.0	1.4	2.2	<0.058	<0.018	0.02	0.7	180	<0.01	0.01	306	40	85	218	7.10	21.9	1,081
	12-Apr-05	4.5	0.050	0.062	6.9	R	NM	NM	NM	0.02	<0.6	170	0.01	NM	NM	35	NM	13	6.99	9.4	1,403
PES-MW-6	15-Nov-01	2.0 U	1.6 U	1.4 U	1.4	0.22	Na	<0.2	<0.2	0.01	<0.6	160	0.20	0.04	306	40	55	-158	7.79	11.5	1,030
	15-Feb-02	2.0 U	1.6 U	1.4 U	12	0.35	Na	<0.13	<0.077	0.47	1.1	290	1.2	0.04	408	50	55	-408	7.29	11.0	1,107
	23-May-02	2.0 U	1.6 U	1.4 U	<0.83	0.03	1.9	<0.13	<0.077	0.28	<0.6	190	1.8	0.07	391	30	45	-160	7.30	11.1	1,256
	28-Aug-02	3.8	1.6 U	1.4 U	7	<0.01	2.6	<0.13	<0.077	0.52	1.0	170	0.80	0.07	357	70	55	-296	7.09	12.7	1,109
	12-Dec-02	70	0.019	0.082	16	0.90	3.5	<0.057	<0.018	0.55	<0.6	220	0.59	0.08	391	35	50	R	7.31	10.5	R
	10-Apr-03	12	0.012	0.051	<1.0	0.88	2.9	<0.058	<0.018	0.51	1.1	180	0.61	0.09	340	25	50	-292	7.30	11.0	1,163
	21-Aug-03	8.0	0.010	0.066	1.7 J	3.6	1.9	<0.058	<0.018	0.56	2.2	200	0.31	0.06	306	40	60	-98	7.19	14.3	1,075
	15-Apr-05	210	0.051	0.110	2.6	R	NM	NM	NM	0.38	1.5	200	0.02	NM	NM	30	NM	-89	7.37	12.3	1,104
PES-MW-7	16-Nov-01	2.0 U	1.6 U	1.4 U	1.4	2.3	Na	<0.2	<0.2	<0.01	<0.6	110	<0.01	0.03	238	50	60	-26	8.96	11.6	854
	14-Feb-02	2.0 U	1.6 U	1.4 U	26,000	0.50	Na	<0.13	<0.077	1.9	3.0	160	0.51	0.04	765	85	55	-314	6.93	10.9	1,552
	22-May-02	3.4	1.6 U	1.4 U	150	0.01	5.8	<0.65	2.2	7.8	18	80	0.35	0.23	663	200	60	-188	6.70	12.3	1,531
	28-Aug-02	7,400	1.6 U	1.4 U	150	0.06	3.2	<0.13	1.0	3.9	9.8	60	1.5	2.5	561	180	60	-395	6.58	12.5	1,351
	12-Dec-02	18,000	0.005 U	0.95	200	0.78	4.3	<0.057	0.69	6.3	29	100	0.36	0.70	629	190	60	R	6.74	10.6	R
	10-Apr-03	9,800	0.170	0.076	210	R	3.1	<0.058	<0.018	3.2	28	<7.0	0.25	0.50	629	200	60	-173	6.60	11.9	1,523
	21-Aug-03	8,500	0.006 U	0.001 U	53	0.29	2.5	<0.058	<0.018	4.7	33	<7.0	2.50	1.15	544	165	60	-161	6.71	13.0	1,285
	15-Apr-05	16,000	0.100	0.092	29	R	NM	NM	NM	5.2	33	140	0.07	NM	NM	70	NM	-110	6.80	11.4	1,123
PES-MW-8	15-Nov-01	2.0 U	1.6 U	1.4 U	2.4	0.43	Na	<0.2	<0.2	0.70	0.9	110	<0.01	0.04	408	55	65	-54	7.02	11.6	1,120
	14-Feb-02	2.0 U	1.6 U	1.4 U	6.8	0.55	Na	<0.13	<0.077	1.3	0.8	310	<0.01	0.05	442	40	50	-200	7.29	9.8	1,129
	22-May-02	2.0 U	1.6 U	1.4 U	1.9	0.07	1.2	<0.13	<0.077	1.1	0.7	220	<0.01	<0.01	408	40	60	-85	7.20	12.1	1,318
	28-Aug-02	2.6 J	1.6 U	1.4 U	14	<0.01	2.1	<0.13	<0.077	1.2	1.3	220	0.01	0.04	374	75	60	-69	6.83	12.7	1,160
	12-Dec-02	35	0.016	0.062	4.6	0.12	1.2	<0.057	<0.018	1.2	1.0	180	0.05	0.06	357	35	50	-80	7.15	10.2	R
	9-Apr-03	3.7	0.002 J	0.011	<1.0	2.55	1.7	<0.058	<0.018	1.2	1.4	160	<0.01	0.04	374	30	55	-128	7.25	11.2	1,201
	21-Aug-03	12	0.015	0.066	3.7	0.29	1.6	<0.058	<0.018	1.1	2.3	150	0.01	0.04	306	50	70	-82	7.08	13.3	1,087
	14-Apr-05	11	0.035	0.049	1.7	R	NM	NM	NM	1.0	1.5	180	0.03	NM	NM	50	NM	-87	7.22	11.9	1,097
PES-MW-9	15-Nov-01	2.0 U	1.6 U	1.4 U	1.4	1.1	Na	<0.2	<0.2	0.40	1.1	140	0.01	0.03	391	45	60	-123	7.09	10.9	1,051
	13-Feb-02	2.0 U	1.6 U	1.4 U	1.8	0.79	Na	<0.13	<0.077	0.55	0.9	220	0.01	0.05	340	25	50	-183	7.30	10.7	1,018
	22-May-02	2.0 U	1.6 U	1.4 U	58	0.15	1.5	<0.65	<0.39	4.7	2.1	30	0.04	<0.01	510	80	50	-460	7.10	11.2	1,346
	27-Aug-02	28	5.4 J	13	180	<0.01	8.2	<0.13	0.66	3.3	8.5	7.0	0.22	0.60	646	250	80	-180	6.58	12.5	1,445
	11-Dec-02	3,200	0.012	0.210	240	0.15	3.3	<0.057	0.37	NA	13	<7.0	0.06	1.1	646	600	60	R	7.03	10.4	1,650
	9-Apr-03	5,500	0.001 U	0.035	2.6	1.88	1.8	<0.058	<0.018	4.1	10	110	0.12	0.68	347	65	45	-192	7.52	11.1	1,182
	21-Aug-03	5,000	0.006 U	0.001 U	1.5 J	0.42	1.9	<0.058	<0.018	4.7	2.7	135	0.10	0.25	340	55	60	-180	7.30	15.9	1,141
	16-Apr-05	300	0.012	0.030	3.6	R	NM	NM	NM	2.5	1.6	190	0.02	NM	NM	35	NM	-93	7.41	10.7	991
PES-CW-1	13-Nov-01	2.0 U	1.6 U	1.4 U	1.0	0.25	Na	<0.2	<0.2	0.04	0.6	80	<0.01	<0.01	333	60	60	-25	7.08	11.9	1,064
	11-Feb-02	2.0 U	1.6 U	1.4 U	1.3	0.92	Na	0.49	<0.077	0.05	<0.6	130	<0.01	0.03	387	116	65	-195	7.23	11.3	1,079
	20-May-02	2.0 U	1.6 U	1.4 U	<1.3	2.3	2.3	0.20	<0.077	0.01	<0.6	160	<0.01	0.01	347	60	65	-28	7.04	11.2	1,079
	26-Aug-02	2.0 U	1.6 U	1.4 U	11	1.8	3.3	0.19	<0.077	0.04	<0.6	110	<0.01	0.04	408	70	110	45	6.47	13.1	1,258
	9-Dec-02	2.6 J	0.017	0.014	1.6	0.25	2.5	<0.057	<0.018	0.03	<0.6	120	<0.01	0.04	391	35	60	120	7.27	10.4	770
	7-Apr-03	0.23	0.005 U	0.013	< 1.0	0.65	3.1	0.73	<0.018	<0.01	<0.6	140	<0.01	0.02	408	50	125	72	6.89	10.4	1,354
	18-Aug-03	0.16	0.004 J	0.013	1.6 J	0.71	1.5	0.65	<0.018	0.03	2.0	160	<0.01	0.02	357	70	130	103	7.00	15.7	215
PES-CW-2	13-Nov-01	2.0 U	1.6 U	1.4 U	0.97	0.28	Na	<0.2	<0.2	0.30	1.1	50	<0.01	0.05	323	74	65	-32	7.05	12.0	1,064
	11-Feb-02	2.0 U	1.6 U	1.4 U	0.97	2.3	Na	<0.13	<0.077	<0.01	<0.6	190	<0.01	0.01	340	45	55	-78	7.21	10.6	1,011
	20-May-02	2.0 U	1.6 U	1.4 U	<1.0	1.1	2.9	<0.13	<0.077	0.06	<0.6	140	<0.01	0.06	357	45	60	-44	7.10	11.9	1,020
	26-Aug-02	2.0 U	1.6 U	1.4 U	12	1.1	3.3	0.15	<0.077	0.02	<0.6	130	0.01	<0.01	357	55	80	82	6.59	13.2	1,134
	9-Dec-02	4.0	0.017	0.006	5.4	0.33	1.8	<0.057	<0.018	0.01	<0.6	170	<0.01	0.09	357	30	55	210	7.35	10.6	819
	7-Apr-03	0.12	0.005 U	0.011	< 1.0	0.85	3.8	0.84	<0.018	<0.01	0.6	140	<0.01	0.02	425	45	100	128	6.94	10.6	1,292
	19-Aug-03	0.3	0.007	0.023	1.7 J	1.79	1.8	1.10	<0.018	0.02	0.4	120	<0.01	0.01	391	50	125	87	6.50	15.8	140
	11-Apr-05	NM	NM	NM	3.6	R	NM	NM	NM	0.03	0.3	160	<0.01	NM	NM	60	NM	-3	7.14	11.9	1,164

TABLE 12
SUMMARY OF GROUNDWATER GEOCHEMICAL DATA
NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
ANOKA COUNTY PARK
FRIDLEY, MINNESOTA

Sample Location	Sample Date	Methane (µg/L)[a]	Ethane (µg/L)	Ethene (µg/L)	TOC[b] (mg/L)[c]	Dissolved Oxygen (mg/L)	Dissolved Hydrogen (nM)[d]	Nitrate (mg/L)	Nitrite (mg/L)	Ferrous Iron (mg/L)	Manganese (mg/L)	Sulfate (mg/L)	Sulfide (mg/L)	Ammonia (mg/L)	Total Alkalinity (mg/L)	Carbon Dioxide (mg/L)	Chloride (mg/L)	Redox Potential (mV)[e]	pH (SU)[f]	Temperature (°C)[g]	Specific Conductivity (µs/cm)[h]
PES-CW-3	13-Nov-01	2.0 U	1.6 U	1.4 U	0.75	0.60	Na	<0.2	<0.2	0.02	1.0	110	<0.01	0.04	357	70	63	32	7.07	12.8	1,014
	12-Feb-02	2.0 U	1.6 U	1.4 U	2.1	1.0	Na	<0.13	<0.077	<0.01	<0.6	150	<0.01	0.03	323	25	50	71	7.03	10.4	988
	20-May-02	2.0 U	1.6 U	1.4 U	<1.6	1.5	2.6	<0.13	<0.077	0.04	<0.6	130	<0.01	0.03	340	40	60	-60	7.10	14.0	920
	26-Aug-02	2.8	1.6 U	1.4 U	11	1.3	6.7	<0.13	<0.077	0.04	<0.6	150	0.01	0.08	238	35	50	81	6.74	13.4	962
	10-Dec-02	2.0 U	0.016	0.013	14	0.20	2.6	<0.057	<0.018	0.02	<0.6	140	<0.01	0.05	306	30	55	200	7.02	10.2	458
	7-Apr-03	1.2	0.007	0.011	< 1.0	0.80	3.0	<0.058	<0.018	0.03	<0.6	180	<0.01	0.01	289	30	55	103	7.29	7.4	1,056
	19-Aug-03	1.3	0.012	0.026	<1.0	0.98	3.4	0.360	<0.018	0.01	1.0	140	<0.01	<0.01	340	50	80	215	6.92	20.0	1,142
	11-Apr-05	NM	NM	NM	3.7	R	NM	NM	NM	0.03	0.4	170	<0.01	NM	NM	45	NM	29	7.50	11.5	1,153
PES-MW-10A	15-Apr-05	21,000	0.360	0.110	190	R	NM	NM	NM	5.1	17	87	0.10	NM	NM	120	NM	-111	6.61	11.4	1,365
PES-MW-10B	14-Apr-05	4.5	0.034	0.045	3.3	R	NM	NM	NM	0.04	0.8	180	0.04	NM	NM	40	NM	-52	7.15	13.0	1,064
PES-MW-11A	13-Apr-05	3,900	0.090	0.066	8.9	R	NM	NM	NM	3.1	2.4	150	0.01	NM	NM	35	NM	-21	6.91	10.8	1,047
PES-MW-12A	12-Apr-05	2.1	0.042	0.080	6.0	R	NM	NM	NM	0.08	<0.6	150	0.03	NM	NM	35	NM	60	7.31	11.7	1,291
PES-MW-12B	20-Apr-05	7.8	0.140	0.180	5.5	R	NM	NM	NM	0.03	1.6	150	0.01	NM	NM	25	NM	18	7.08	10.6	1,348
PES-MW-13A	22-Apr-05	4.8	0.032	0.042	5.1	R	NM	NM	NM	0.19	1.3	190	0.01	NM	NM	25	NM	-34	7.57	13.5	1,102
PES-MW-14A	12-Apr-05	6,900	0.150	0.180	50	R	NM	NM	NM	3.19	2.3	130	0.12	NM	NM	65	NM	-44	6.88	12.0	901
PES-MW-14B	20-Apr-05	7.7	0.120	0.140	4.2J	R	NM	NM	NM	0.01	0.7	220	0.01	NM	NM	20	NM	57	7.28	12.1	1,082
INJECTION WELLS																					
PES-INJ-1	19-Nov-01	2.0 U	1.6 U	1.4 U	1.1	0.14	Na	<0.2	<0.2	0.01	0.6	140	<0.01	0.03	323	25	55	-1	7.62	10.7	1,015
	18-Feb-02	200 U	160 U	140 U	11,000	0.15	Na	19	<13	NA	NA	NA	36	6.3	8,500	8,500	85	-325	5.67	10.9	4,660
	23-May-02	140 U	280 U	250 U	2,500	0.10	4.4	0.9	9.7	280	3.3	<7.0	1.0	0.6	21,250	5,500	2,500	-89	5.50	11.3	1,702
	29-Aug-02	190	70	41	2,900	<0.01	16	<2.6	21	17	6.6	<7.0	0.11	0.1	2,975	2,500	125	-98	5.23	12.0	4,520
	13-Dec-02	630	35	24	2,600	R	5.2	<2.5	7.9	13	6.9	<7.0	0.14	1.3	4,675	2,800	125	-40	5.25	8.2	R
	10-Apr-03	73	3.1	7.6	2,300	1.58	4.4	<0.58	13	3.9	16	<7.0	0.04	0.7	4,250	2,500	250	-91	5.24	12.6	3,310
	22-Aug-03	660	21	25	2,100	0.65	32	<0.58	9.8 J	4.8	9.3	<7.0	0.03	0.5	2,040	2,000	100	-33	5.21	12.1	2,950
	19-Apr-05	14,000	6.3	4.6	2,500	R	NM	NM	NM	3.6	14	<7.0	6.9	NM	NM	2,500	NM	0 R	5.60	11.6	3,081
PES-INJ-2	19-Nov-01	2.0 U	1.6 U	1.4 U	0.8	<0.01	Na	<0.2	<0.2	0.01	<0.6	130	<0.01	0.04	289	25	55	74	7.77	10.5	971
	15-Feb-02	50 U	40 U	35 U	9,500	0.01	Na	34	110	NA	NA	NA	9	7.0	8,500	3,000	2,500	-323	5.44	10.6	4,200
	23-May-02	28 U	56 U	50 U	4,100	0.05	93	2.7	19	2.6	14	<7.0	1.9	3.1	29,750	7,500	2,500	-93	5.10	12.3	1,872
	29-Aug-02	13	5	2.8	4,130	<0.01	4.9	<2.6	28	NA	17	23	2.9	0.72	2,550	2,250	100	-55	5.10	12.4	4,870
	13-Dec-02	11	0.34	1.4	4,400	R	12	20	13	NA	5.4	61	0.8	0.68	4,250	2,900	100	-30	5.10	10.5	R
	11-Apr-03	99	0.35	1.4	2,300	0.63	39	<0.58	11 J	NA	78	<7.0	0.8	0.40	5,100	2,750	100	-33	5.09	11.1	3,160
	22-Aug-03	1,500	1.1	4.5	2,000	1.05	300	<0.58	6.7 J	2.4	69	<7.0	0.3	0.56	1,700	1,300	150	1	5.11	12.8	2,650
	19-Apr-05	5,800	1.1	3.8	2,400	R	NM	NM	NM	1.6	50	5	12	NM	NM	3,500	NM	5 R	5.35	11.0	2,434
PES-INJ-3	16-Nov-01	2.0 U	1.6 U	1.4 U	1.0	0.92	Na	<0.2	<0.2	0.01	0.6	110	<0.01	0.06	255	10	60	-79	8.47	12.1	881
	18-Feb-02	200 U	160 U	140 U	6,900	0.67	Na	15	<7.7	NA	NA	NA	23	3.3	11,900	4,500	60	-317	5.65	10.8	6,310
	23-May-02	140 U	280 U	250 U	4,100	0.12	30	1.9	23	NA	NA	66	1.8	2.2	25,500	7,500	2,500	-76	5.30	12.9	1,843
	29-Aug-02	7.5	5.6 J	1.4 U	3,650	<0.01	15	<2.6	32	5.6	31	<7.0	1.6	1.5	2,975	2,875	100	-98	5.23	12.0	4,520
	13-Dec-02	3.3	0.630	1.2	4,900	0.47	57	<2.5	13	NA	30	<7.0	2.8	2.0	5,525	3,875	100	-35	5.26	10.3	R
	11-Apr-03	58	0.35	1.4	4,600	0.04	39	<0.58	17 J	NA	20	<7.0	4.6	2.7	5,950	5,000	100	-88	5.14	11.3	4,010
	22-Aug-03	290	1.4	3.7	2,600	2.34	150	<0.58	15 J	5.7	22	<7.0	0.2	0.7	2,380	2,100	100	-54	5.19	15.0	3,710
	19-Apr-05	2,800	3.6	3.4	4,700	R	NM	NM	NM	4.5	74	<7.0	14	NM	NM	2,000	NM	9 R	5.33	11.6	3,328

[a] µg/L = micrograms per liter.
[b] TOC = total organic carbon.
[c] mg/L = milligrams per liter.
[d] nM = nano-Mol
[e] mV = millivolts.
[f] SU = pH standard units.
[g] °C = degrees Centigrade.
[h] µs/cm = microsiemens per centimeter.
[i] J indicates that the analyte was detected at a concentration above the method detection limit but below the reporting limit resulting in an estimated value.
[j] NM = Not measured.
[k] <20 indicates that the analyte was not detected above the referenced method detection limit.
[l] R = This data point is of suspect quality or was collected in the incorrect units (as percent saturation instead of mg/L). Therefore it is rejected and was not considered during data interpretation.

TABLE 13
BIOMASS AND VOLATILE FATTY ACIDS IN GROUNDWATER
NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
ANOKA COUNTY PARK
FRIDLEY, MINNESOTA

Sample Location	Distance Downgradient From Injection Wells (feet)	Sample Date	Total Organic Carbon (mg/L)[a/]	Bacterial Biomass (pmol/mL)[b/]	Starvation Ratio (unitless)	Total Volatile Fatty Acids (mg/L)	Metabolic Acids					
							Pyruvic (mg/L)	Lactic (mg/L)	Formic (mg/L)	Acetic (mg/L)	Proprionic (mg/L)	Butyric (mg/L)
MONITORING WELLS												
18S		4/18/2005	3.8		0.00	< 4	< 4	< 1	< 1	< 1	< 1	< 1
26-S		4/15/2005			0.09							
GWMS-27S	220	21-May-02	<1.7 [c/]	NM [d/]	NM	< 4 [b/]	< 80	< 1	< 1	< 1	< 1	< 1
		26-Aug-02	9.9	NM	NM	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		9-Dec-02	16	NM	NM	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		7-Apr-03	2.8	NM	NM	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		18-Aug-03	1.2 J	NM	NM	< 4	< 4	< 1	< 1	< 1	< 1	< 1
GWMS-46S [e/]	-22	22-May-02	2.3	NM	NM	5.6	< 40	< 1	4.0	1.6	< 1	< 1
		28-Aug-02	10	NM	NM	6.2	< 4	0.8 J [f/]	1.9	2.6	0.9 J	< 1
		11-Dec-02	18	13.4	0.56	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		8-Apr-03	1.0 J	3	0.12	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		20-Aug-03	1.0 UJ	11	0.32	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		18-Apr-05	4		1.22	< 4	< 4	< 1	< 1	< 1	< 1	< 1
GWMS-47S	224	21-May-02	<1.1	NM	NM	< 4	< 80	< 1	< 1	< 1	< 1	< 1
		26-Aug-02	11	NM	NM	3.8	< 4	< 1	1.8	2.0	< 1	< 1
		10-Dec-02	38	NM	NM	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		8-Apr-03	1.1	NM	NM	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		19-Aug-03	1.0 J	NM	NM	< 4	< 4	< 1	< 1	< 1	< 1	< 1
PES-MW-1	16	22-May-02	3.0	NM	NM	6.5	< 40	< 1	3.7	1.8	0.97	< 1
		28-Aug-02	14	NM	NM	10.4	< 4	< 1	1.7	6.8	1.9	< 1
		12-Dec-02	12	31.3	1.13	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		10-Apr-03	<1.0	54	0.07	3.0	< 4	1.0	< 1	1.0	1.0	< 1
		21-Aug-03	1.4 J	14	0.25	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		15-Apr-05	3		0.26	< 4	< 4	< 1	< 1	< 1	< 1	< 1
PES-MW-2	28	22-May-02	2.5	NM	NM	8.0	< 40	< 1	3.9	1.9	2.2	< 1
		28-Aug-02	12	NM	NM	3.6	< 4	< 1	1.7	1.9	< 1	< 1
		9-Dec-02	6.5	0.2	1.54	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		9-Apr-03	<1.0	7	0.11	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		20-Aug-03	1 J	19	0.07	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		14-Apr-05	1.9		0.16	< 4	< 4	< 1	< 1	< 1	< 1	< 1
PES-MW-3	48	21-May-02	2.9	NM	NM	8.1	< 40	< 1	4.0	2.4	1.7	< 1
		27-Aug-02	13	NM	NM	6.7	< 4	< 1	1.7	3.8	1.2	< 1
		10-Dec-02	24	0.0	0.00	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		8-Apr-03	2.0 J	194	0.92	3.6	< 4	< 1	< 1	1.9	1.7	< 1
		20-Aug-03	2.6 J	44	0.27	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		14-Apr-05	2		0.76	< 4	< 4	< 1	< 1	< 1	< 1	< 1
PES-MW-4	76	21-May-02	2.0	NM	NM	1.5	< 80	< 1	1.5	< 1	< 1	< 1
		27-Aug-02	10	NM	NM	3.7	< 4	< 1	1.8	1.9	< 1	< 1
		10-Dec-02	15	1.0	0.09	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		8-Apr-03	1.7 J	6.0	0.36	2.0	< 4	< 1	< 1	1.0	1.0	< 1
		19-Aug-03	1.2 J	119	0.62	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		12-Apr-05	51			< 4	< 4	< 1	< 1	< 1	< 1	< 1

TABLE 13
BIOMASS AND VOLATILE FATTY ACIDS IN GROUNDWATER
NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
ANOKA COUNTY PARK
FRIDLEY, MINNESOTA

Sample Location	Distance Downgradient From Injection Wells (feet)	Sample Date	Total Organic Carbon (mg/L)[a]	Bacterial Biomass (pmol/mL)[b]	Starvation Ratio (unitless)	Total Volatile Fatty Acids (mg/L)	Metabolic Acids					
							Pyruvic (mg/L)	Lactic (mg/L)	Formic (mg/L)	Acetic (mg/L)	Proprionic (mg/L)	Butyric (mg/L)
PES-MW-5	142	21-May-02	1.8	NM	NM	1.4	< 80	< 0	1.4	< 1	< 1	< 1
		27-Aug-02	12	NM	NM	4.3	< 4	< 0.9	1.8	2.5	< 1	< 1
		10-Dec-02	23	NM	NM	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		8-Apr-03	<1.0	NM	NM	2.0	< 4	< 1	< 1	1.0	1.0	< 1
		19-Aug-03	<1.0	NM	NM	< 4	< 4	< 1	< 1	< 1	< 1	< 1
PES-MW-6	16	23-May-02	<0.83	NM	NM	19.1	< 40	< 1	4.1	12.3	2.7	< 1
		28-Aug-02	7	NM	NM	6.3	< 4	< 1	2.1	4.2	< 1	< 1
		12-Dec-02	16	NM	NM	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		10-Apr-03	<1.0	57	0.07	8.0	4.0	1.0	< 1	1.0	1.0	1.0
		21-Aug-03	1.7 J	18	0.02	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		15-Apr-05	3		0.07	< 4	< 4	< 1	< 1	< 1	< 1	< 1
PES-MW-7	16	22-May-02	150	NM	NM	347	< 20	< 1	3.9	133	182	28
		28-Aug-02	150	NM	NM	212	< 4	< 1	1.9	57.8	122	30
		12-Dec-02	200	NM	NM	149	< 4	< 1	< 1	28.3	98	23
		10-Apr-03	210	87	0.50	202.2	< 4	< 1	< 1	43.4	153.5	5.3
		21-Aug-03	53	558	0.21	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		15-Apr-05	29		0.10	< 4	< 4	< 1	< 1	< 1	< 1	< 1
PES-MW-8	40	22-May-02	1.9	NM	NM	5.6	< 40	< 1	4.0	1.6	< 1	< 1
		28-Aug-02	14	NM	NM	3.9	< 4	< 1	1.9	2.0	< 1	< 1
		12-Dec-02	4.6	NM	NM	< 1	< 4	< 1	< 1	< 1	< 1	< 1
		9-Apr-03	<1.0	62	2.35	8.0	4.0	1.0	< 1	1.0	1.0	1.0
		21-Aug-03	3.7	29	1.45	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		14-Apr-05	1.7		0.67	< 4	< 4	< 1	< 1	< 1	< 1	< 1
PES-MW-9	36	22-May-02	58 J	NM	NM	140	< 40	< 1	4.2	53.8	82.4	< 1
		27-Aug-02	180	NM	NM	308	< 4	< 0.5	1.9	199	99.1	7.6
		11-Dec-02	240	NM	NM	295	< 4	< 1	0.6 J	229	47.5	18.1
		9-Apr-03	2.6	45	0.42	4.0	< 4	1.0	< 1	1.0	1.0	1.0
		20-Aug-03	1.5 J	121	0.19	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		16-Apr-05	4		0.58	< 4	< 4	< 1	< 1	< 1	< 1	< 1
PES-MW-10A	16	15-Apr-05	190		0.20	50.5	< 4	< 1	< 1	26.8	11.6	12.1
PES-MW-10B	13	14-Apr-05	3		0.07	< 4	< 4	< 1	< 1	< 1	< 1	< 1
PES-MW-11A	38	13-Apr-05	9		0.17	< 4	< 4	< 1	< 1	< 1	< 1	< 1
PES-MW-12A	155	12-Apr-05	6		0.08	< 4	< 4	< 1	< 1	< 1	< 1	< 1
PES-MW-12B	155	20-Apr-05	6		0.00	< 4	< 4	< 1	< 1	< 1	< 1	< 1
PES-MW-13A	NA	20-Apr-05	5		0.08	< 4	< 4	< 1	< 1	< 1	< 1	< 1
PES-MW-14A	75	12-Apr-05	50		0.37	< 4	< 4	< 1	< 1	< 1	< 1	< 1
PES-MW-14B	75	20-Apr-05	4.2J		0.05	< 4	< 4	< 1	< 1	< 1	< 1	< 1
PES-CW-1	220	20-May-02	<1.3	NM	NM	<1	< 80	< 1	< 1	< 1	< 1	< 1
		26-Aug-02	11	NM	NM	3.4	< 4	< 1	1.6	1.8	< 1	< 1
		9-Dec-02	1.5	NM	NM	< 1	< 4	< 1	< 1	< 1	< 1	< 1
		7-Apr-03	<1.0	NM	NM	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		18-Aug-03	1.6 J	NM	NM	< 4	< 4	< 1	< 1	< 1	< 1	< 1

TABLE 13
BIOMASS AND VOLATILE FATTY ACIDS IN GROUNDWATER
NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
ANOKA COUNTY PARK
FRIDLEY, MINNESOTA

Sample Location	Distance Downgradient From Injection Wells (feet)	Sample Date	Total Organic Carbon (mg/L)[a]	Bacterial Biomass (pmol/mL)[b]	Starvation Ratio (unitless)	Total Volatile Fatty Acids (mg/L)	Metabolic Acids: Pyruvic (mg/L)	Lactic (mg/L)	Formic (mg/L)	Acetic (mg/L)	Proprionic (mg/L)	Butyric (mg/L)
PES-CW-2	212	20-May-02	<1.0	NM	NM	<1	< 80	< 1	< 1	< 1	< 1	< 1
		26-Aug-02	12	NM	NM	3.4	< 4	< 1	1.7	1.7	< 1	< 1
		9-Dec-02	5.4	NM	NM	< 1	< 4	< 1	< 1	< 1	< 1	< 1
		7-Apr-03	<1.0	NM	NM	< 4	< 4	< 1	< 1	< 1	< 1	< 1
		19-Aug-03	1.7 J	NM	NM	< 4	< 4	< 1	< 1	< 1	< 1	< 1
PES-CW-3	220	20-May-02	<1.6	NM	NM	<1	< 80	< 1	< 1	< 1	< 1	< 1
		26-Aug-02	11	NM	NM	4.0	< 4	0.4 J	1.8	1.8	< 1	< 1
		10-Dec-02	14	NM	NM	< 1	< 4	< 1	< 1	< 1	< 1	< 1
		8-Jul-03	<1.0	NM	NM	3.0	< 4	< 1	< 1	1.0	1.0	1.0 J
		19-Aug-03	<1.0	NM	NM	< 4	< 4	< 1	< 1	< 1	< 1	< 1
INJECTION WELLS												
PES-INJ-1	NA[e]	23-May-02	2,500	NM	NM	3,279	< 80	1.2	4.9	1,500	843	930
		29-Aug-02	2,900	NM	NM	2,910	< 4	1.2	3.0	1,468	458	980
		13-Dec-02	2,600	NM	NM	2,509	< 4	< 1	3.8	1,294	255	956
		10-Apr-03	2,300	3.0	2.47	2,321	< 4	< 1	1.5	1,276	179	865
		22-Aug-03	2,100	4.0	1.73	1,973	< 4	< 1	< 1	963	311	699
		19-Apr-05	2,500	NM	NM	1,954	< 4	< 1	< 1	1,222	167	565
PES-INJ-2	NA	23-May-02	4,100	NM	NM	5,777	< 80	< 20	32.7	1,471	2,835	1,438
		29-Aug-02	4,130	NM	NM	4,371	333	< 20	< 20	1,059	1,753	1,226
		13-Dec-02	4,400	7,698	0.05	3,176	177	< 10	< 10	917	1,047	1,035
		11-Apr-03	2,300	98	0.18	2,139	40	10	10	905	466	708
		22-Aug-03	2,000	350	0.00	1,879	< 4	< 1	< 1	893	379	607
		19-Apr-05	2,400		0.25	1,334	< 4	< 1	< 1	794	174	366
PES-INJ-3	NA	23-May-02	4,100	NM	NM	5,410	< 80	< 20	33.4	1,303	2,355	1,719
		29-Aug-02	3,650	NM	NM	2,965	< 80	< 20	< 20	889	806	1,270
		13-Dec-02	4,900	NM	NM	3,202	< 4	< 10	< 10	1,265	652	1,285
		11-Apr-03	4,600	27	0.00	2,668	< 4	< 1	2.2	1,039	255	1,372
		22-Aug-03	3,600	59	0.79	2,787	243	< 1	20	963	231	1,330
		19-Apr-05	4,700	NM	NM	1,822	< 4	2.3	84	646	127	963
MS-53PC	NA	11-Apr-05	110	NM	NM	792	< 4	1.0	106	469	210	6

a/ mg/L = milligrams per liter.

b/ pmol/mL = picomoles per milliliter.

c/ "<" indicates that anayte was below the limit of quantitation.

d/ NM = not measured.

e/ This well is located upgradient of the injection area.

f/ J indicates that the analyte was detectedat a concentration greater than the method detection limit and less than the reporting limit. Thus, the concentration is estimated.

FIGURES

S:\ES\cad\739484\05dn0122.dwg 08/18/2005 3:07PM JLH

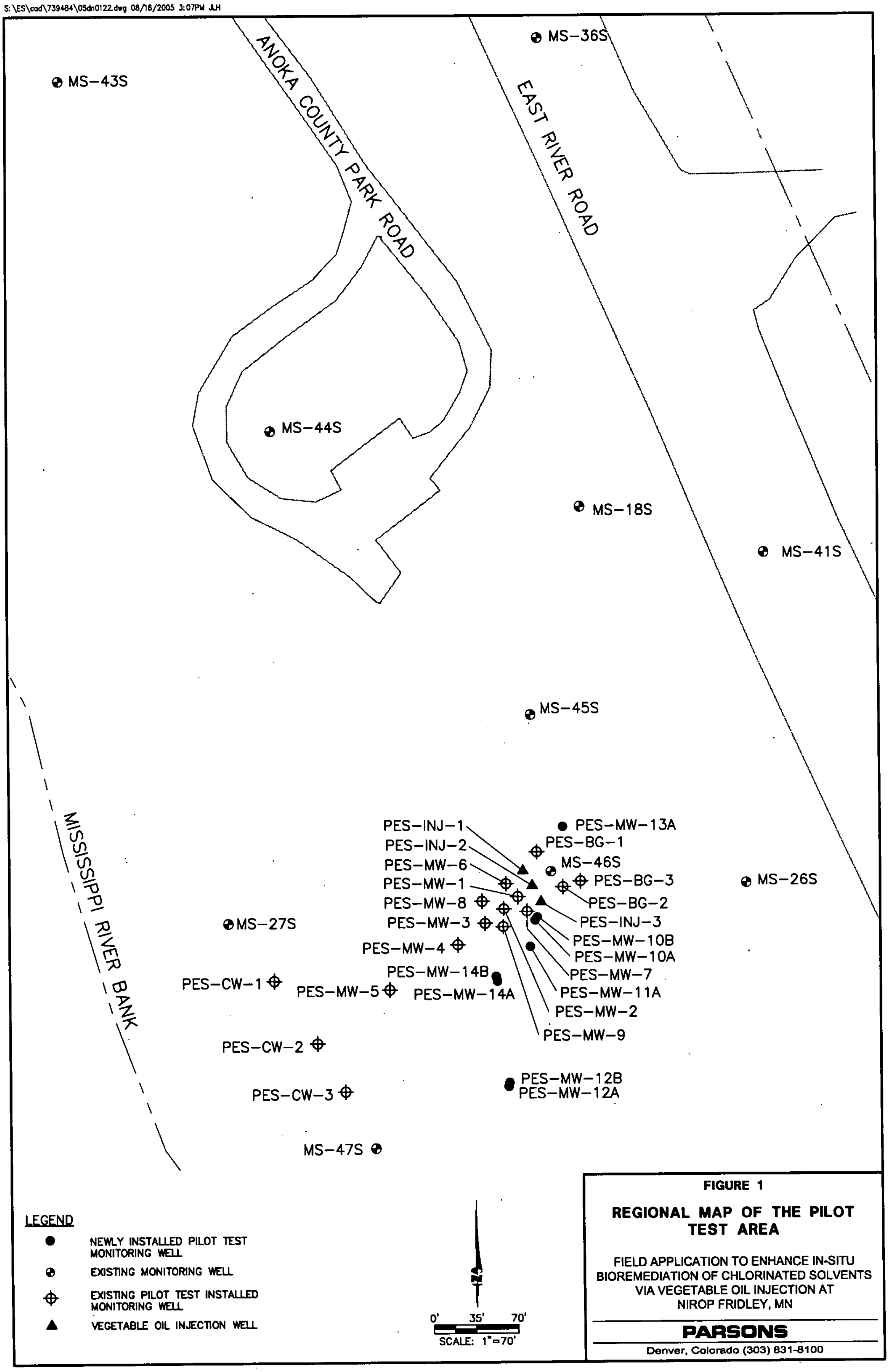


FIGURE 1

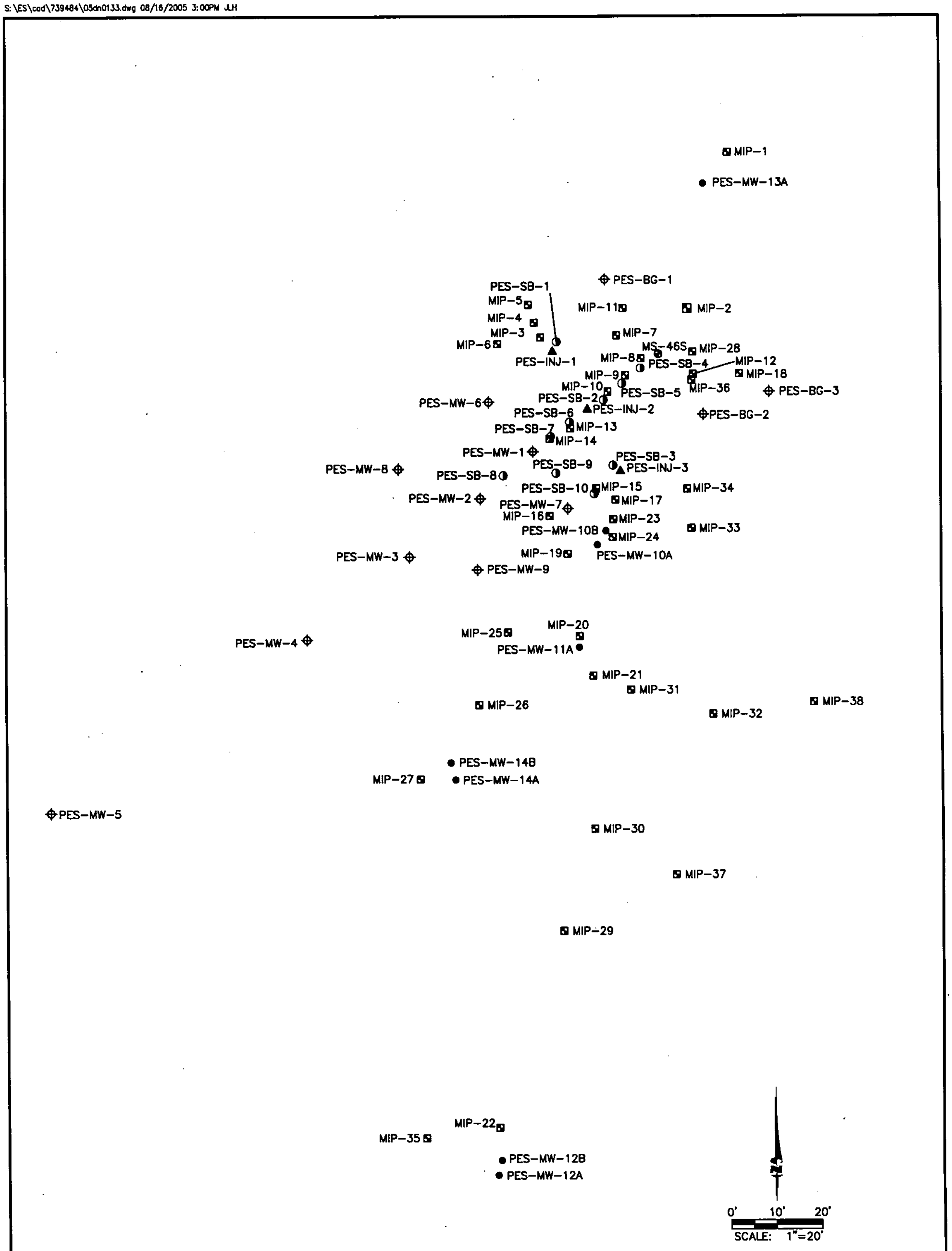
REGIONAL MAP OF THE PILOT TEST AREA

FIELD APPLICATION TO ENHANCE IN-SITU BIOREMEDIATION OF CHLORINATED SOLVENTS VIA VEGETABLE OIL INJECTION AT NIROP FRIDLEY, MN

PARSONS

Denver, Colorado (303) 831-8100

S:\ES\cad\739484\05dn0133.dwg 08/16/2005 3:00PM JLH



LEGEND

- ⌖ EXISTING MONITORING WELL
- ● NEWLY INSTALLED MONITORING WELL
- ▲ VEGETABLE OIL INJECTION WELL
- ◘ MIP WELL LOCATION
- ◑ NEWLY INSTALLED SOIL BORING

FIGURE 2

LOCAL MAP OF THE PILOT TEST AREA

FIELD APPLICATION TO ENHANCE IN-SITU BIOREMEDIATION OF CHLORINATED SOLVENTS VIA VEGETABLE OIL INJECTION AT NIROP FRIDLEY, MN

PARSONS

Denver, Colorado (303) 831-8100

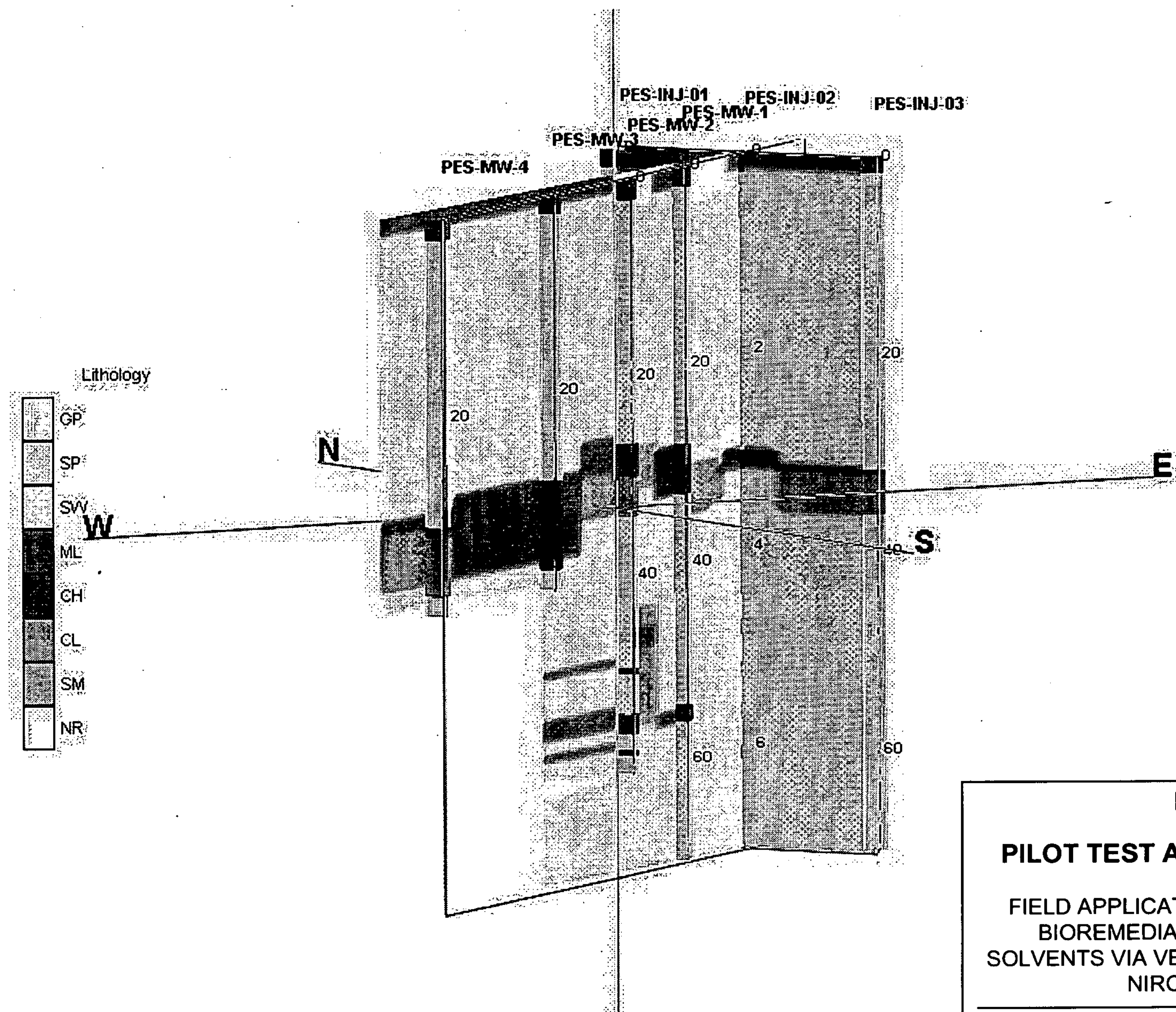


FIGURE 3

PILOT TEST AREA FENCE DIAGRAM

FIELD APPLICATION TO ENHANCE IN-SITU BIOREMEDIATION OF CHLORINATED SOLVENTS VIA VEGETABLE OIL INJECTION AT NIROP FRIDLEY, MN

PARSONS

Denver, Colorado (303) 831-8100

S:\ES\cad\739484\05dn0200.dwg 08/18/2005 11:04AM JLH

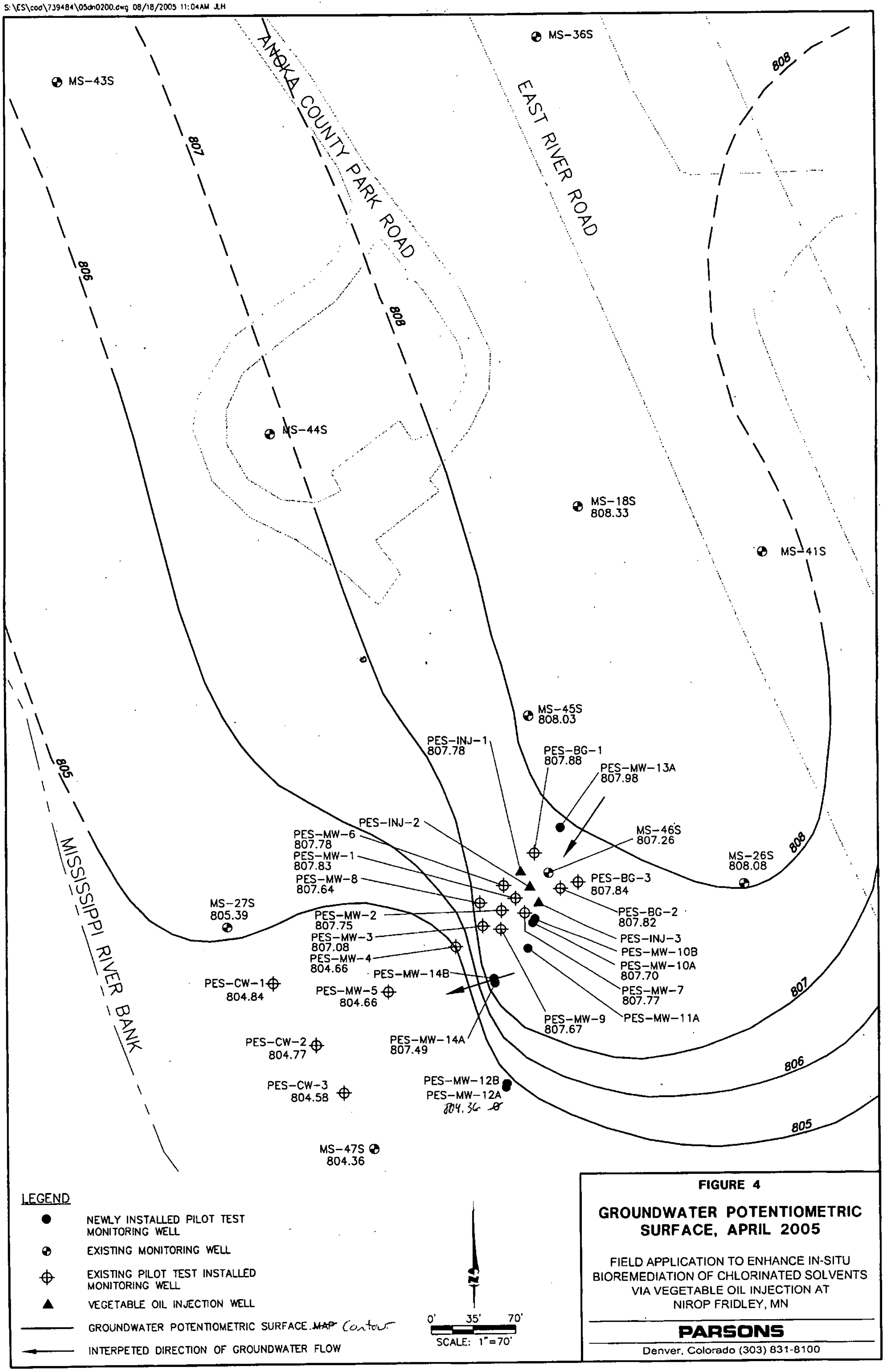


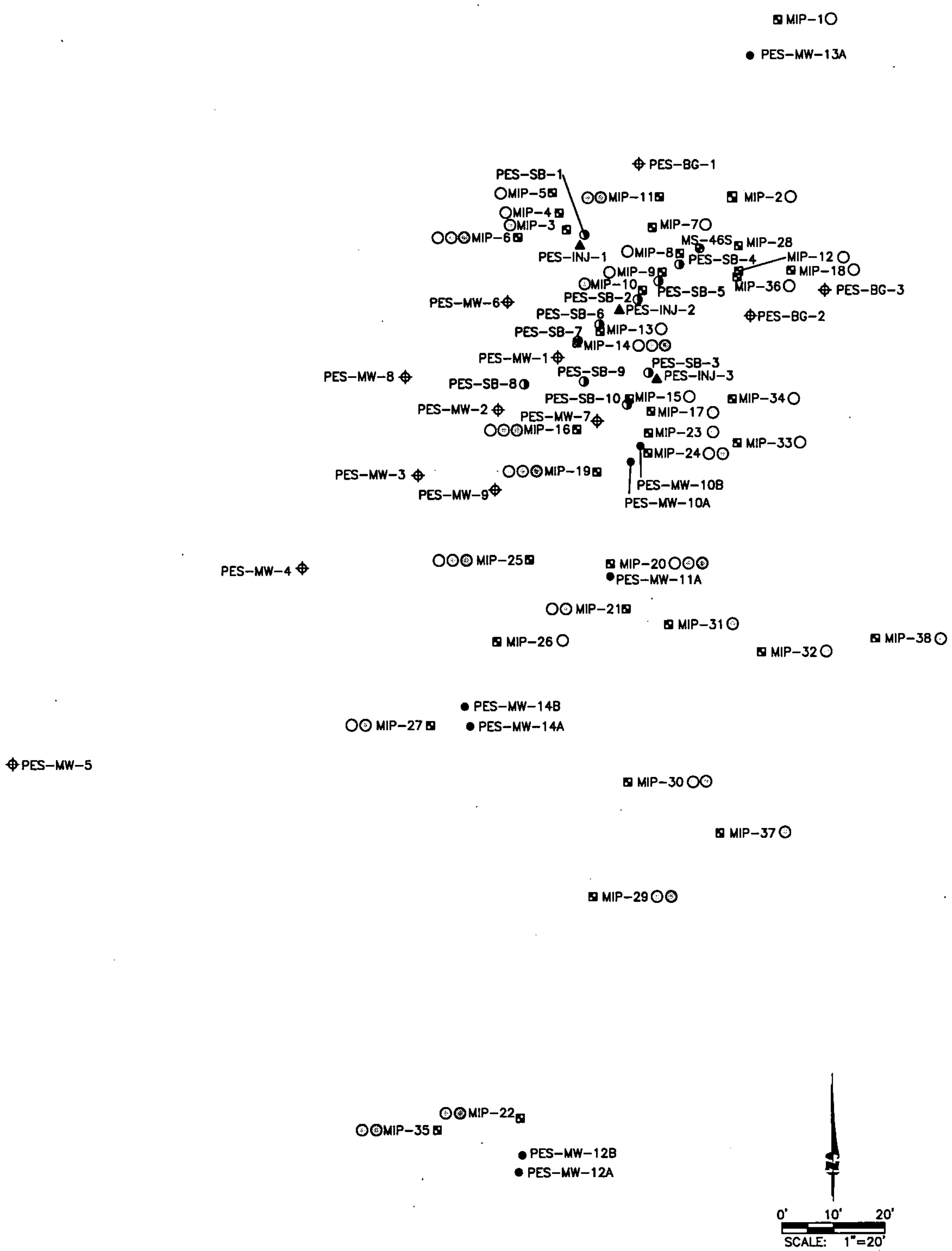
FIGURE 4

GROUNDWATER POTENTIOMETRIC SURFACE, APRIL 2005

FIELD APPLICATION TO ENHANCE IN-SITU BIOREMEDIATION OF CHLORINATED SOLVENTS VIA VEGETABLE OIL INJECTION AT NIROP FRIDLEY, MN

PARSONS

Denver, Colorado (303) 831-8100



LEGEND

- EXISTING MONITORING WELL
- NEWLY INSTALLED MONITORING WELL
- VEGETABLE OIL INJECTION WELL
- MIP WELL LOCATION
- NEWLY INSTALLED SOIL BORING

PRESENCE AND DEPTH OF ELEVATED ECD RESPONSE

- 30 – 40 FEET BGS
- 40 – 50 FEET BGS
- 50 – 60 FEET BGS

FIGURE 5

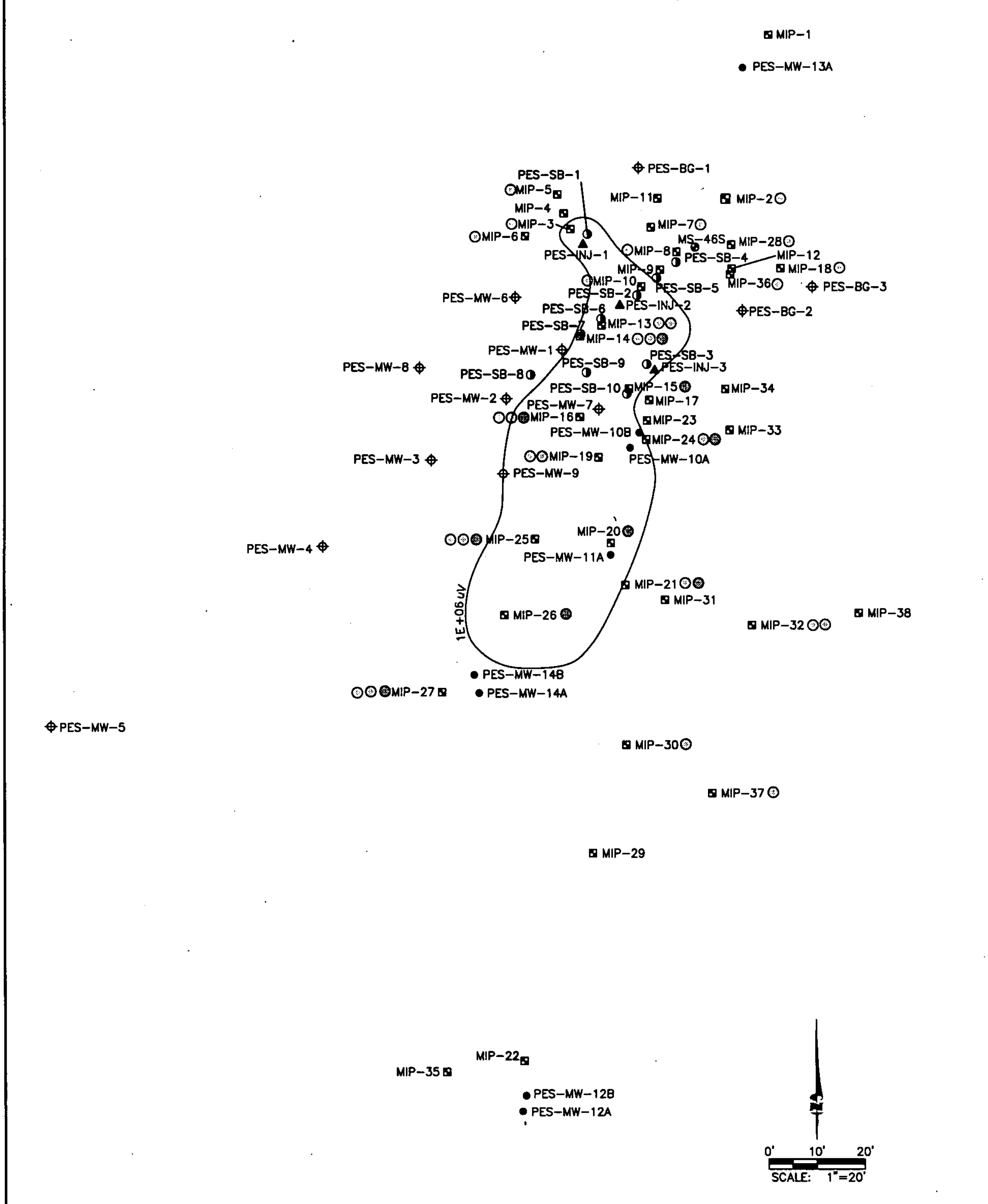
SUMMARY OF ECD RESPONSE

FIELD APPLICATION TO ENHANCE IN-SITU BIOREMEDIATION OF CHLORINATED SOLVENTS VIA VEGETABLE OIL INJECTION AT NIROP FRIDLEY, MN

PARSONS

Denver, Colorado (303) 831-8100

S:\ES\cad\739484\05dn0133.dwg 08/16/2005 3:03PM JLH



LEGEND

- EXISTING MONITORING WELL
- NEWLY INSTALLED MONITORING WELL
- VEGETABLE OIL INJECTION WELL
- MIP WELL LOCATION
- NEWLY INSTALLED SOIL BORING

PRESENCE AND DEPTH OF FID RESPONSE

- < 40 FEET BGS
- < 40 - 50 FEET BGS
- < 50 - 60 FEET BGS

FIGURE 6

SUMMARY OF FID RESPONSE

FIELD APPLICATION TO ENHANCE IN-SITU BIOREMEDIATION OF CHLORINATED SOLVENTS VIA VEGETABLE OIL INJECTION AT NIROP FRIDLEY, MN

PARSONS

Denver, Colorado (303) 831-8100

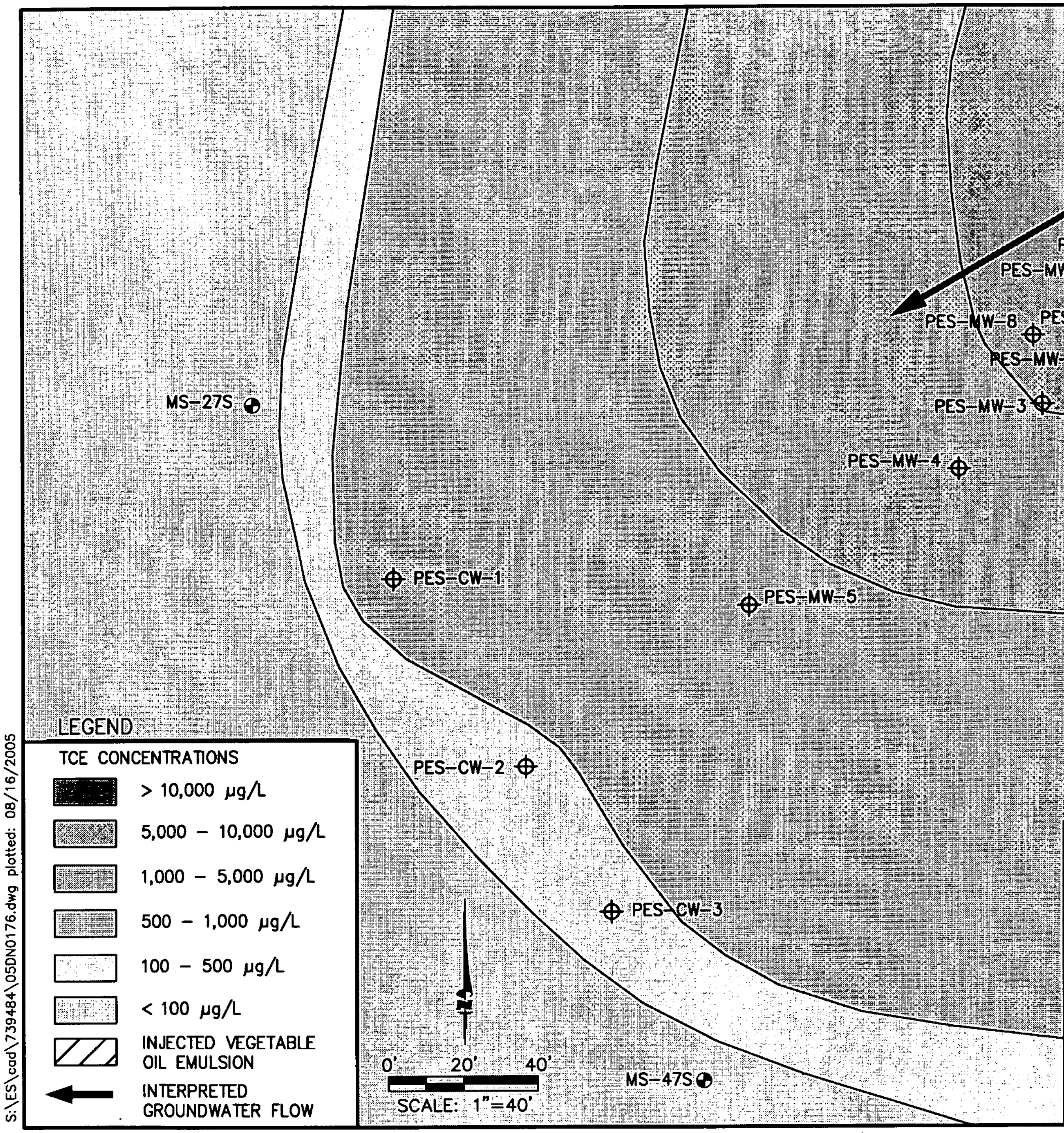


FIGURE 7

TCE CONCENTRATIONS IN GROUNDWATER PRIOR TO SUBSTRATE INJECTION

FIELD APPLICATION TO ENHANCE IN-SITU BIOREMEDIATION OF CHLORINATED SOLVENTS VIA VEGETABLE OIL INJECTION AT NIROP FRIDLEY, MN

PARSONS

Denver, Colorado

S:\ES\cad\739484\05DN0176.dwg plotted: 08/16/2005

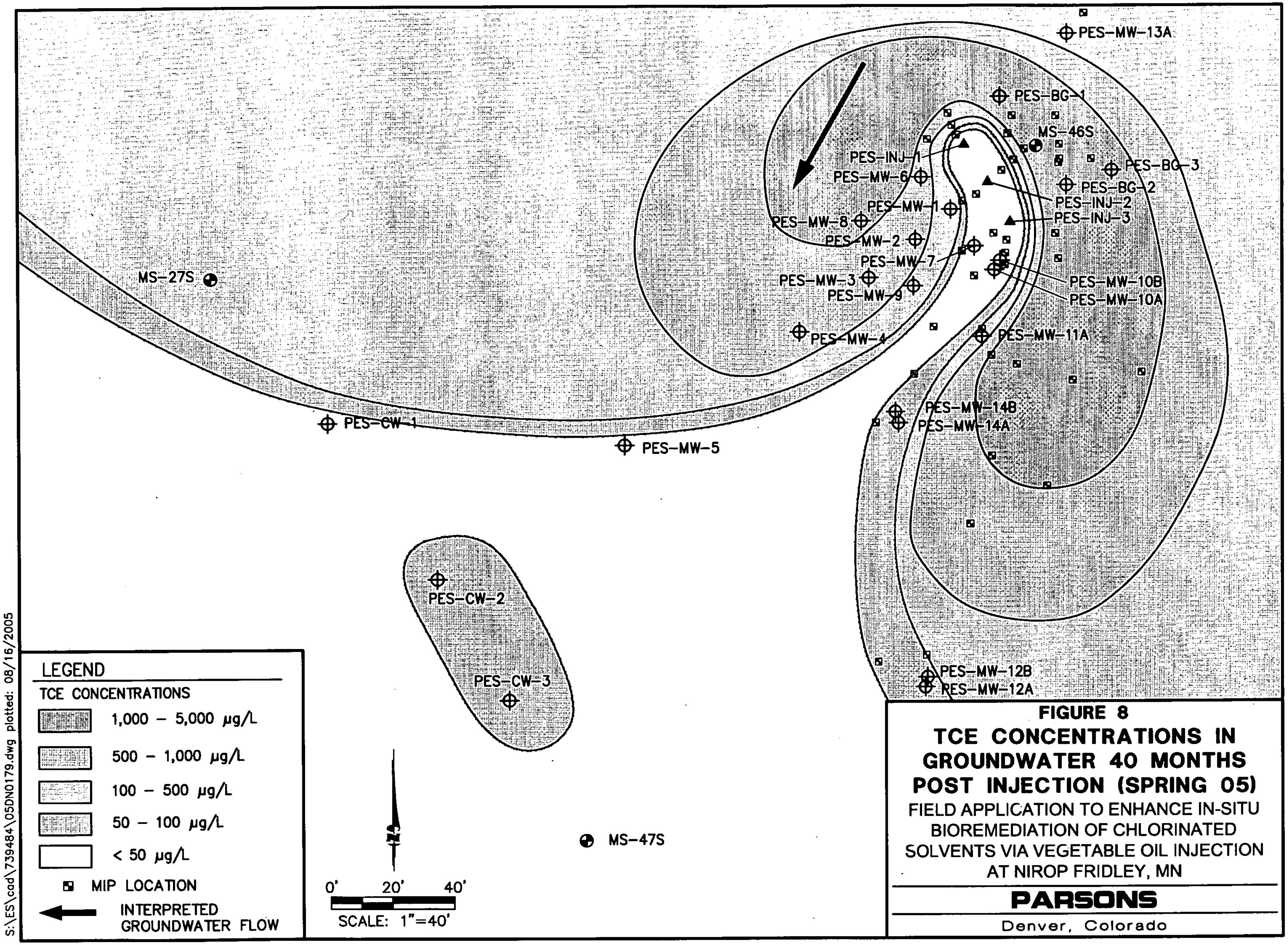


FIGURE 8

TCE CONCENTRATIONS IN GROUNDWATER 40 MONTHS POST INJECTION (SPRING 05)

FIELD APPLICATION TO ENHANCE IN-SITU BIOREMEDIATION OF CHLORINATED SOLVENTS VIA VEGETABLE OIL INJECTION AT NIROP FRIDLEY, MN

PARSONS

Denver, Colorado

S:\ES\cad\739484\05DN0179.dwg plotted: 08/16/2005

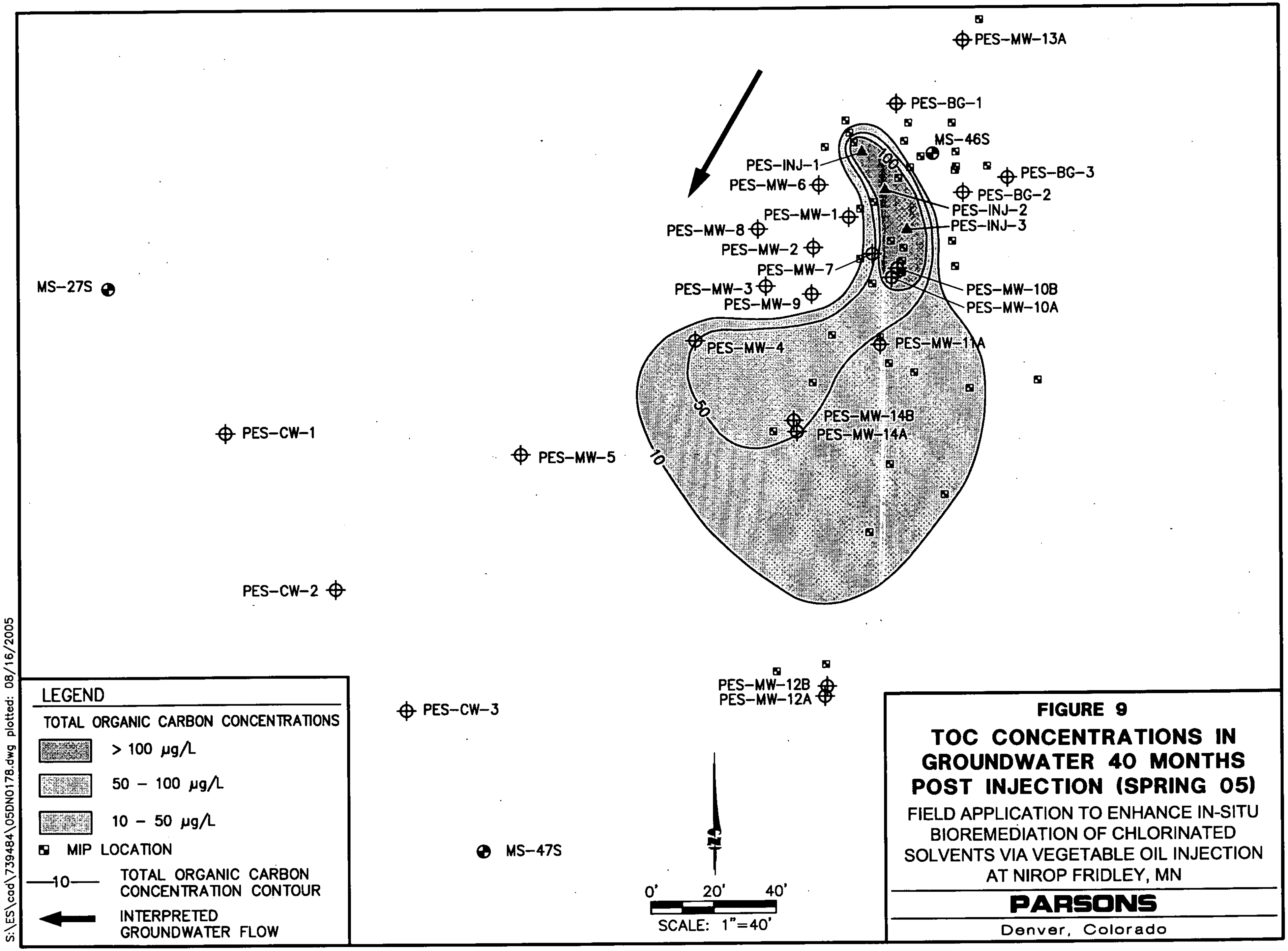


FIGURE 9

TOC CONCENTRATIONS IN GROUNDWATER 40 MONTHS POST INJECTION (SPRING 05)

FIELD APPLICATION TO ENHANCE IN-SITU BIOREMEDIATION OF CHLORINATED SOLVENTS VIA VEGETABLE OIL INJECTION AT NIROP FRIDLEY, MN

PARSONS

Denver, Colorado

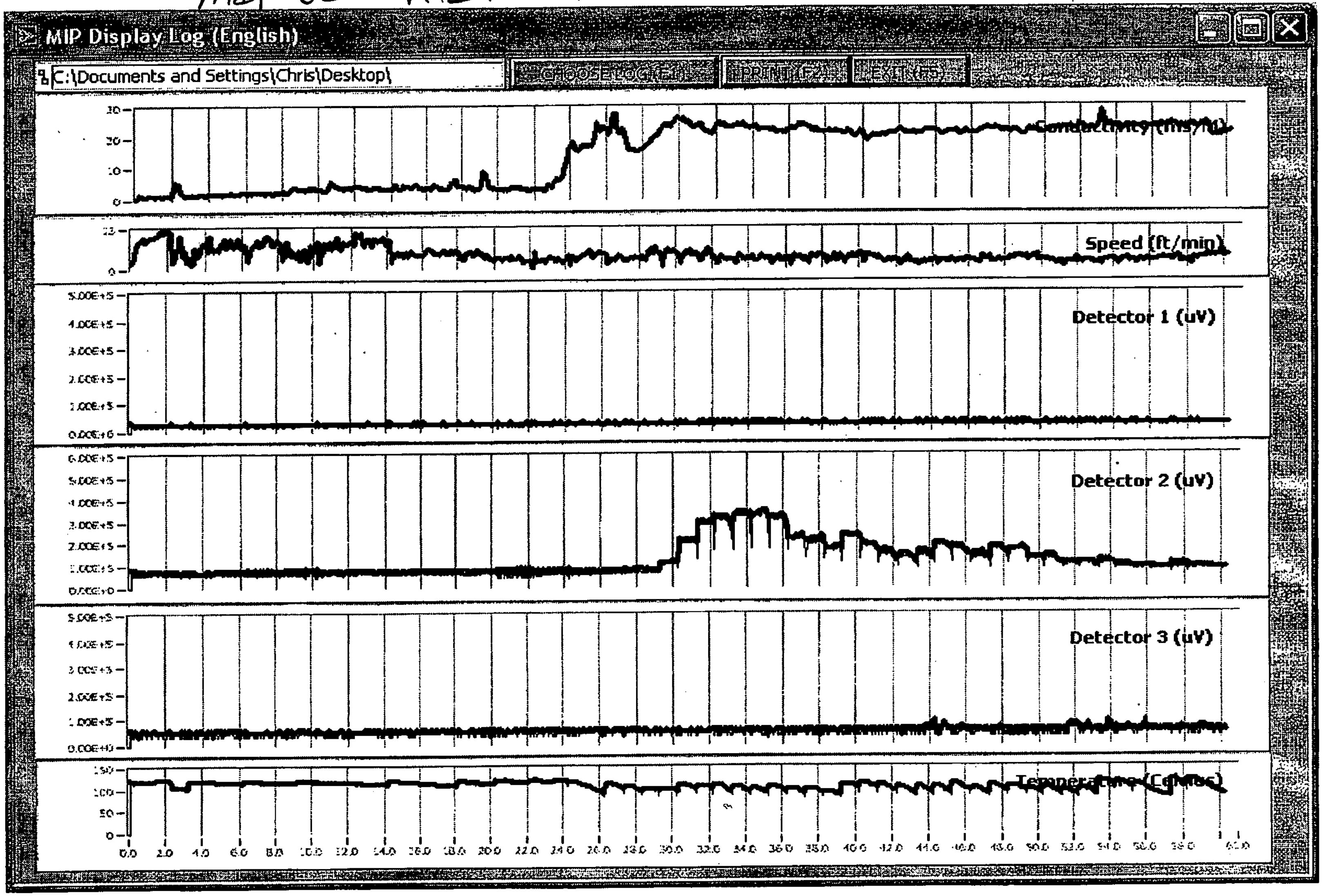
S:\ES\cad\739484\05DN0178.dwg plotted: 08/16/2005

APPENDIX A

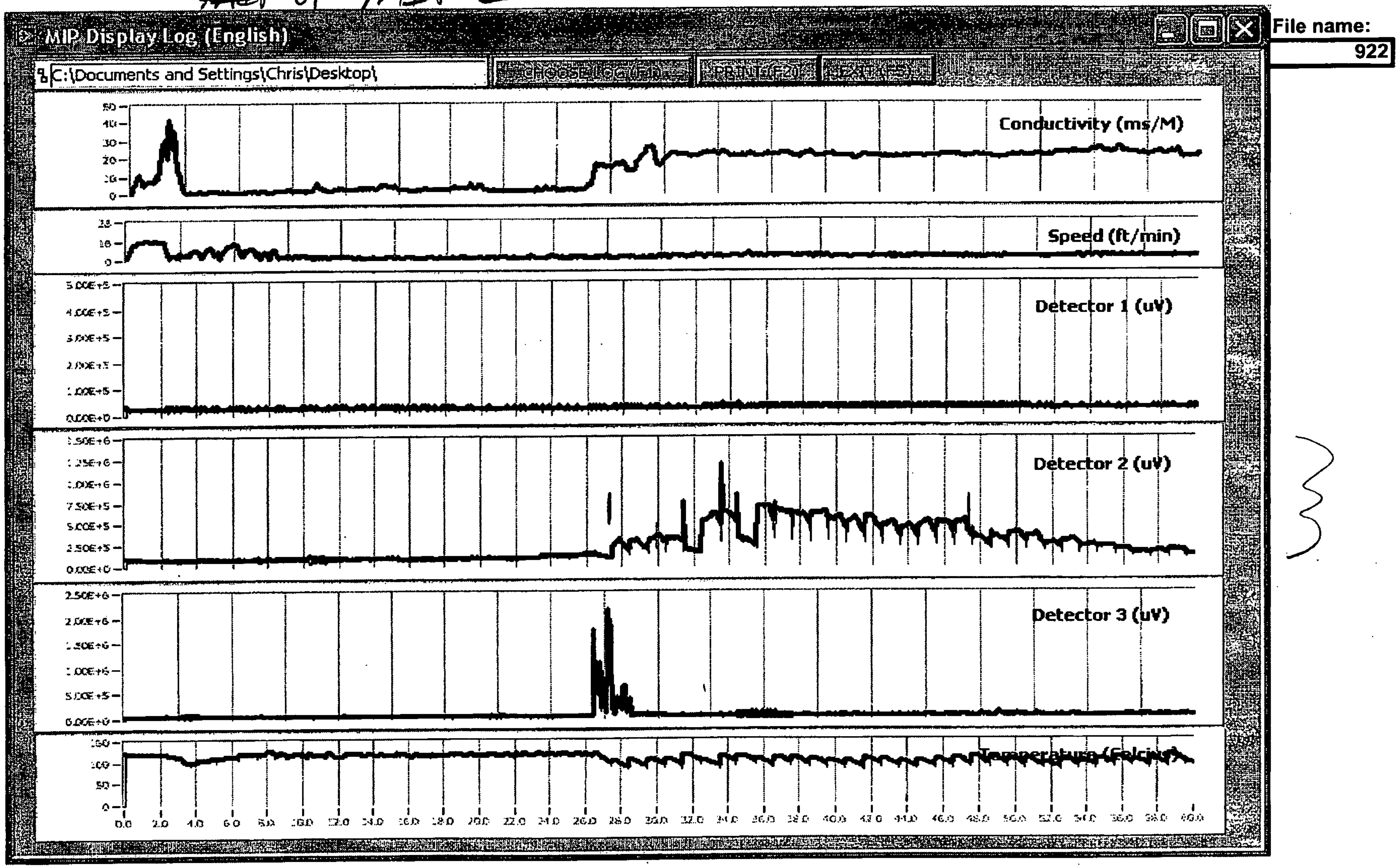
MEMBRANE INTERFACE PROBE LOGS

~~MIP-02~~ MIP-01

File name: 923

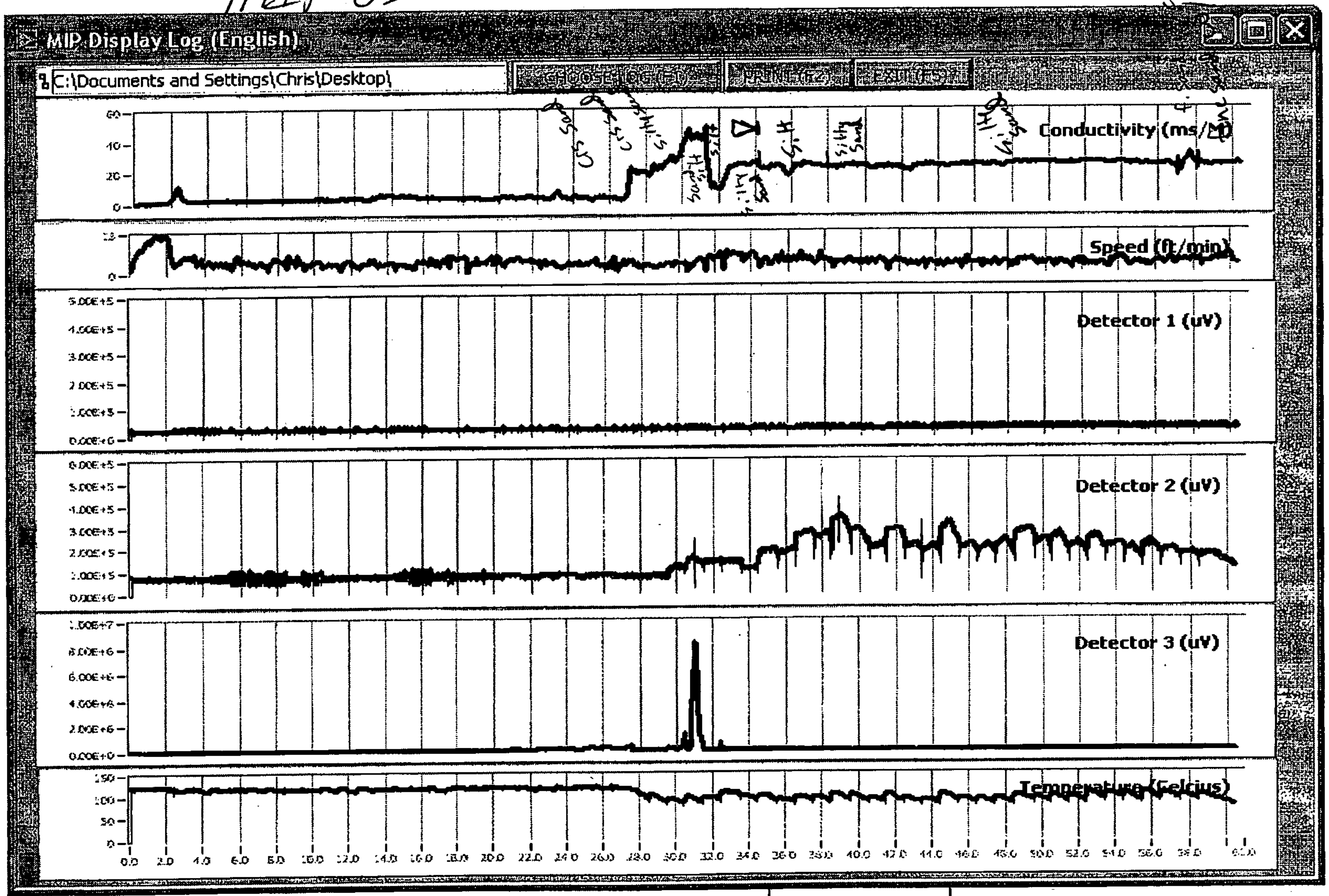


~~MIP-1~~ MIP-2



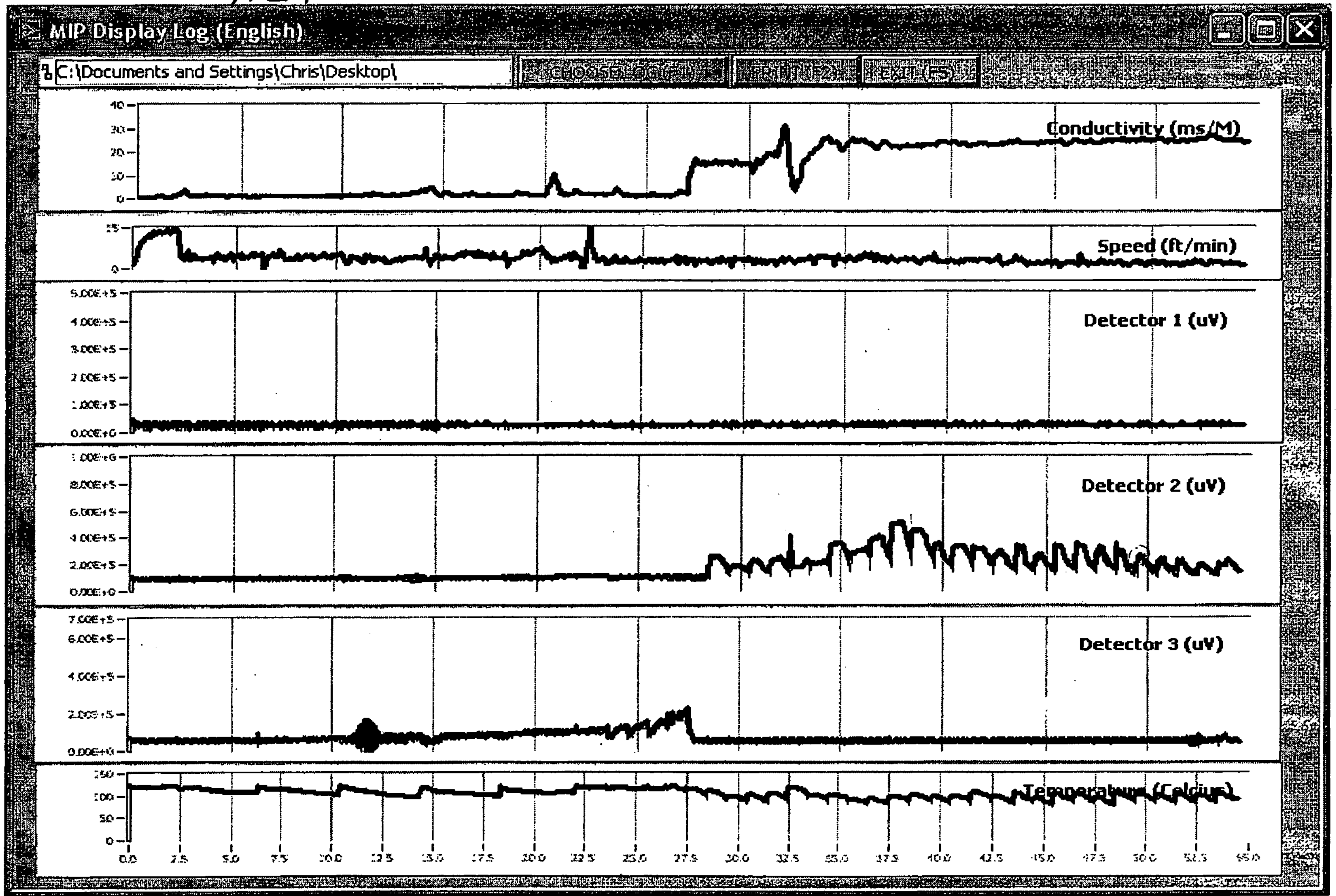
MIP Display Log (English)
C:\Documents and Settings\Chris\Desktop\
CHOOSE LOG (F1)
PRINT (F2)
EXIT (F3)
File name:
922
Conductivity (ms/M)
Speed (ft/min)
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Temperature (Celcius)

MIP-03



File name: 925

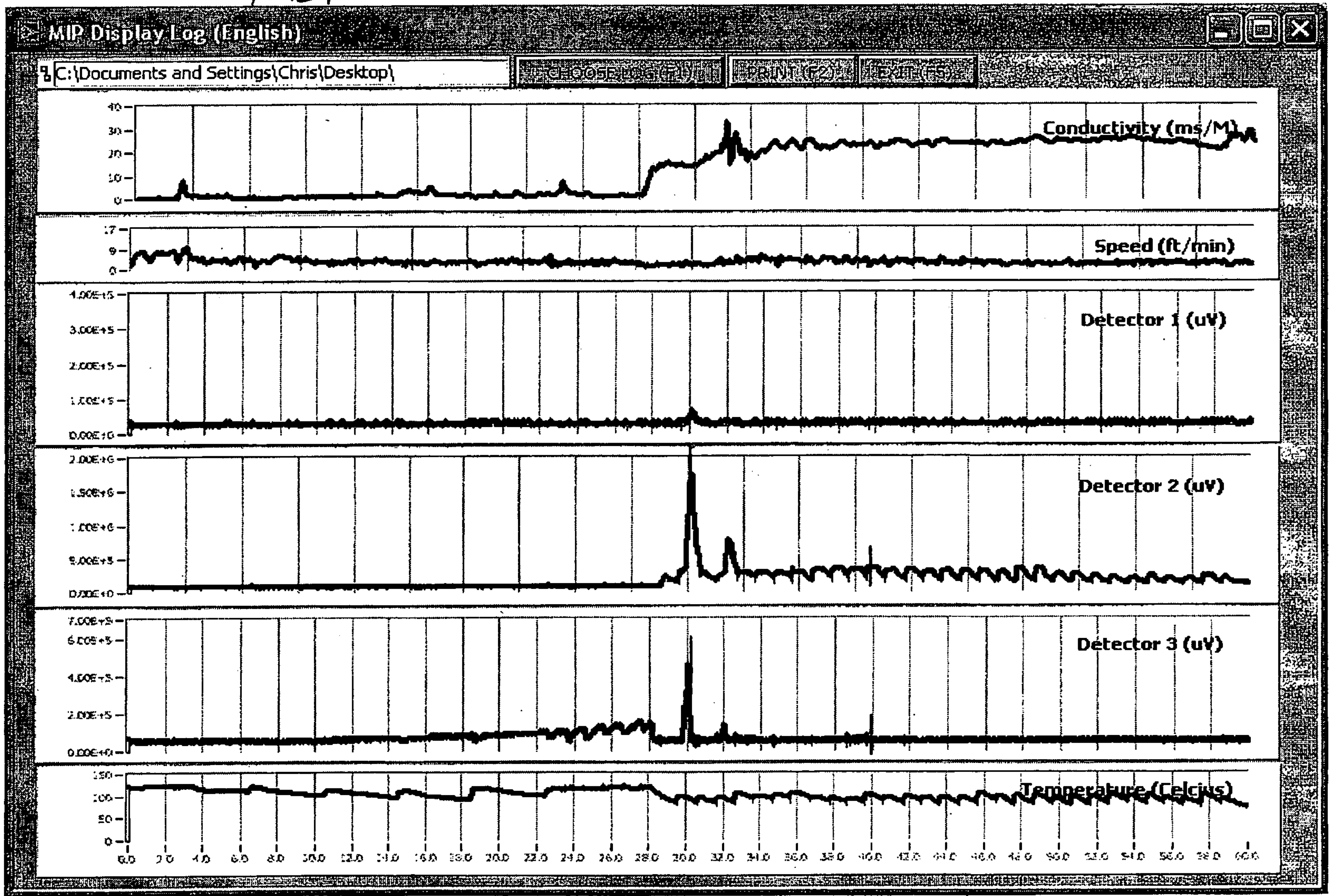
MIP-04



File name:
928

INJ-01

MIP-05

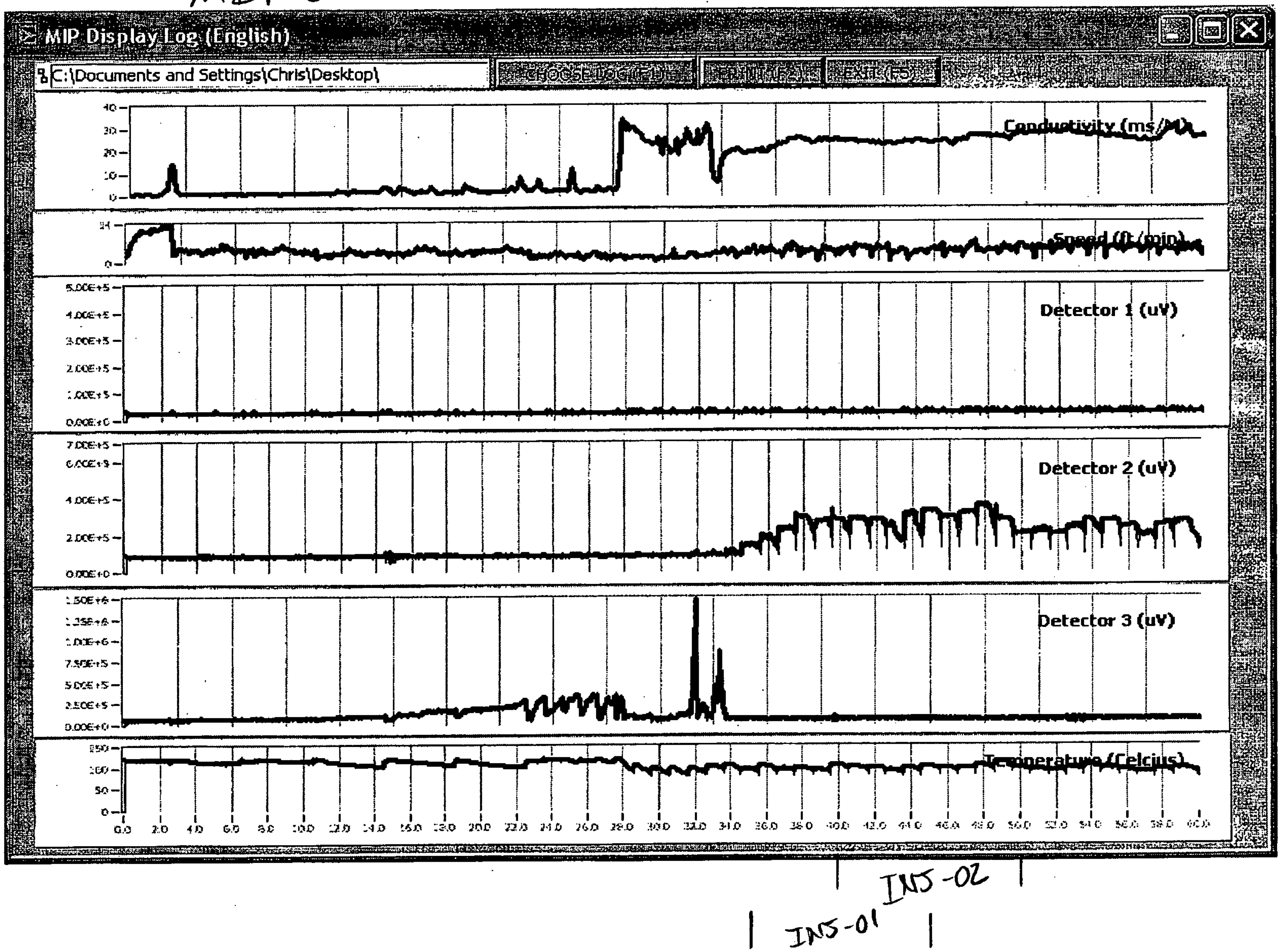


File name: 929

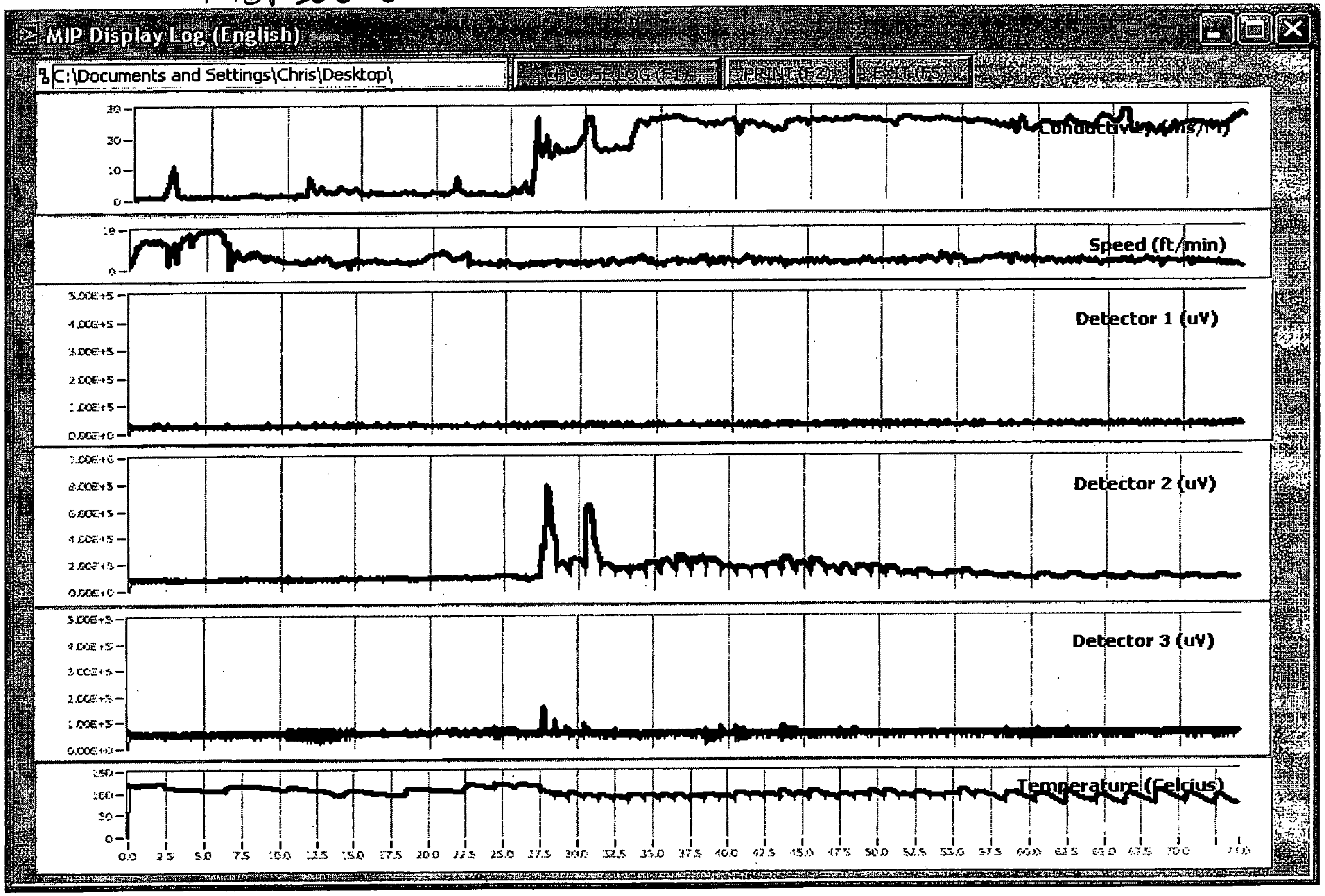
INJ-01

MIP-06

File name: 930

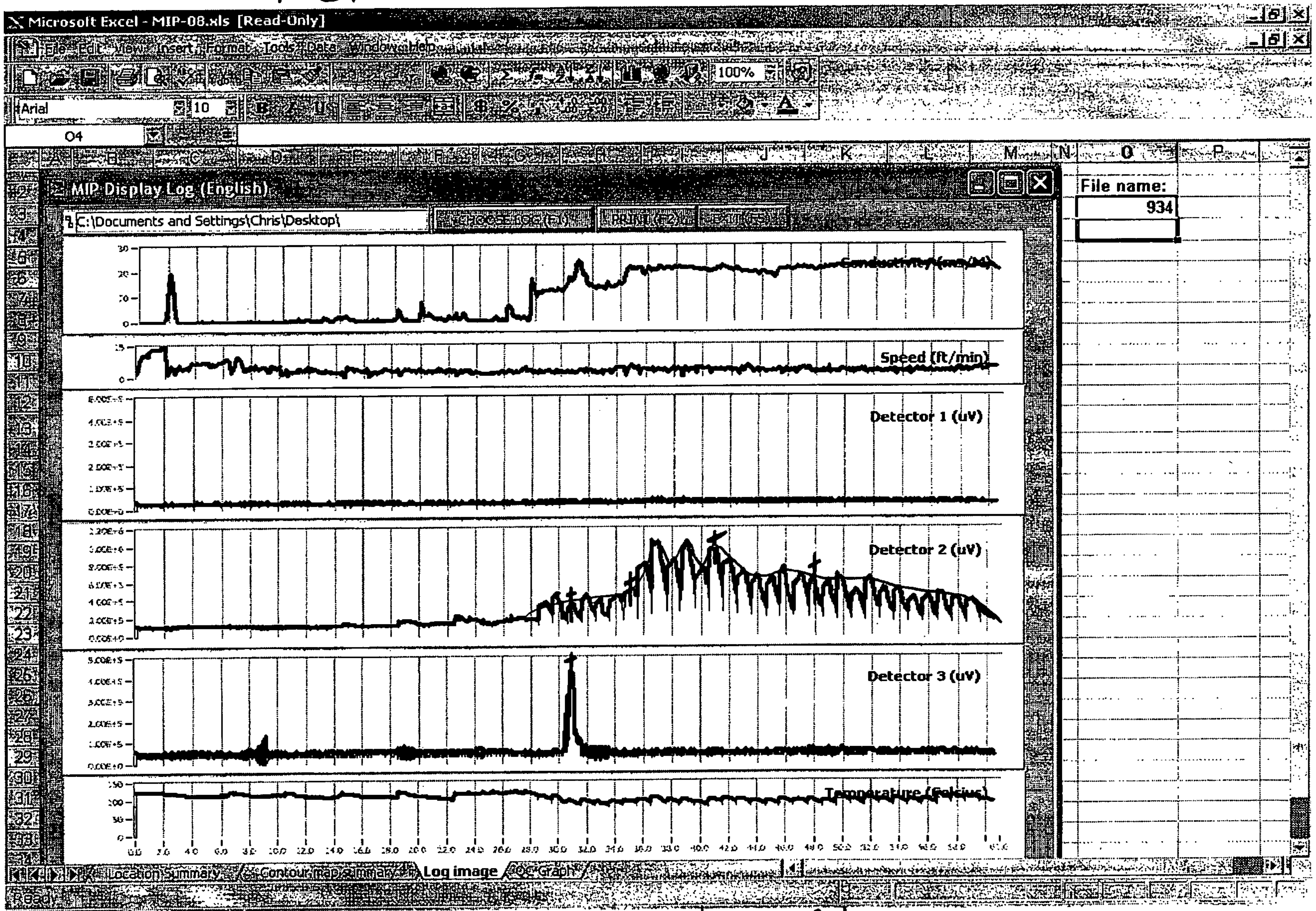


MIP-~~06~~ 07



File name: 931

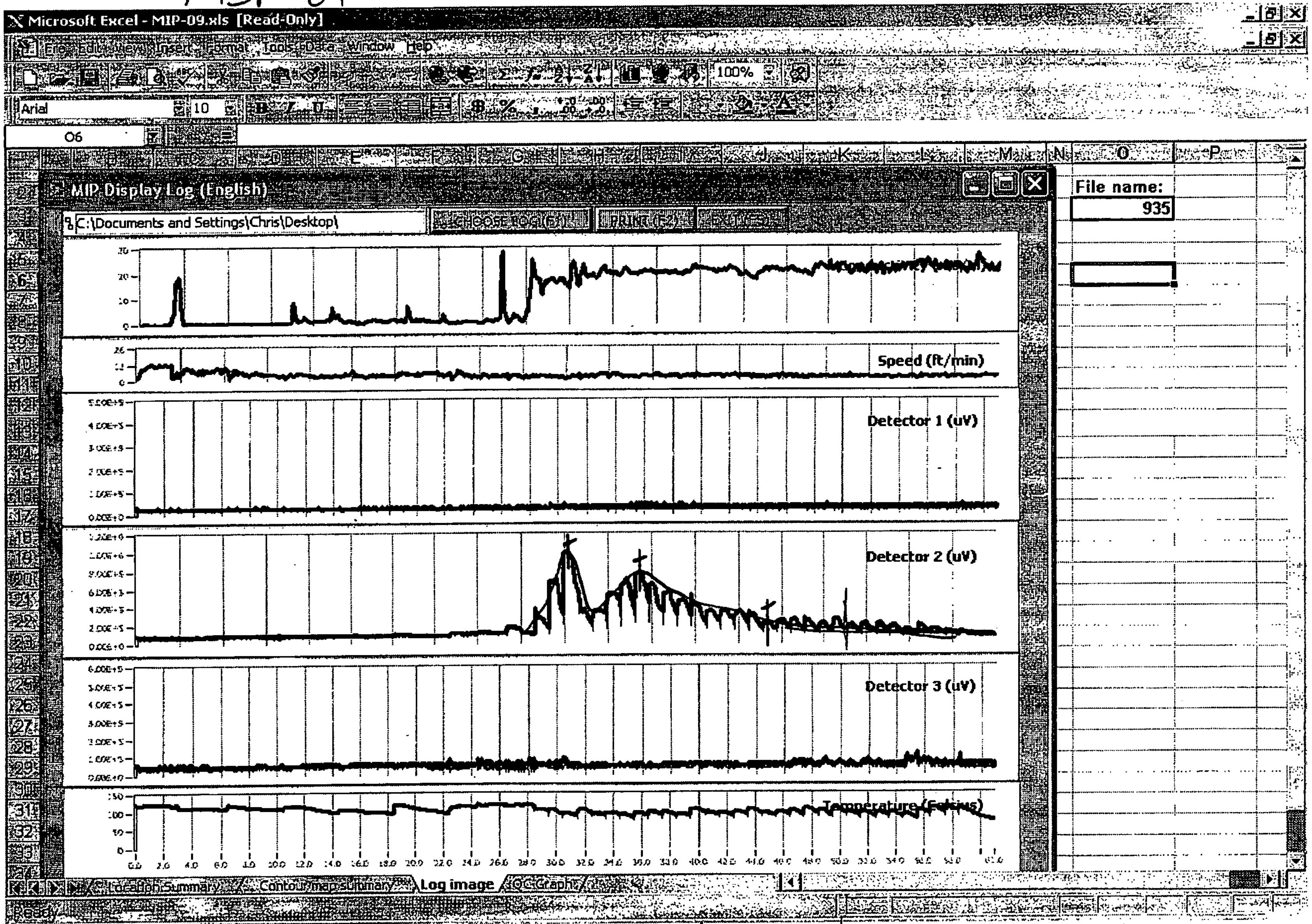
MIP-08



Microsoft Excel - MIP-08.xls [Read-Only]
Arial
10
100%
O4
MIP Display Log (English)
C:\Documents and Settings\Chris\Desktop\
File name:
934
Conductivity (mS/M)
Speed (ft/min)
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Temperature (Celsius)
Location Summary
Contour map summary
Log image
QC Graph

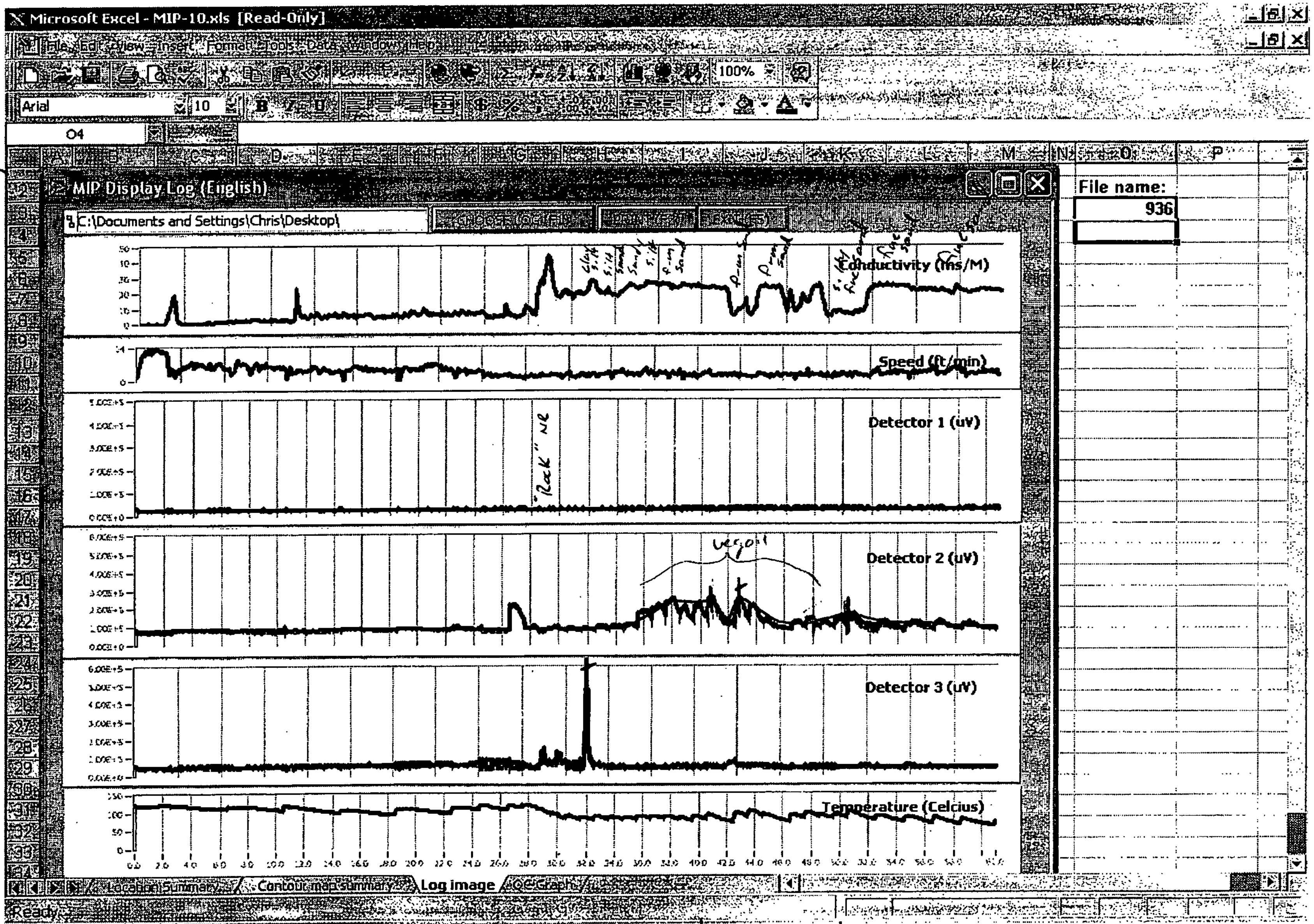
JNS-02

MIP -09



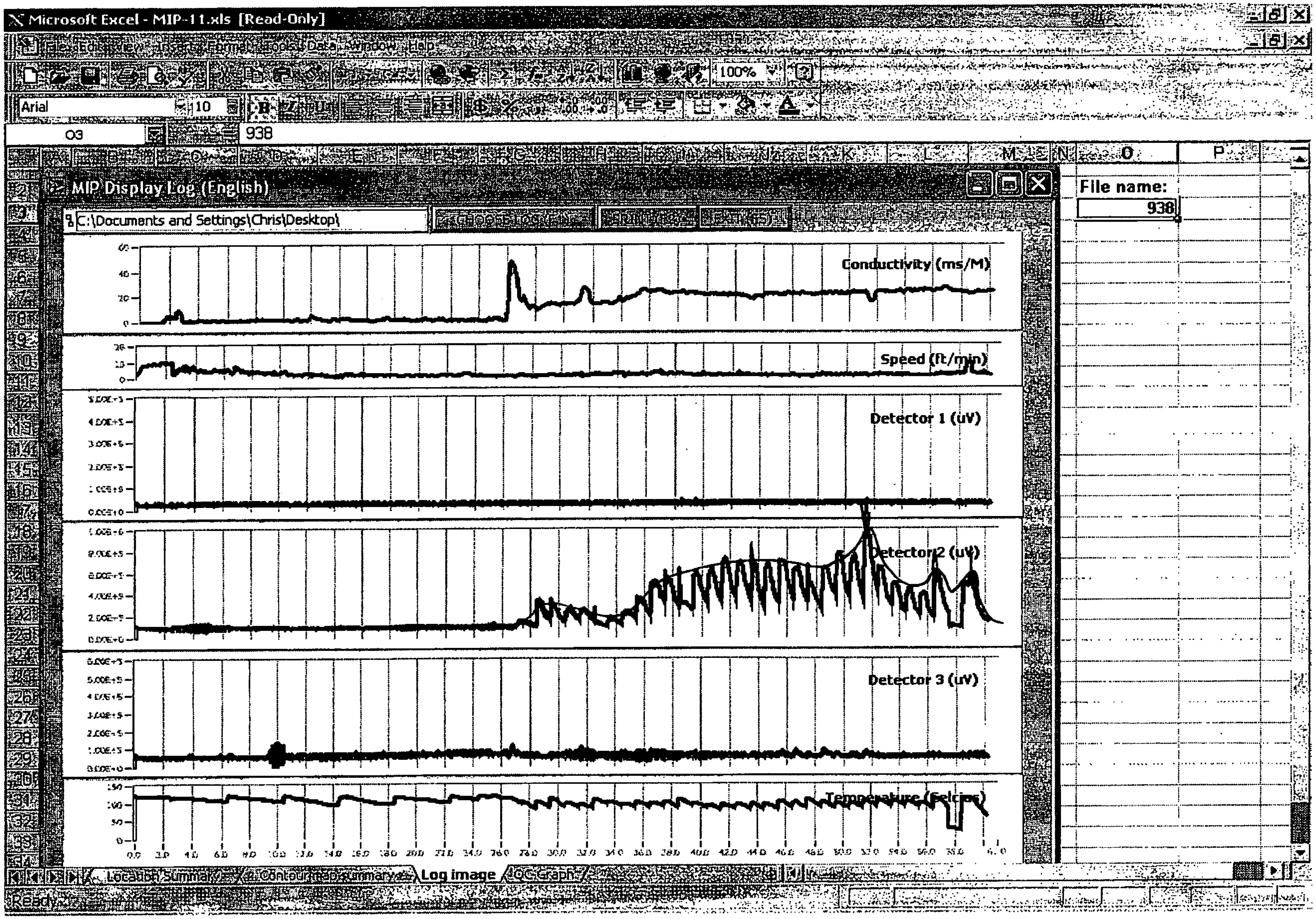
Microsoft Excel - MIP-09.xls [Read-Only]
File Edit View Insert Format Tools Data Window Help
Arial
10
100%
O6
MIP Display Log (English)
C:\Documents and Settings\Chris\Desktop\
File name:
935
Speed (ft/min)
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Temperature (Celsius)
Location Summary
Contour map summary
Log image
QC Graphs
Ready

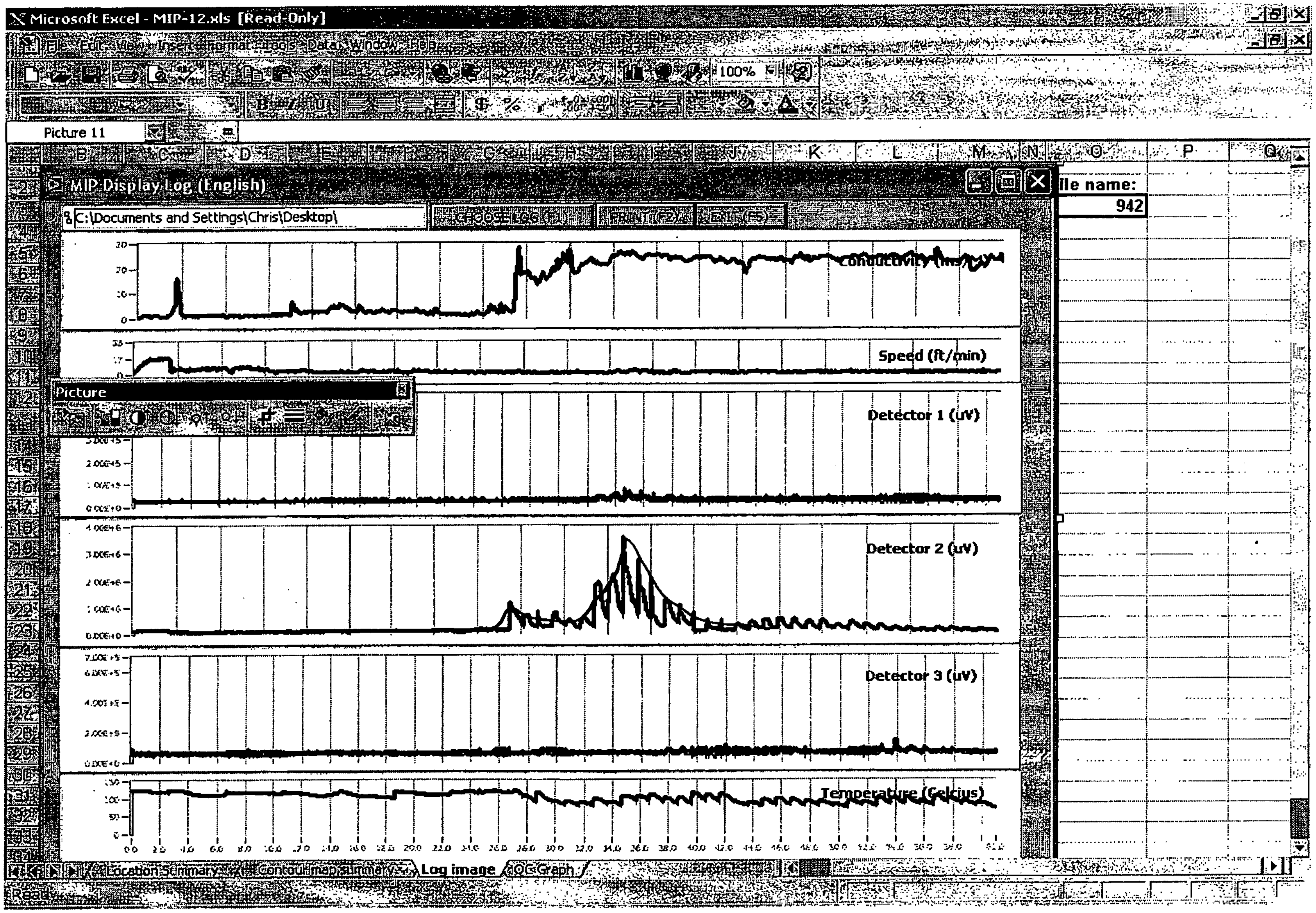
INJ02

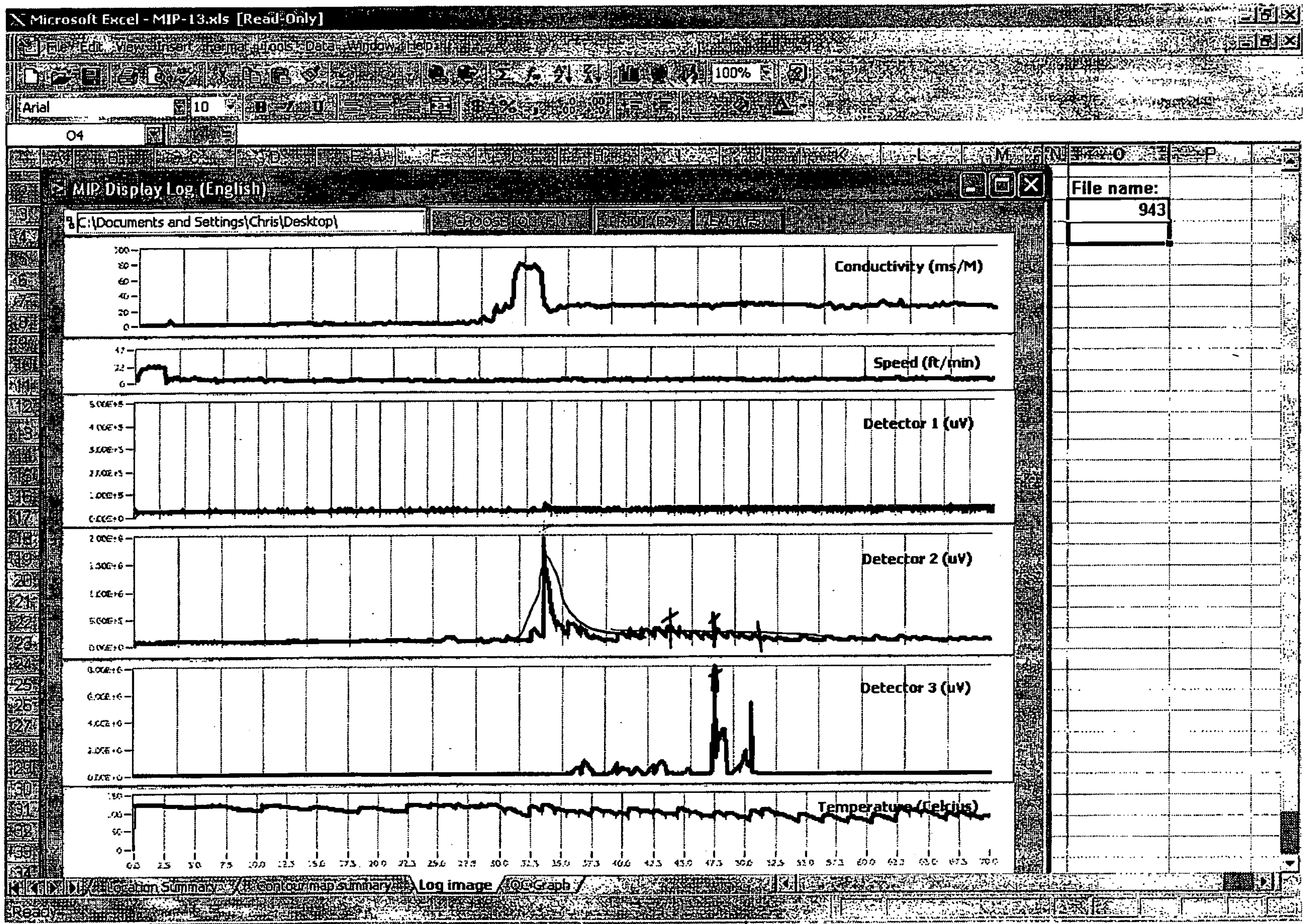


Match w/ SB-2

INJ02


Microsoft Excel - MIP-11.xls [Read-Only]
MIP Display Log (English)
C:\Documents and Settings\Chris\Desktop\
File name:
938
Conductivity (ms/M)
Speed (ft/min)
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Temperature (Celcius)
Location Summary
Contour map summary
Log image
QC Graph
Ready

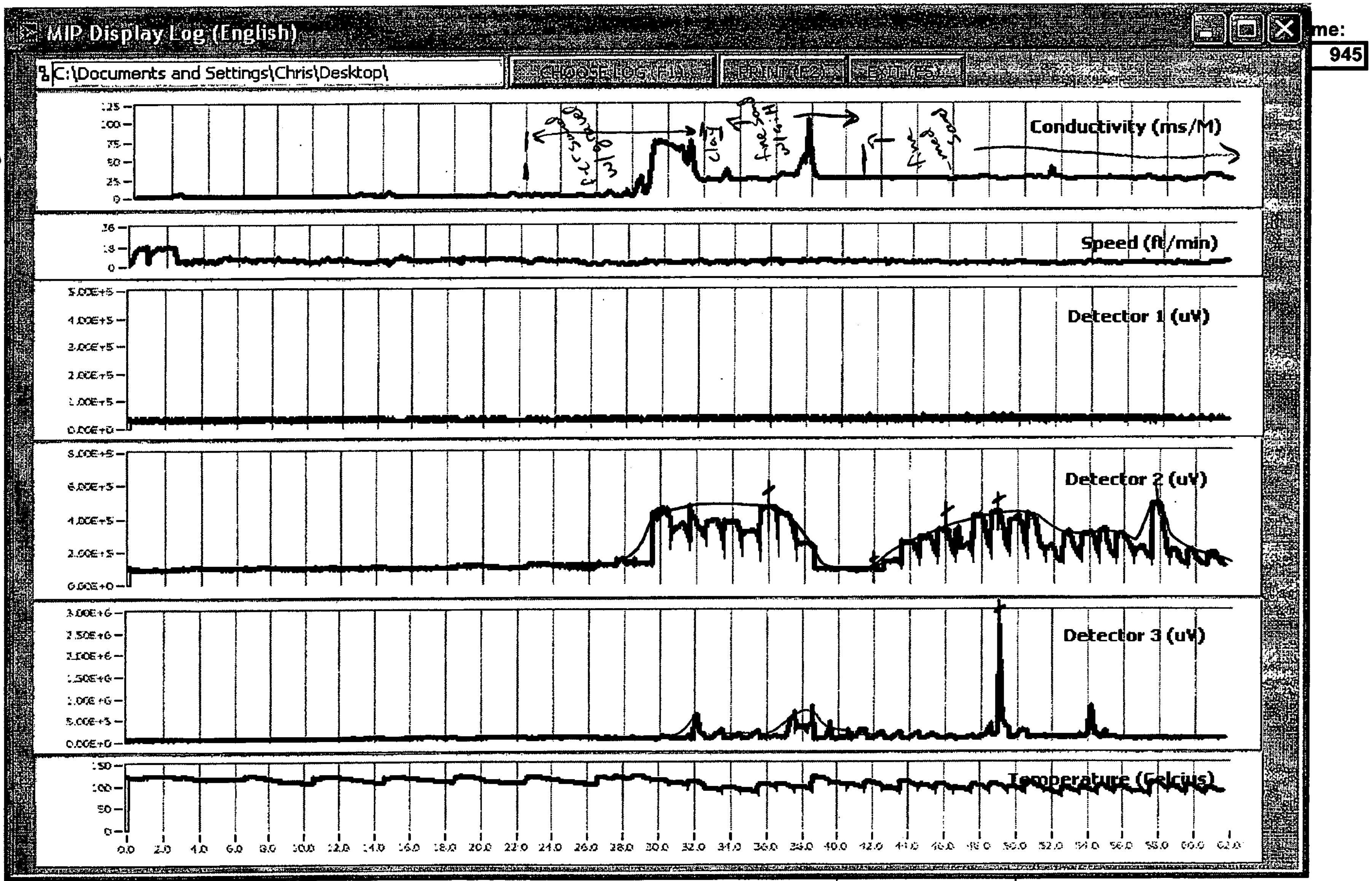

Microsoft Excel - MIP-12.xls [Read-Only]
Picture 11
MIP Display Log (English)
C:\Documents and Settings\Chris\Desktop\
CHOOSE LOG (F1)
PRINT (F2)
EXIT (F5)
ile name:
942
Conductivity (mS/m)
Speed (ft/min)
Picture
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Temperature (Celcius)
Location Summary
contour map summary
Log image
QC Graph
Ready


Microsoft Excel - MIP-13.xls [Read-Only]
MIP Display Log (English)
C:\Documents and Settings\Chris\Desktop\
File name:
943
Conductivity (ms/M)
Speed (ft/min)
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Temperature (Celcius)
Log image

JNJ02

MIP - 14

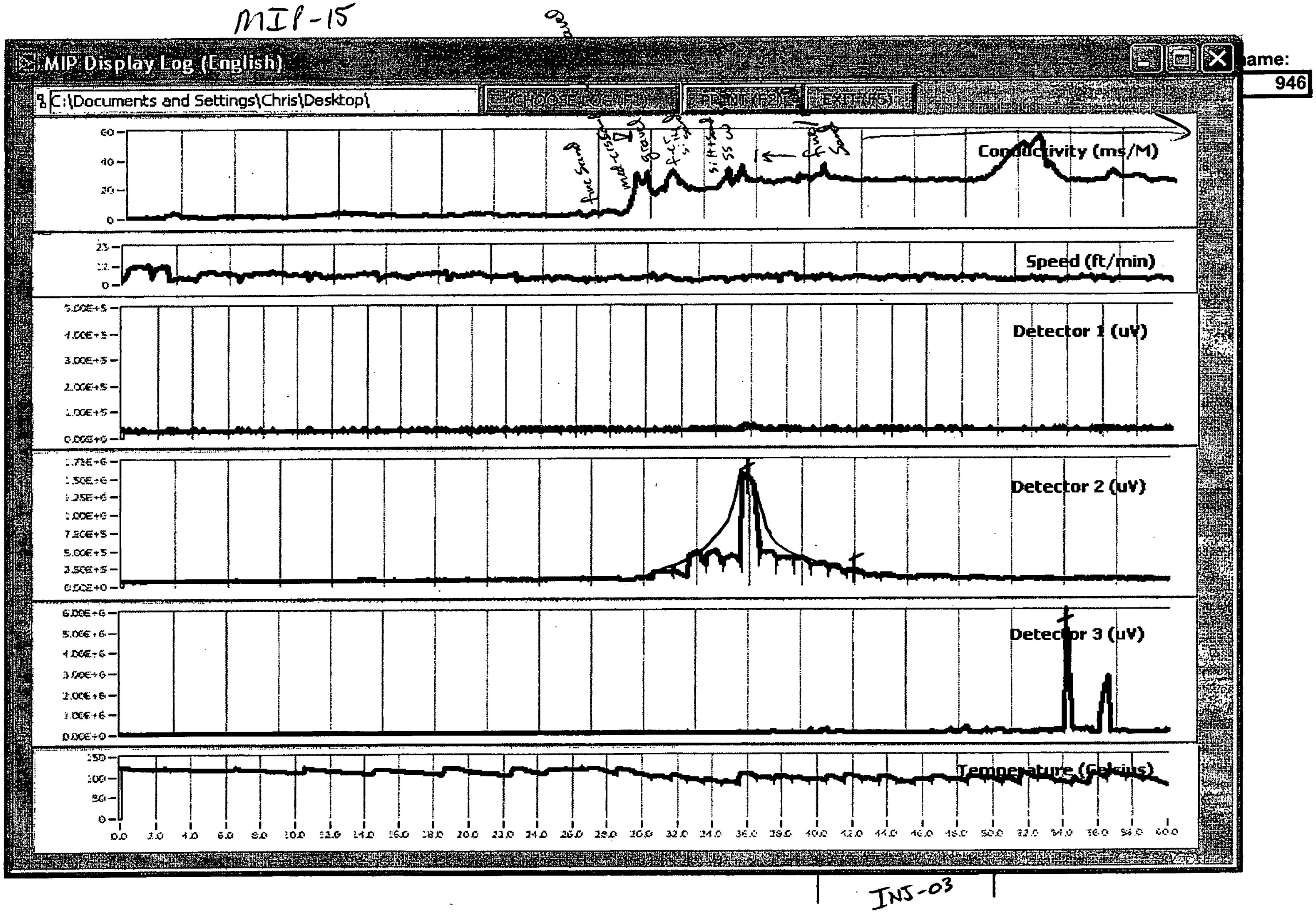
Match to SB-9



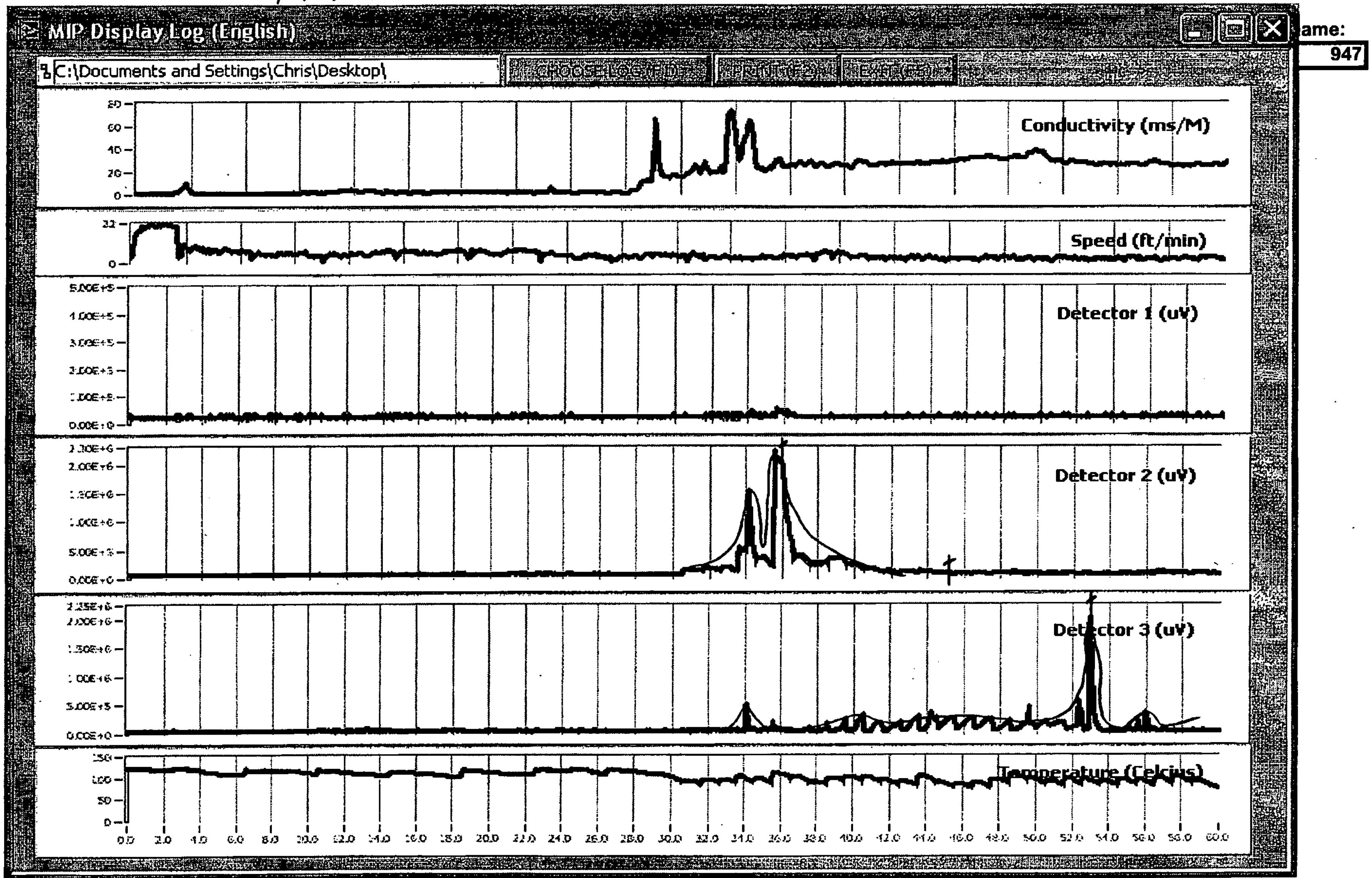
inj 2

MIP-15

Match to SB-10



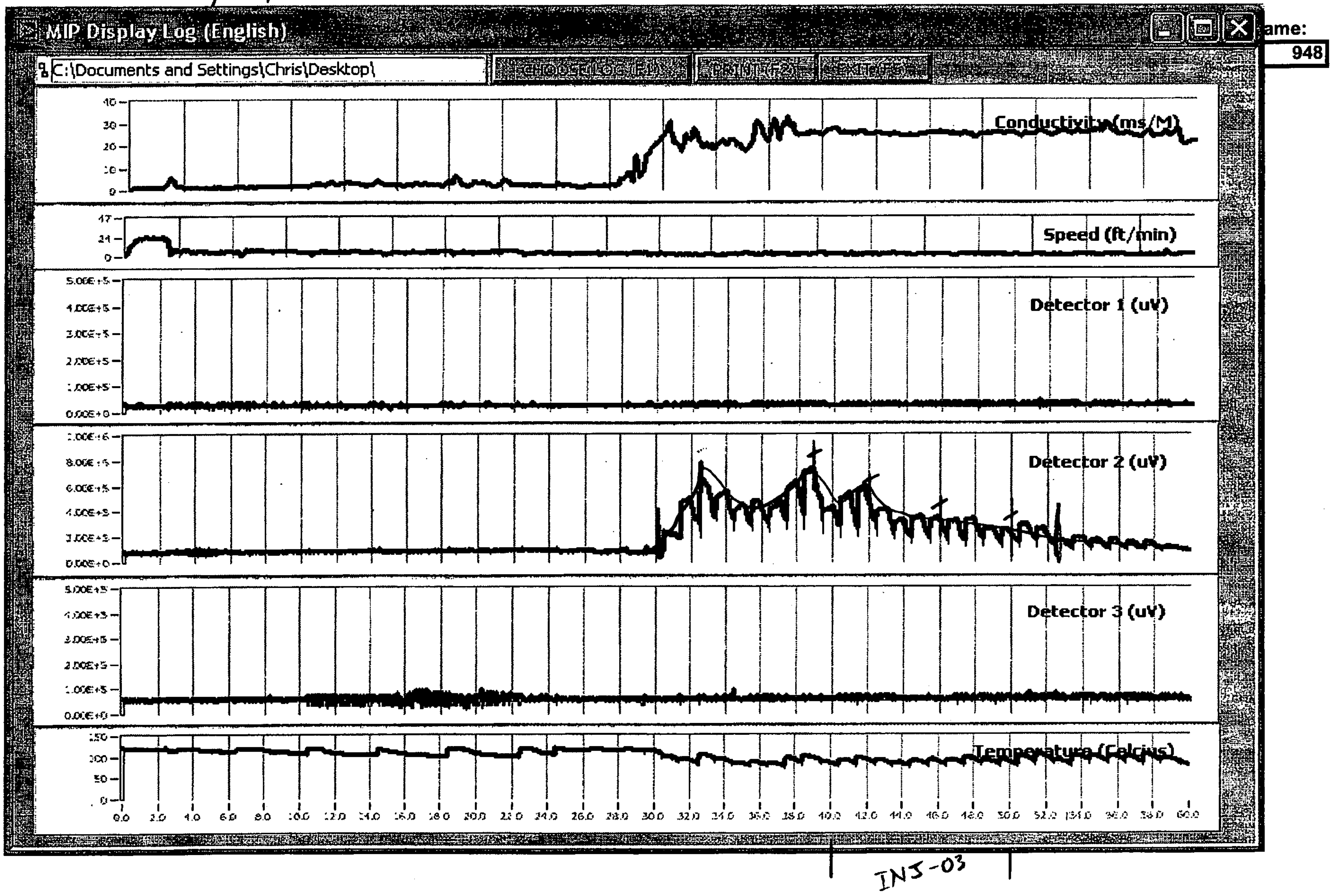
MIP-16



MIP Display Log (English)
C:\Documents and Settings\Chris\Desktop\
Conductivity (ms/M)
Speed (ft/min)
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Temperature (Celcius)
ame:
947

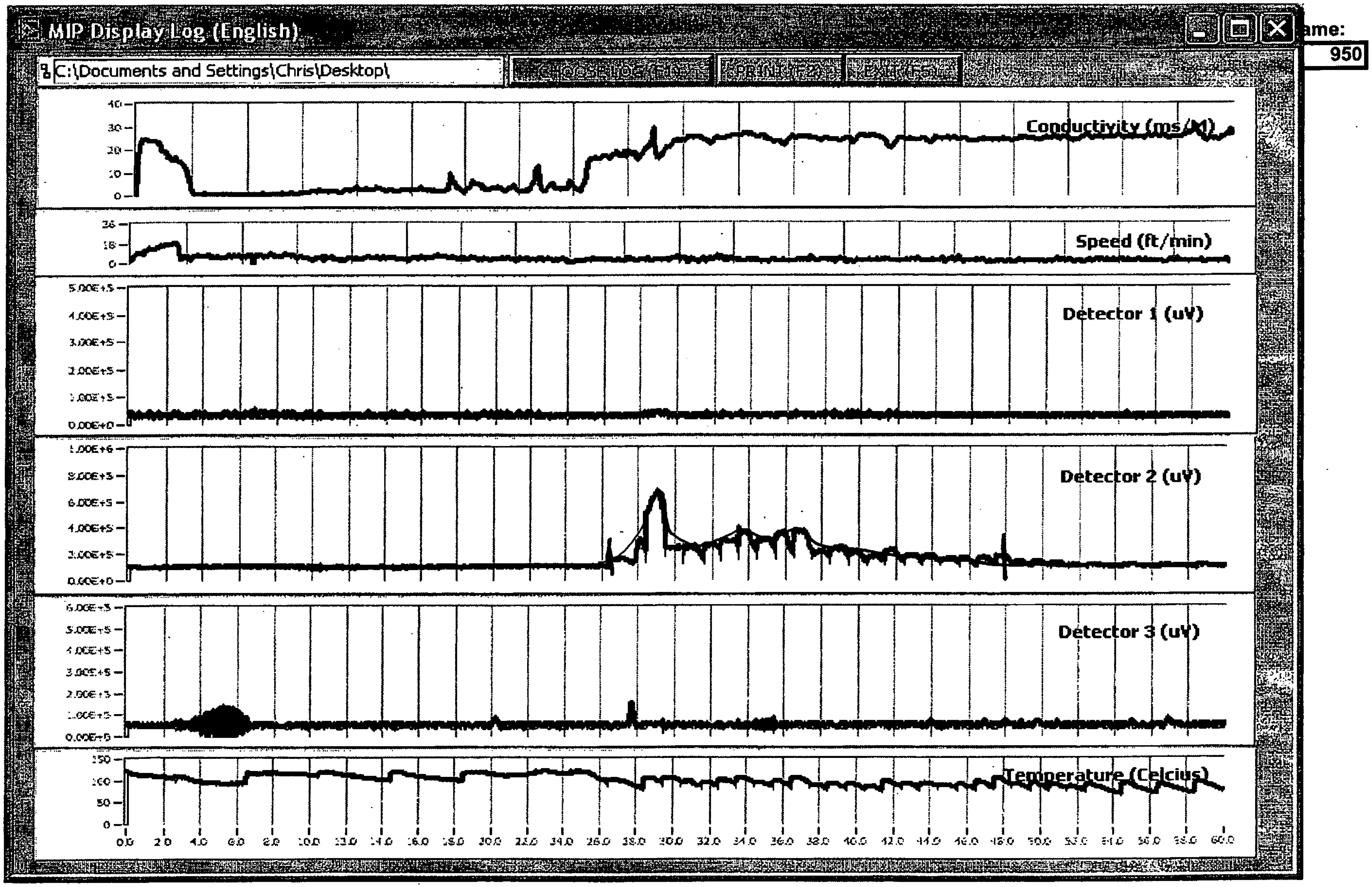
INJ 2,3

MIP-17



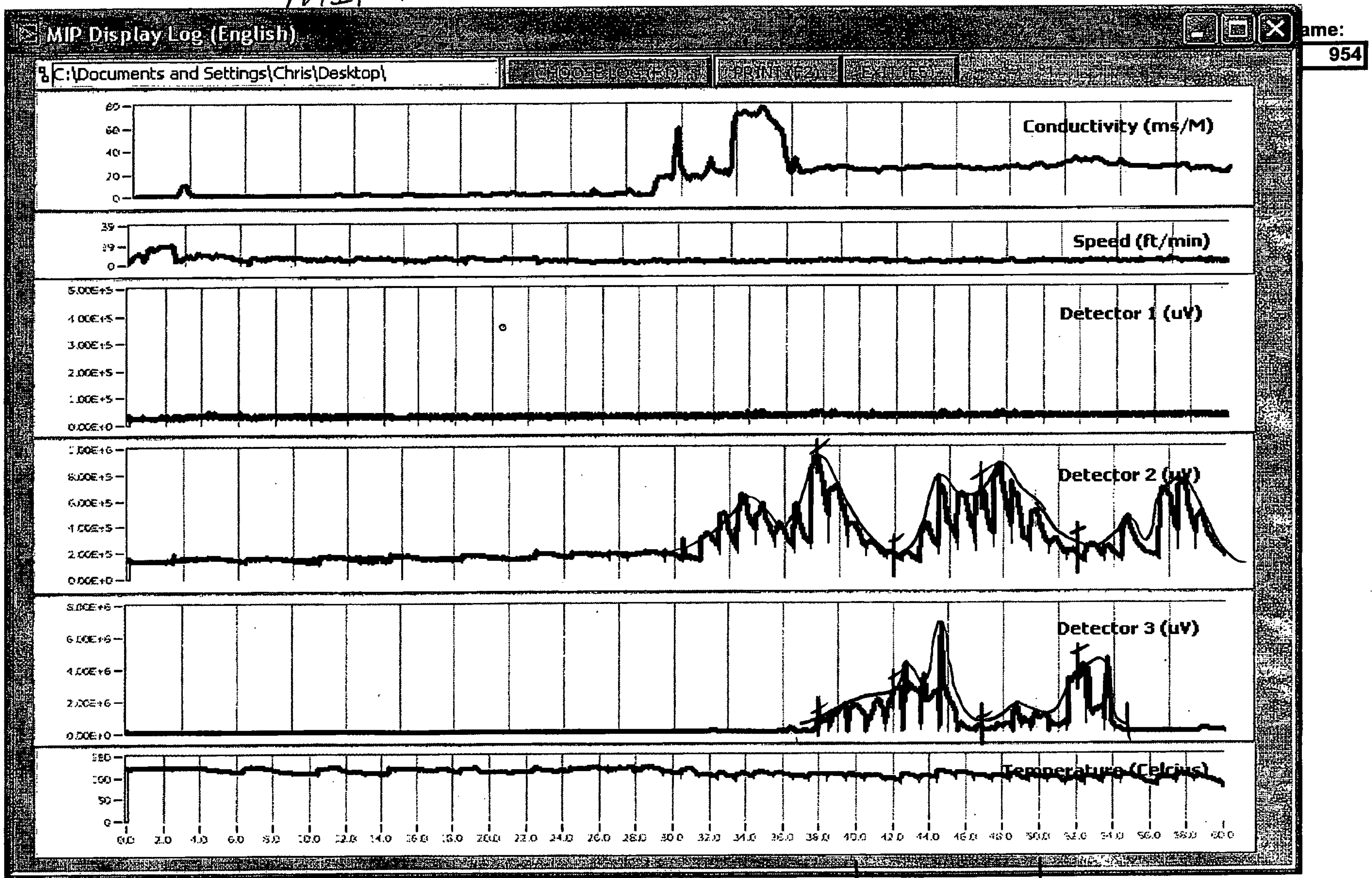
MIP Display Log (English)
C:\Documents and Settings\Chris\Desktop\
ame:
948
Conductivity (ms/M)
Speed (ft/min)
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Temperature (Celcius)
INJ-03

MIP-18



MIP Display Log (English)
C:\Documents and Settings\Chris\Desktop\
950
Conductivity (ms/M)
Speed (ft/min)
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Temperature (Celcius)

MIP-19

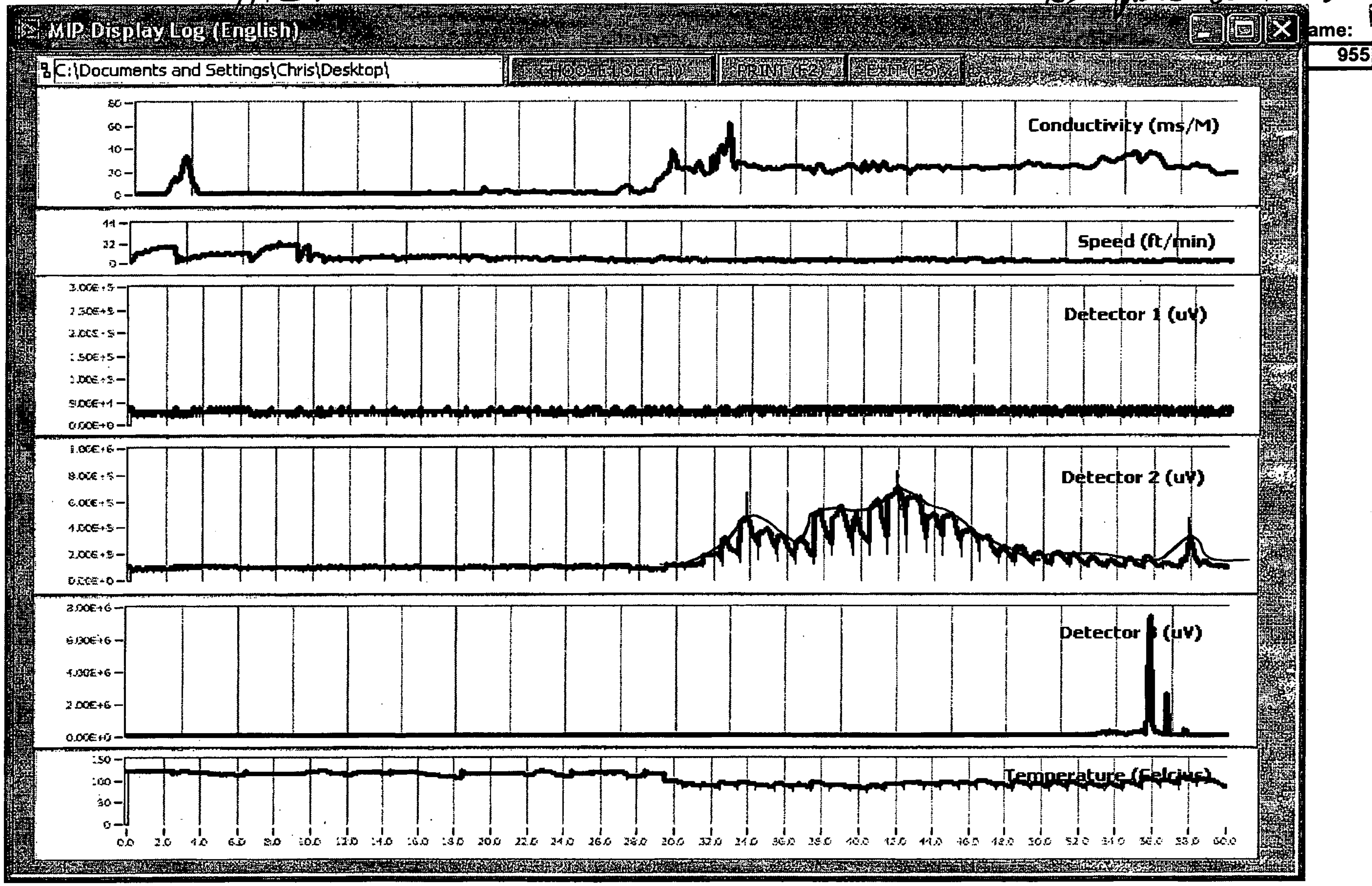


MIP Display Log (English)
C:\Documents and Settings\Chris\Desktop\
Conductivity (ms/M)
Speed (ft/min)
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Temperature (Celcius)
ame:
954

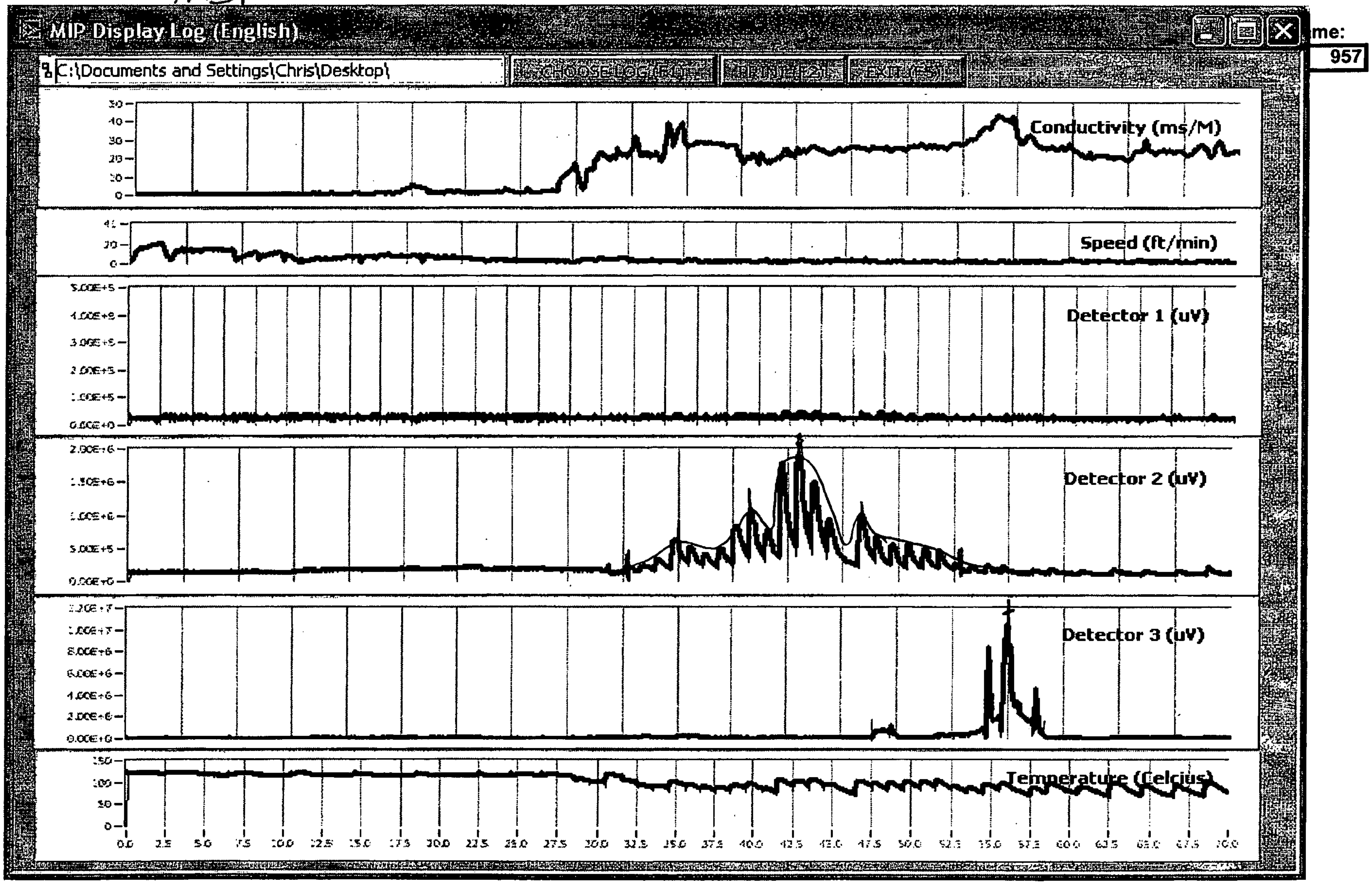
INJ-03

MIP-20

- lost probe at the bottom of Point

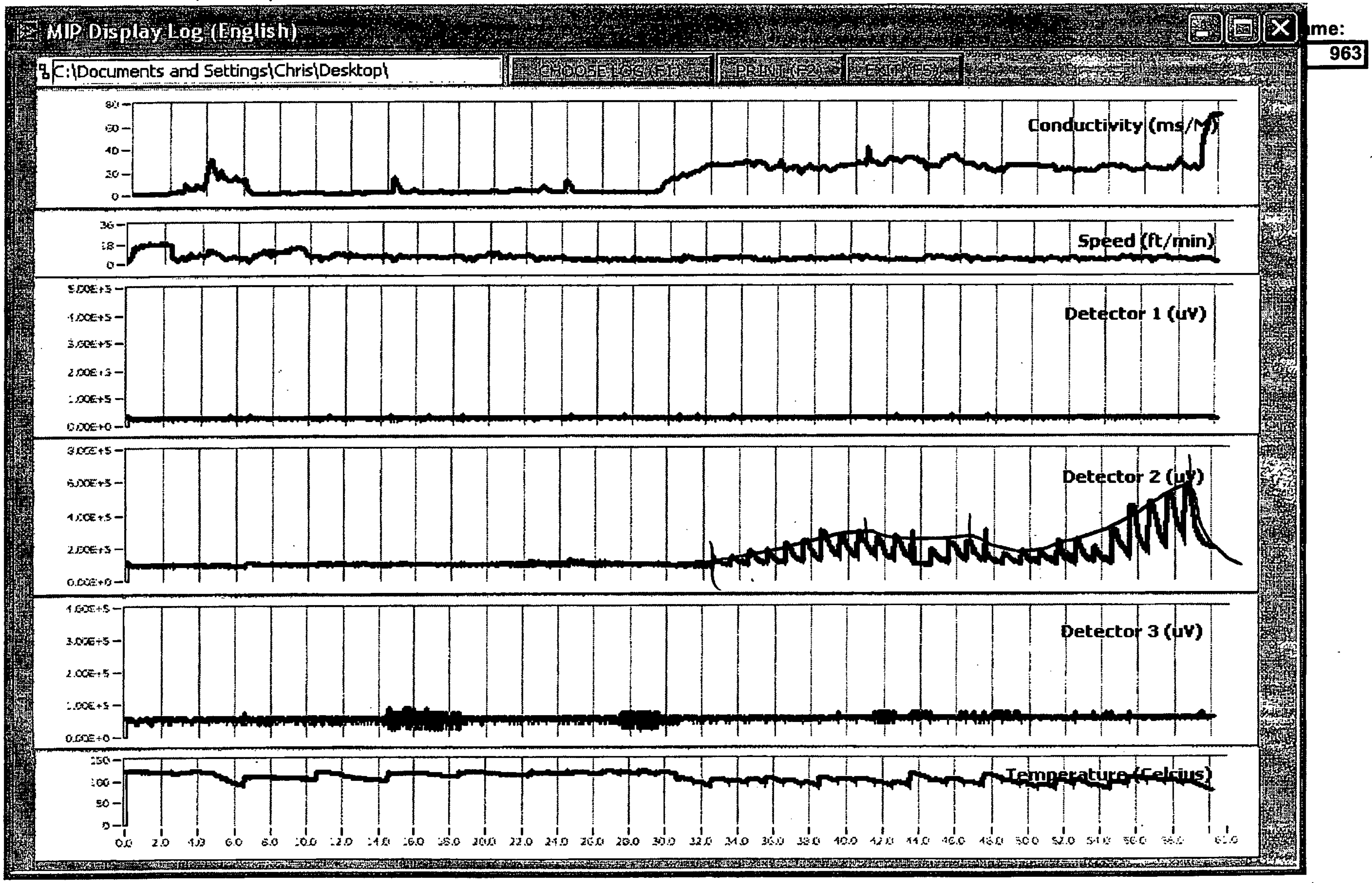


MIP-21

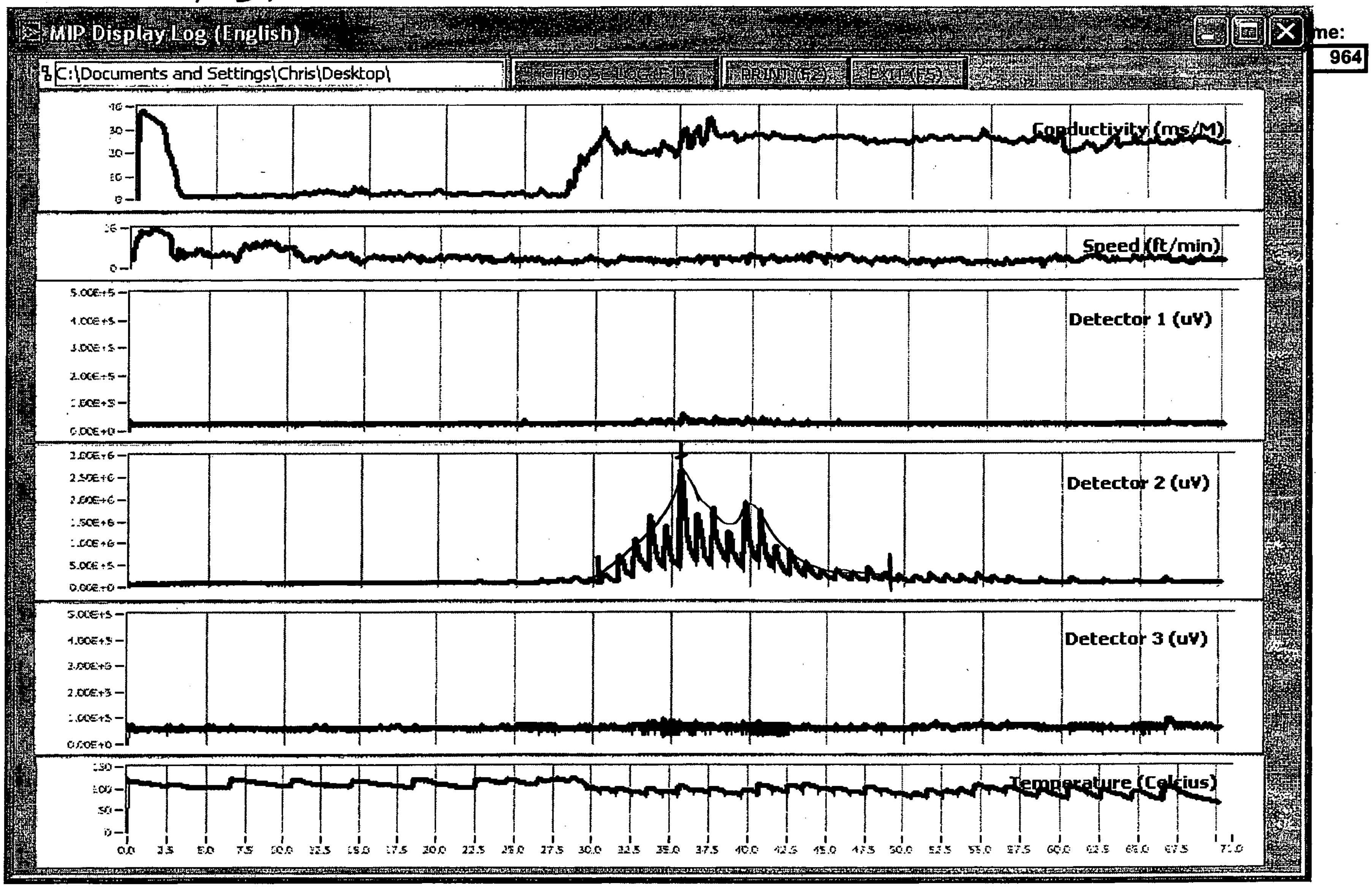


MIP Display Log (English)
C:\Documents and Settings\Chris\Desktop\
Conductivity (ms/M)
Speed (ft/min)
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Temperature (Celcius)
957

MIP-22

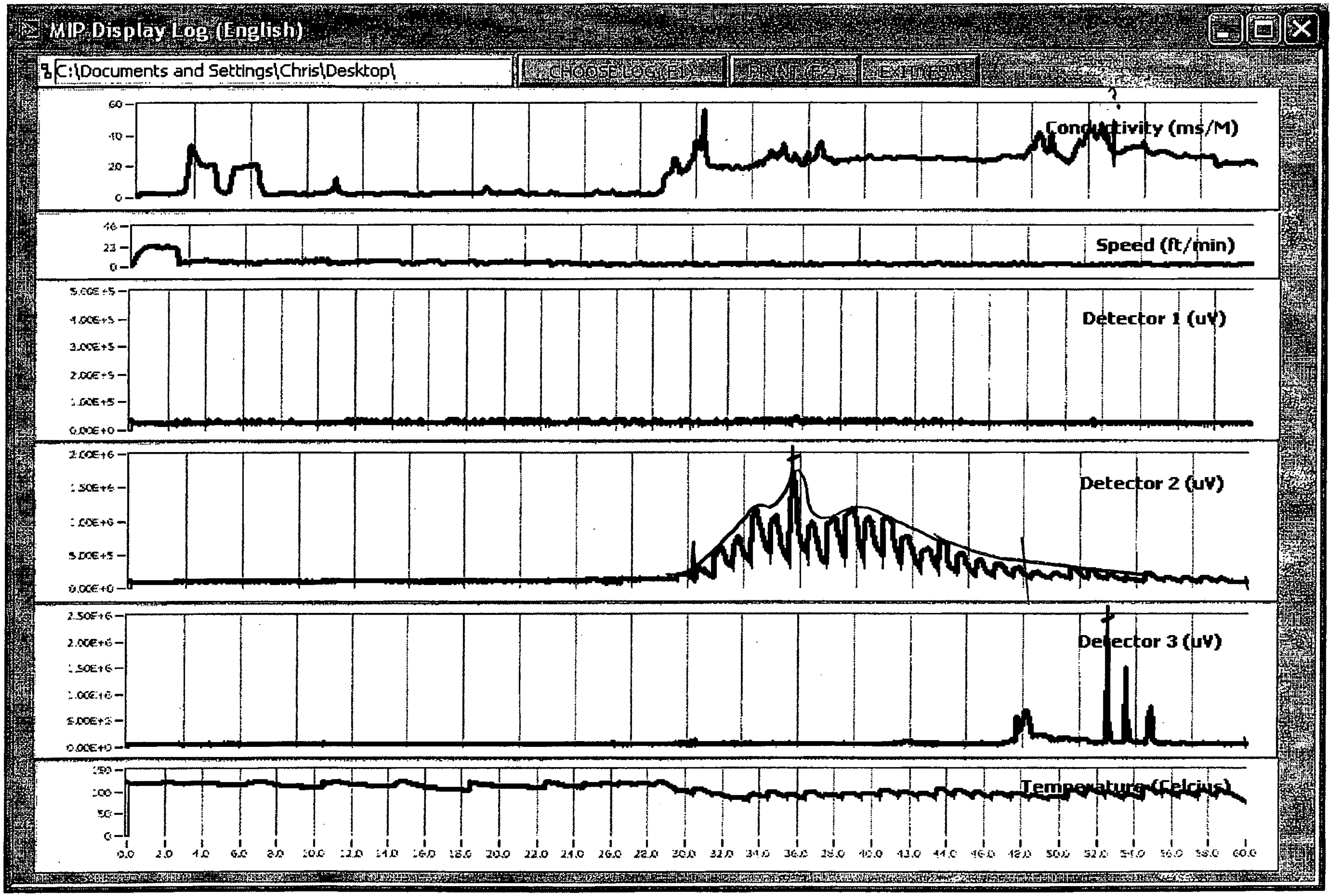

MIP Display Log (English)
C:\Documents and Settings\Chris\Desktop\
CHOOSE LOG (F1)
PRINT (F2)
EXIT (F5)
me:
963
Conductivity (ms/M)
80
60
40
20
0
Speed (ft/min)
36
18
0
Detector 1 (uV)
5.00E+5
4.00E+5
3.00E+5
2.00E+5
1.00E+5
0.00E+0
Detector 2 (uV)
8.00E+5
6.00E+5
4.00E+5
2.00E+5
0.00E+0
Detector 3 (uV)
4.00E+5
3.00E+5
2.00E+5
1.00E+5
0.00E+0
Temperature (Celcius)
150
100
50
0
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0 32.0 34.0 36.0 38.0 40.0 42.0 44.0 46.0 48.0 50.0 52.0 54.0 56.0 58.0 61.0

MIP-23

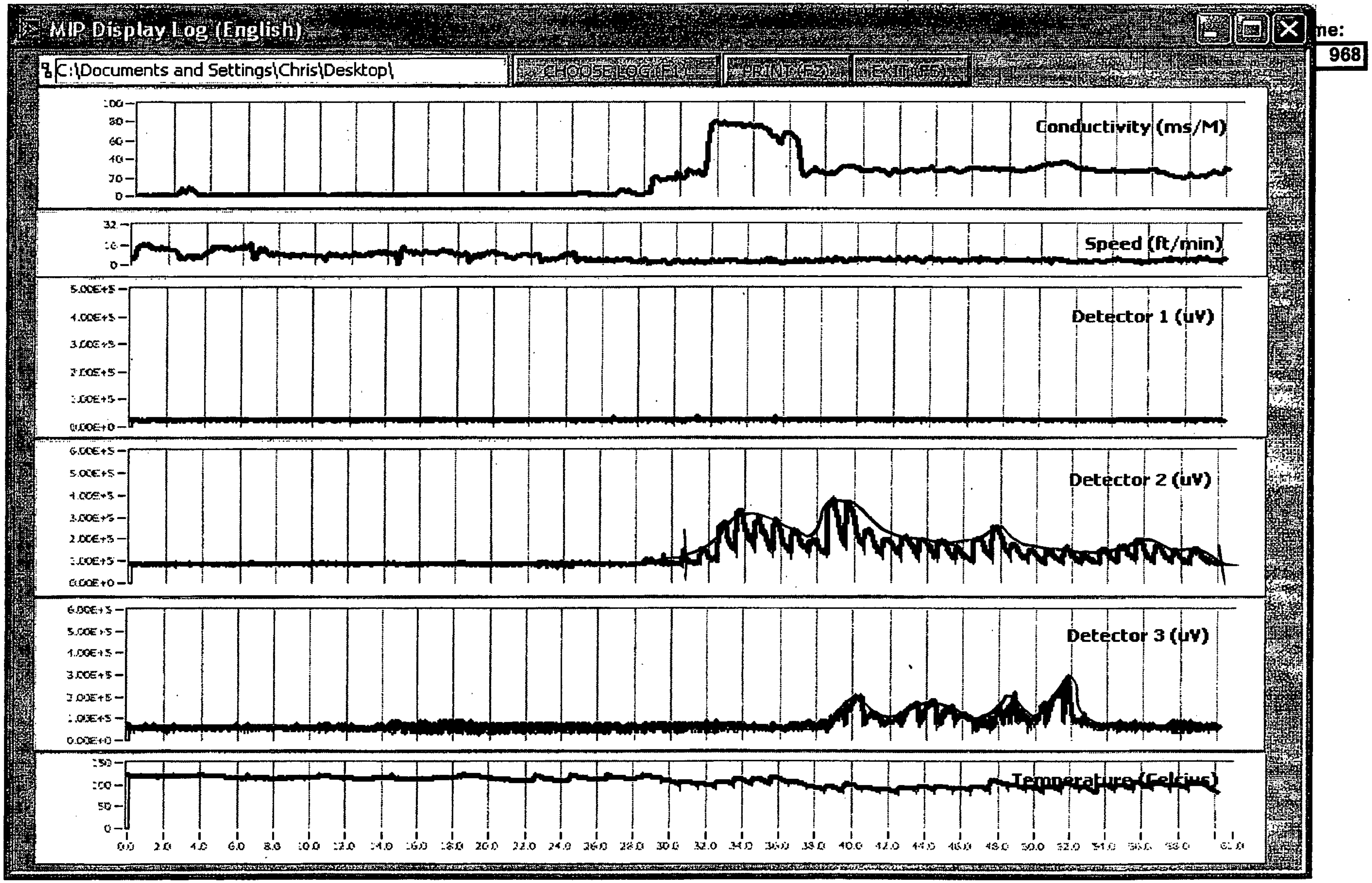


MIP Display Log (English)
C:\Documents and Settings\Chris\Desktop\
me:
964
Conductivity (ms/M)
Speed (ft/min)
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Temperature (Celcius)

MIP-24

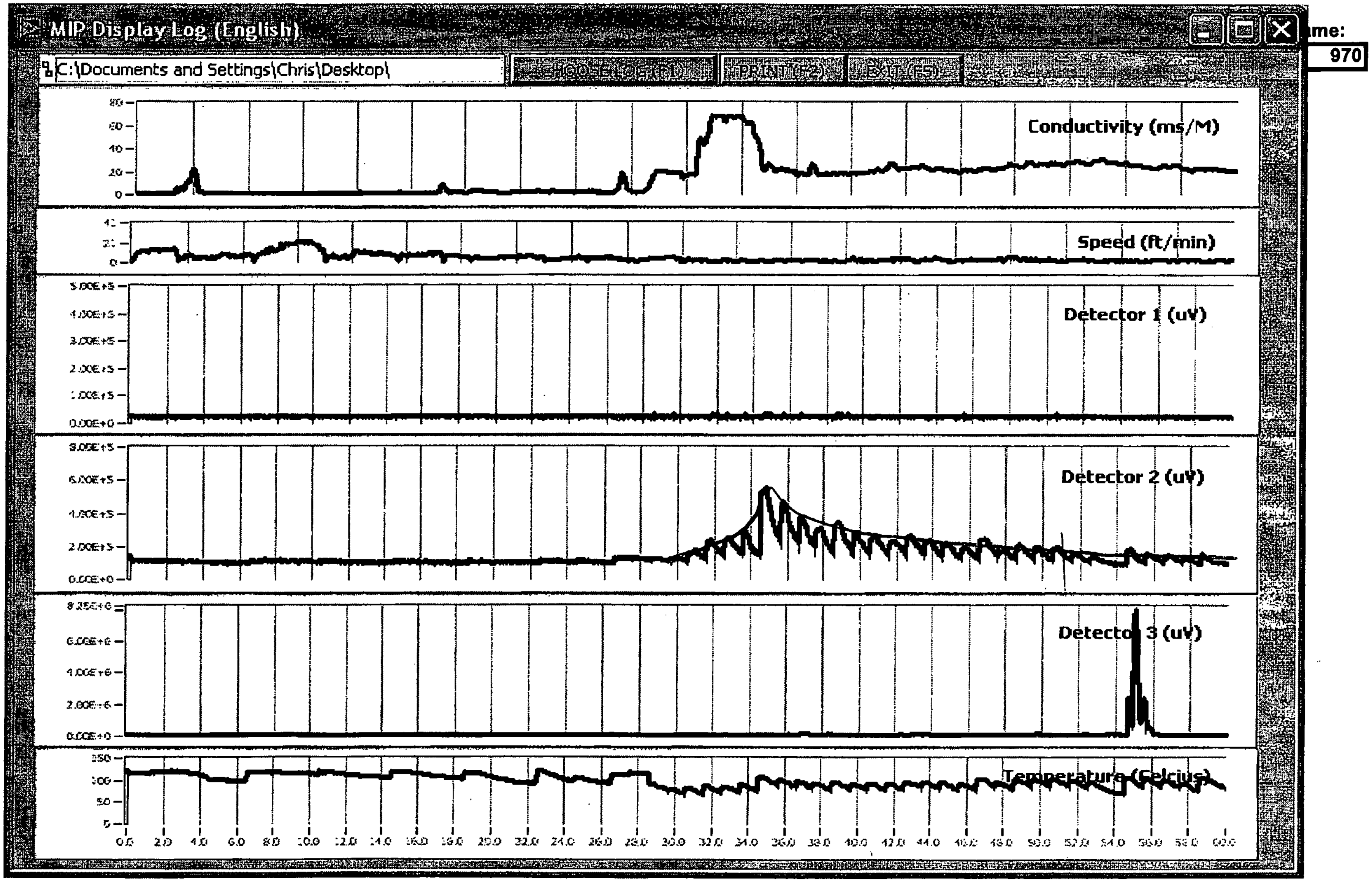

MIP Display Log (English)
C:\Documents and Settings\Chris\Desktop\
Conductivity (ms/M)
Speed (ft/min)
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Temperature (Celcius)

MIP-25

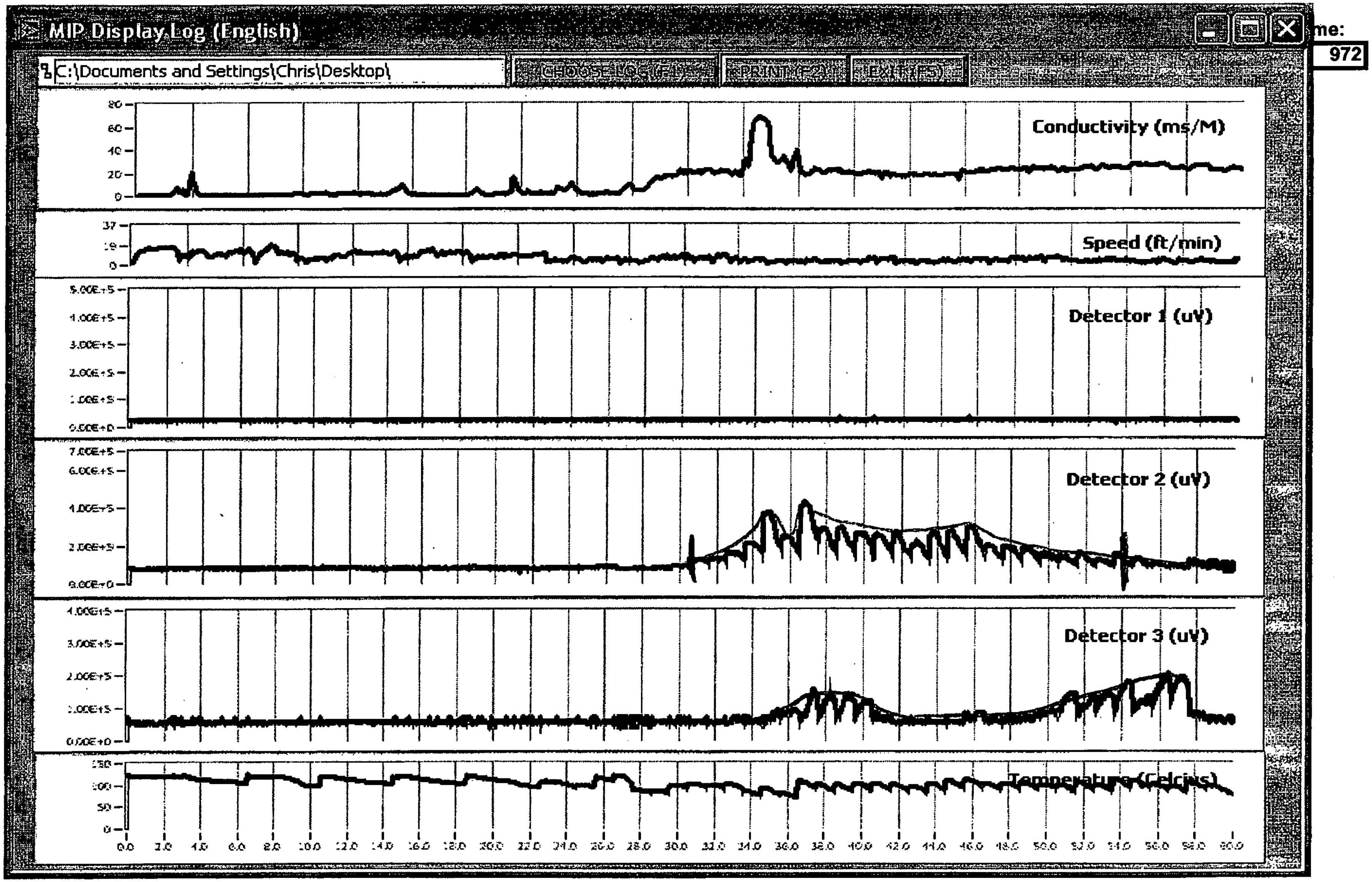


MIP Display Log (English)
C:\Documents and Settings\Chris\Desktop\
CHOOSE LOG (F1)
PRINT (F2)
EXIT (F5)
me:
968
Conductivity (ms/M)
Speed (ft/min)
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Temperature (Celcius)

MIP-26

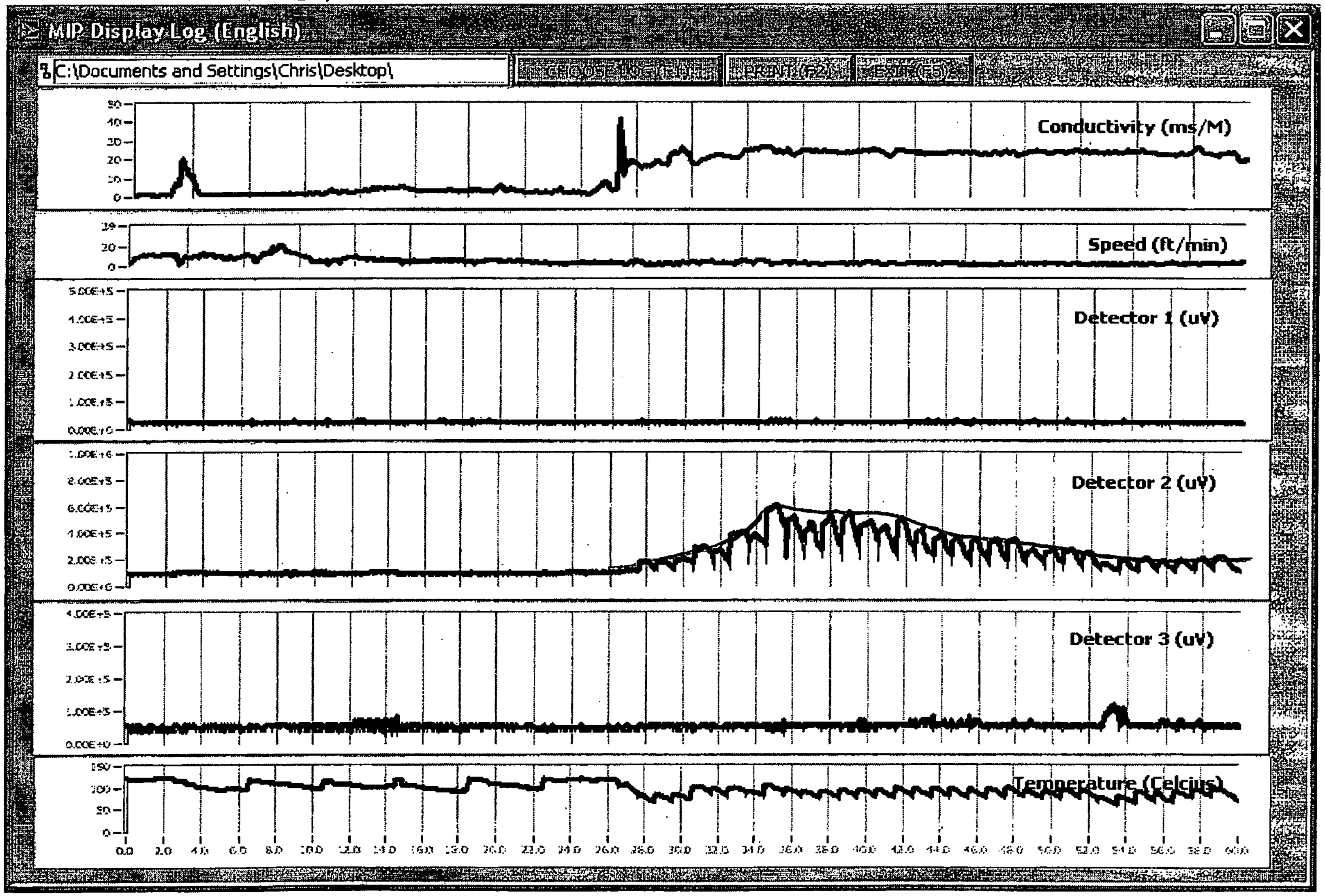

MIP Display Log (English)
C:\Documents and Settings\Chris\Desktop\
970
Conductivity (ms/M)
Speed (ft/min)
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Temperature (Celcius)

MIP-27



MIP Display Log (English)
C:\Documents and Settings\Chris\Desktop\
CHOOSE LOG (F1)
PRINT (F2)
EXIT (F5)
me:
972
Conductivity (ms/M)
Speed (ft/min)
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Temperature (Celcius)

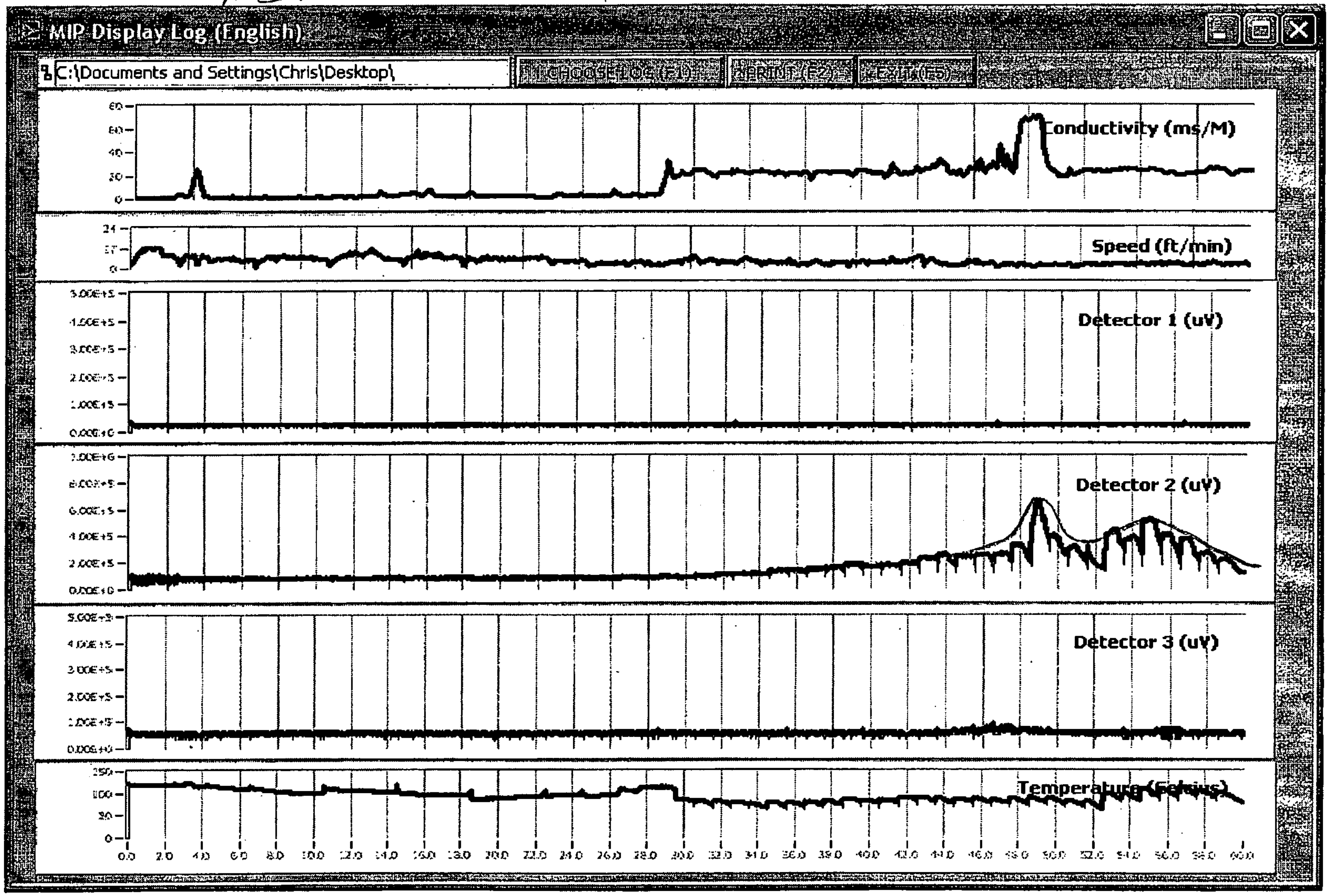
MIP-28



File name:

976

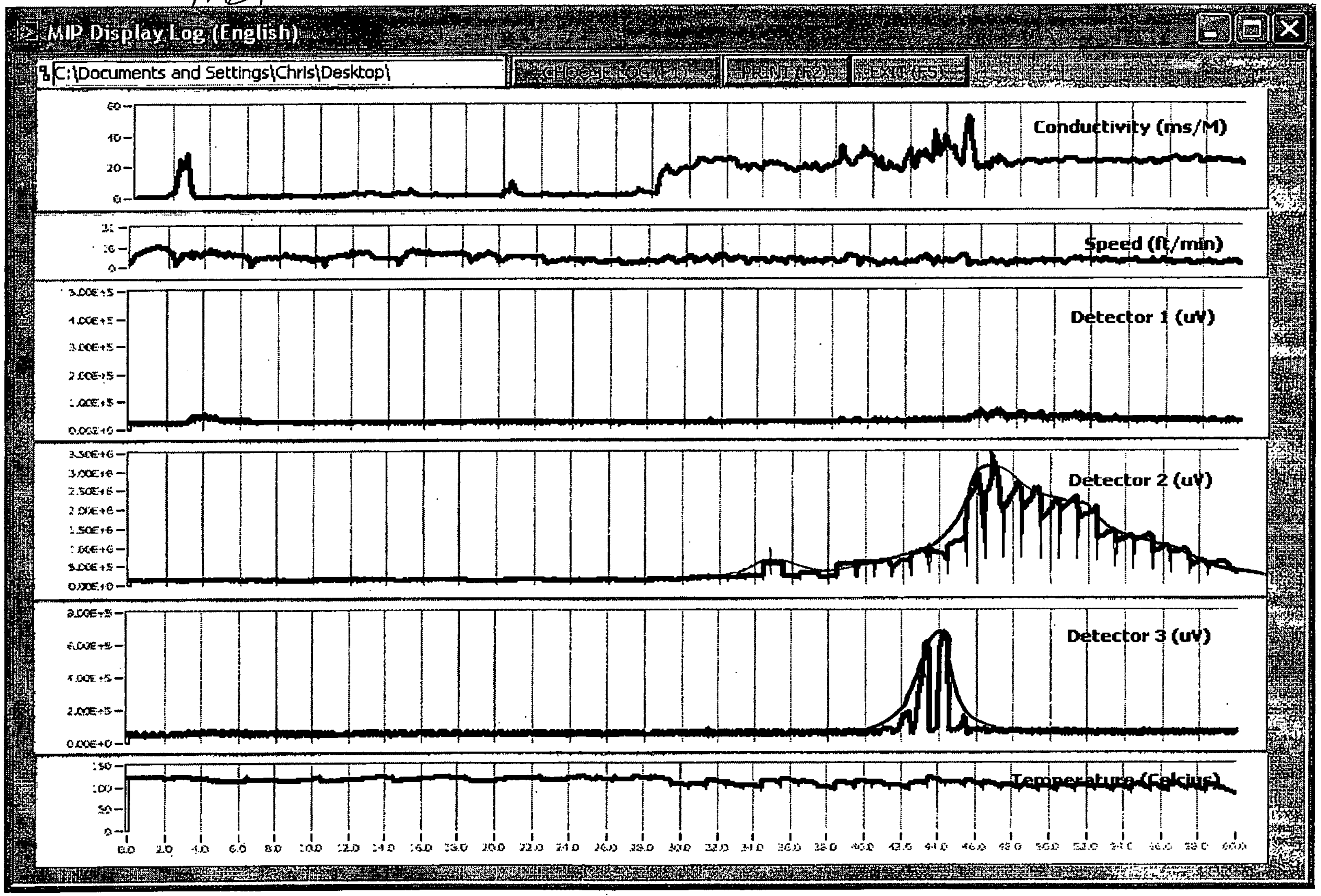
MIP-29



File name:

977

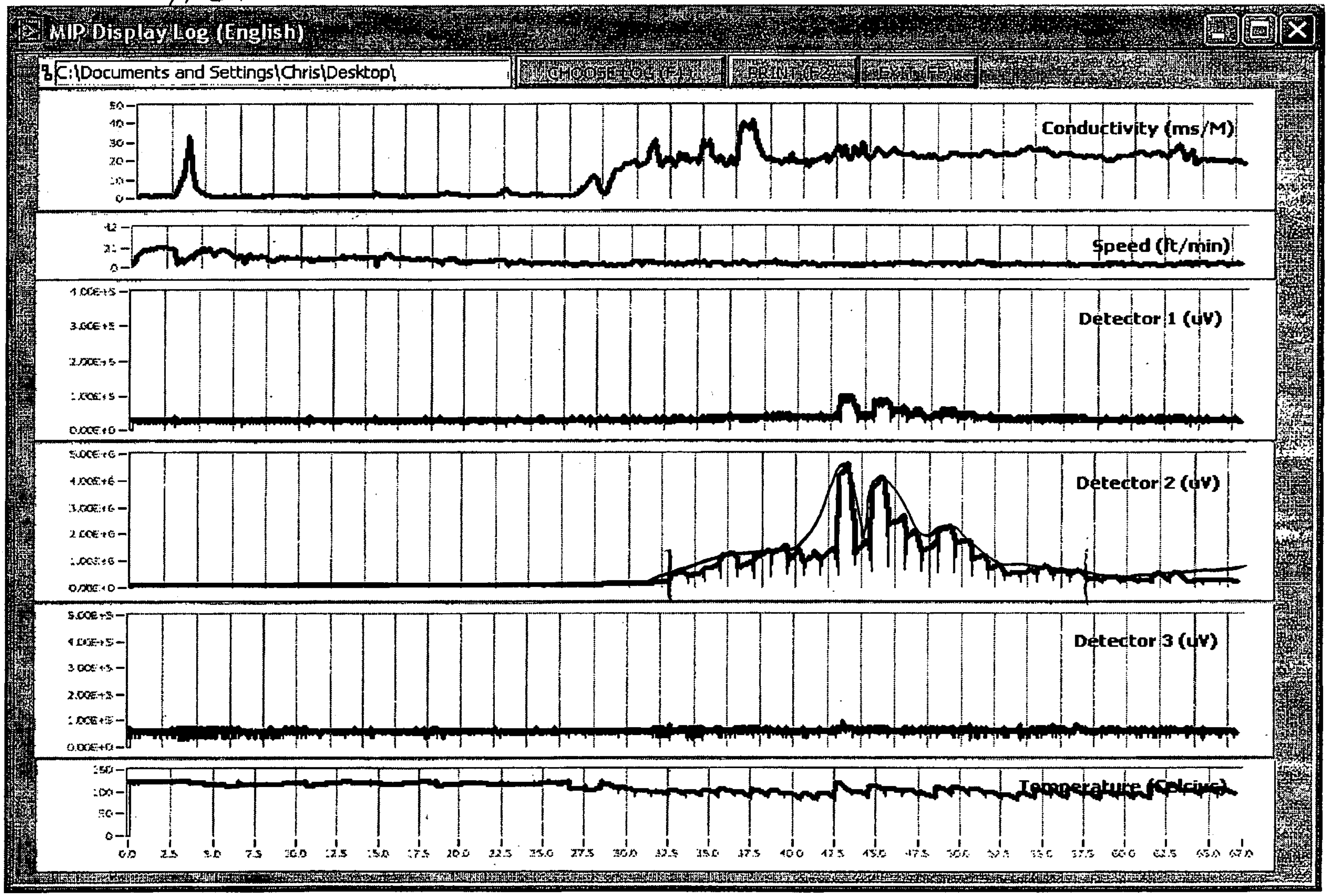
MIP-30



File name:

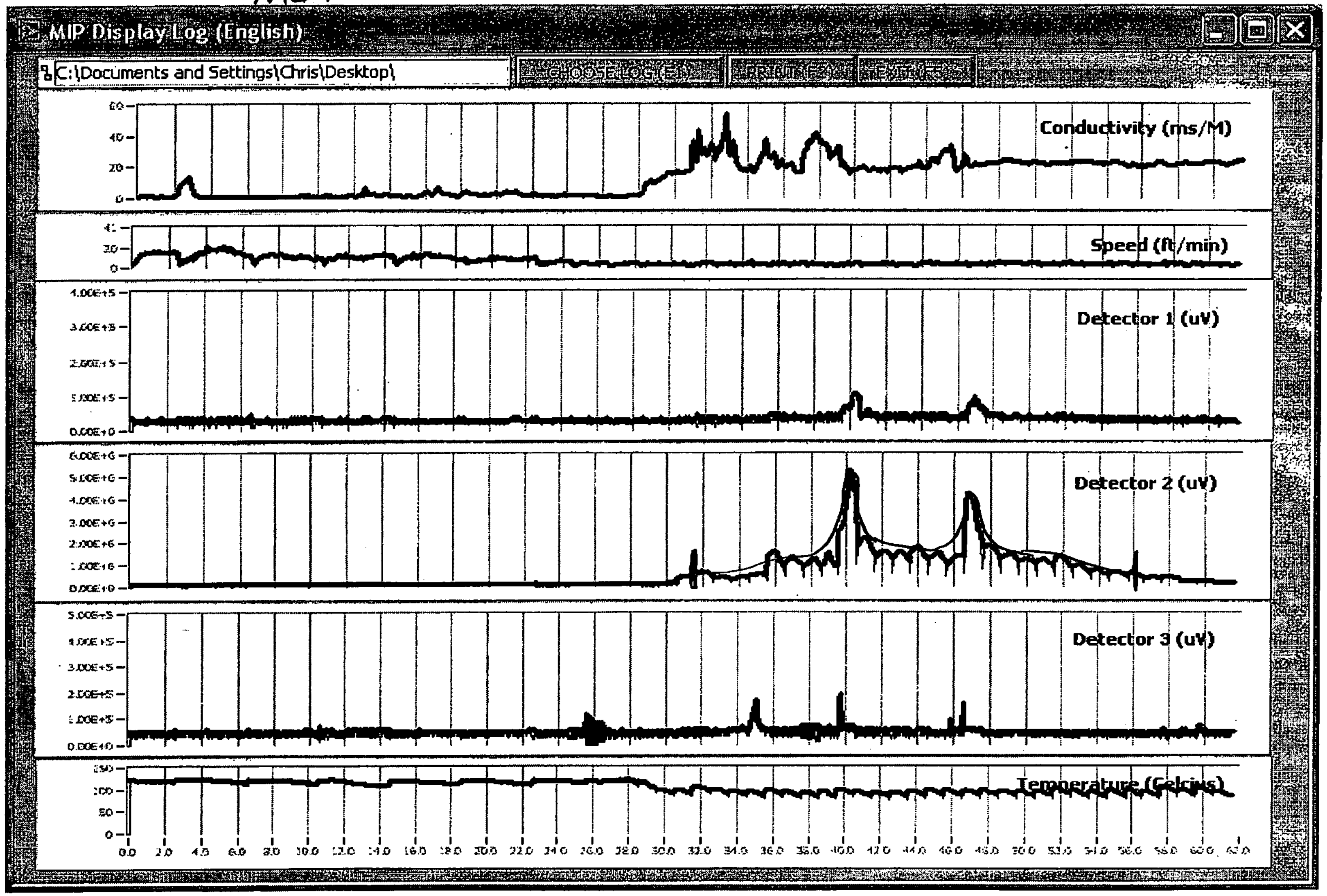
980

MIP-31



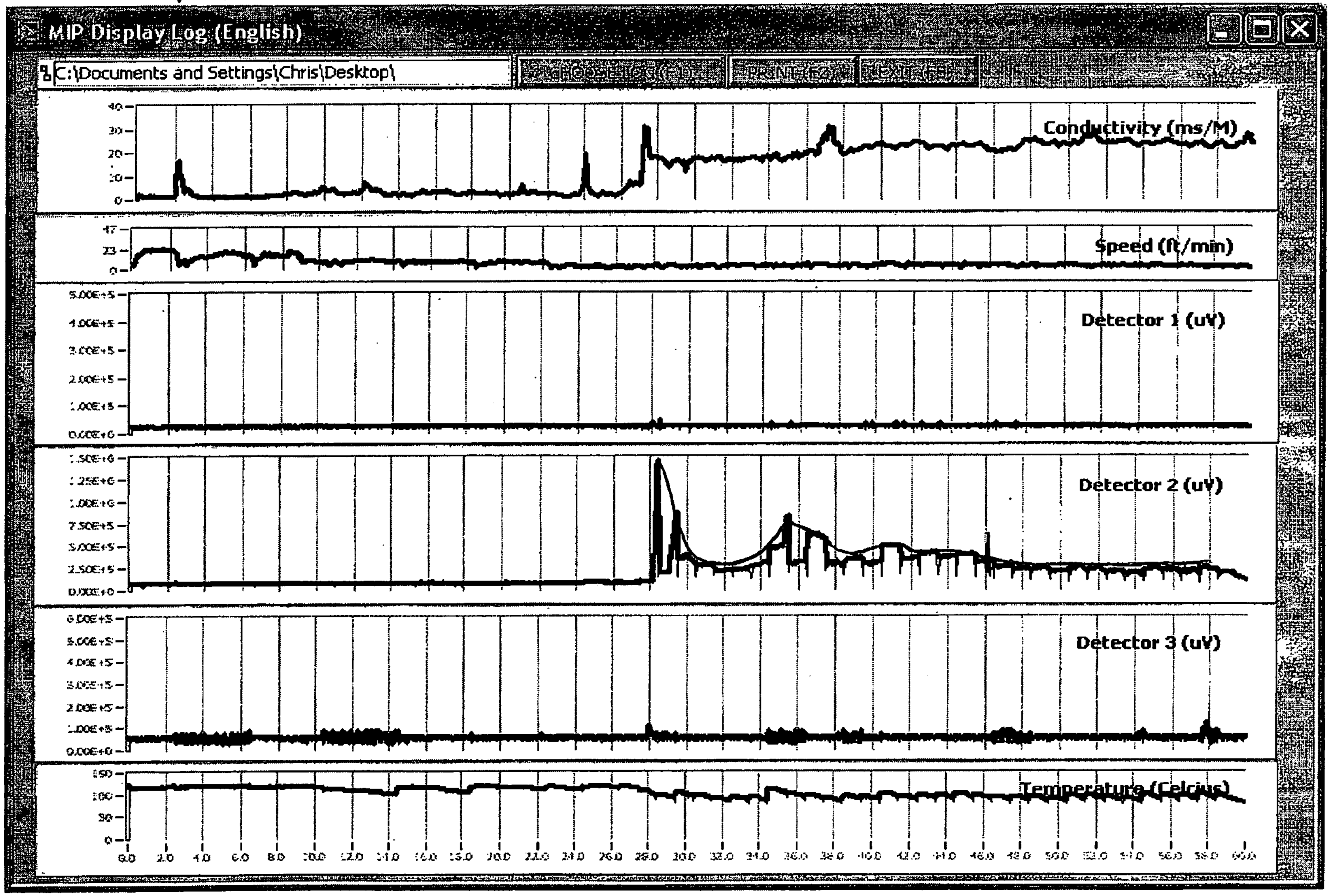
File name:
982

MIP-32



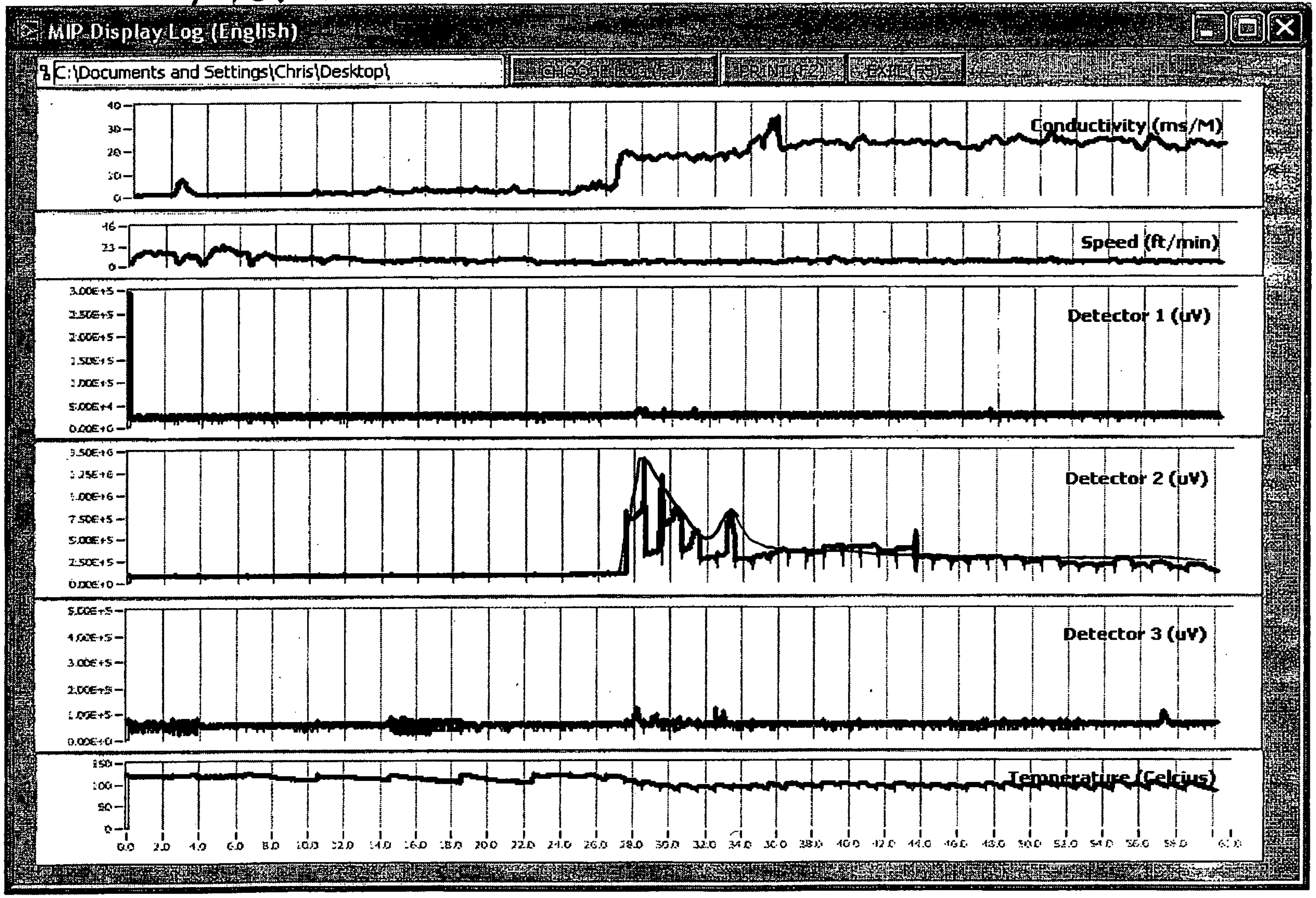
File name:
993

MIP-33



File name: 989

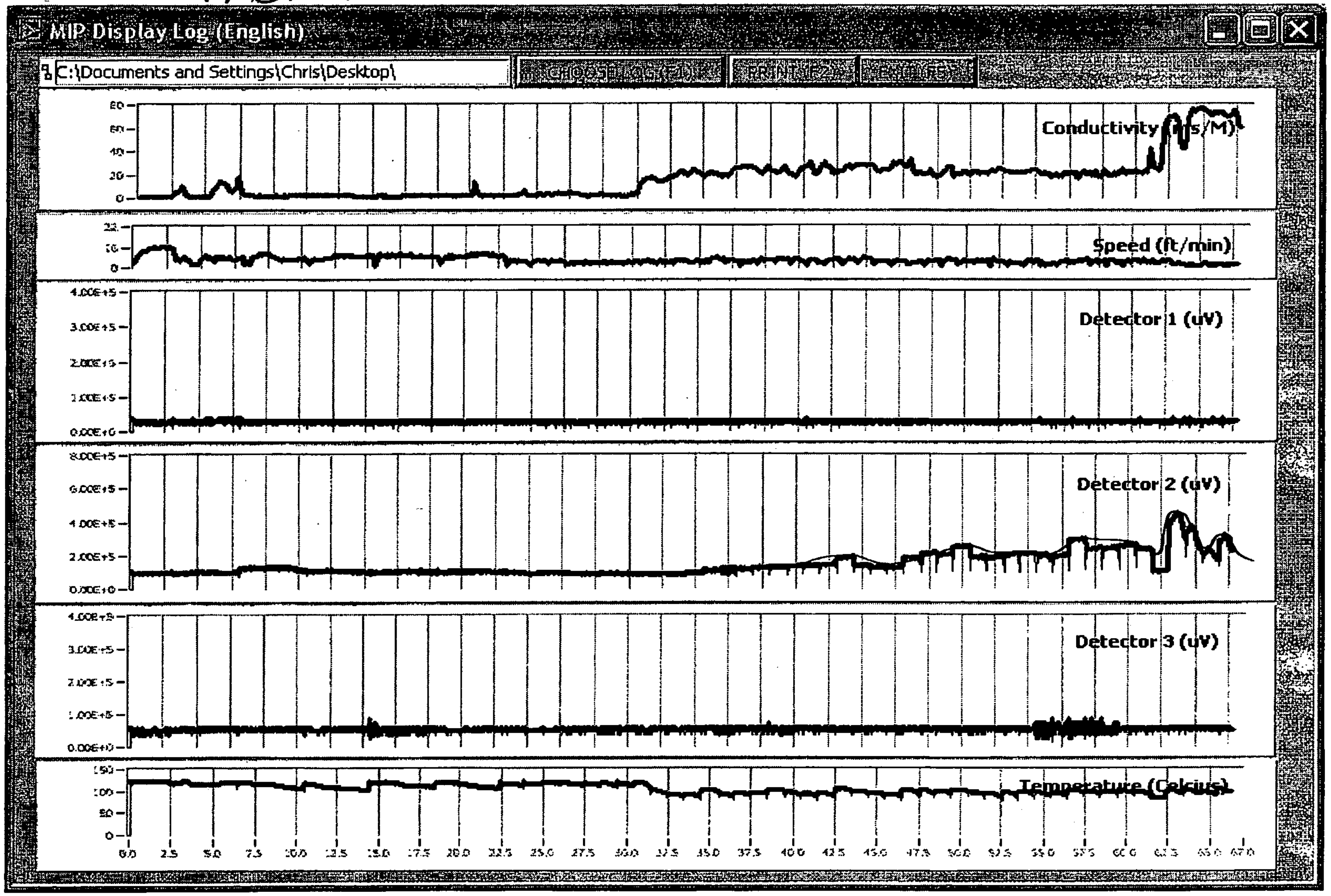
MIP-34



File name:

988

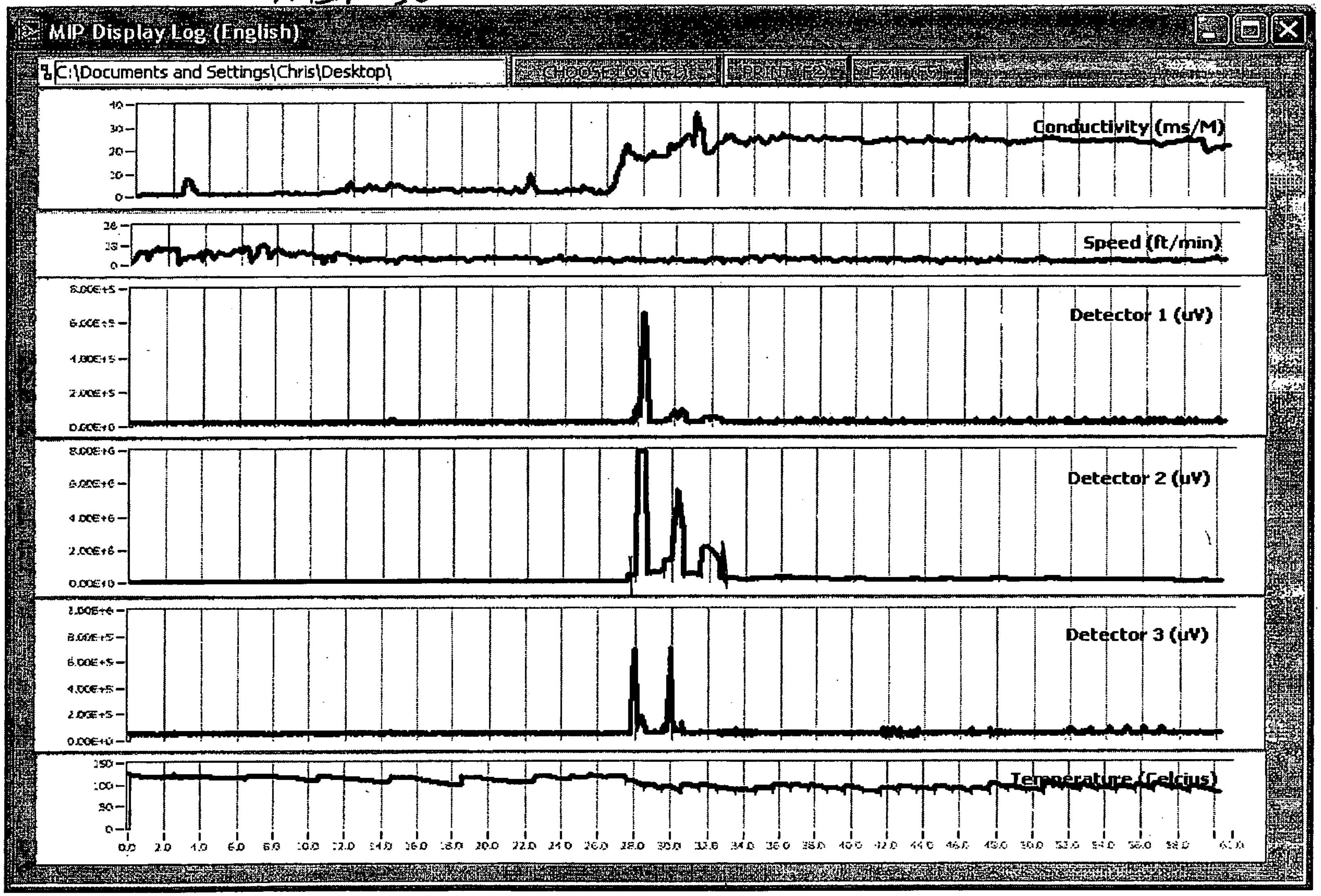
MIP-35



File name:

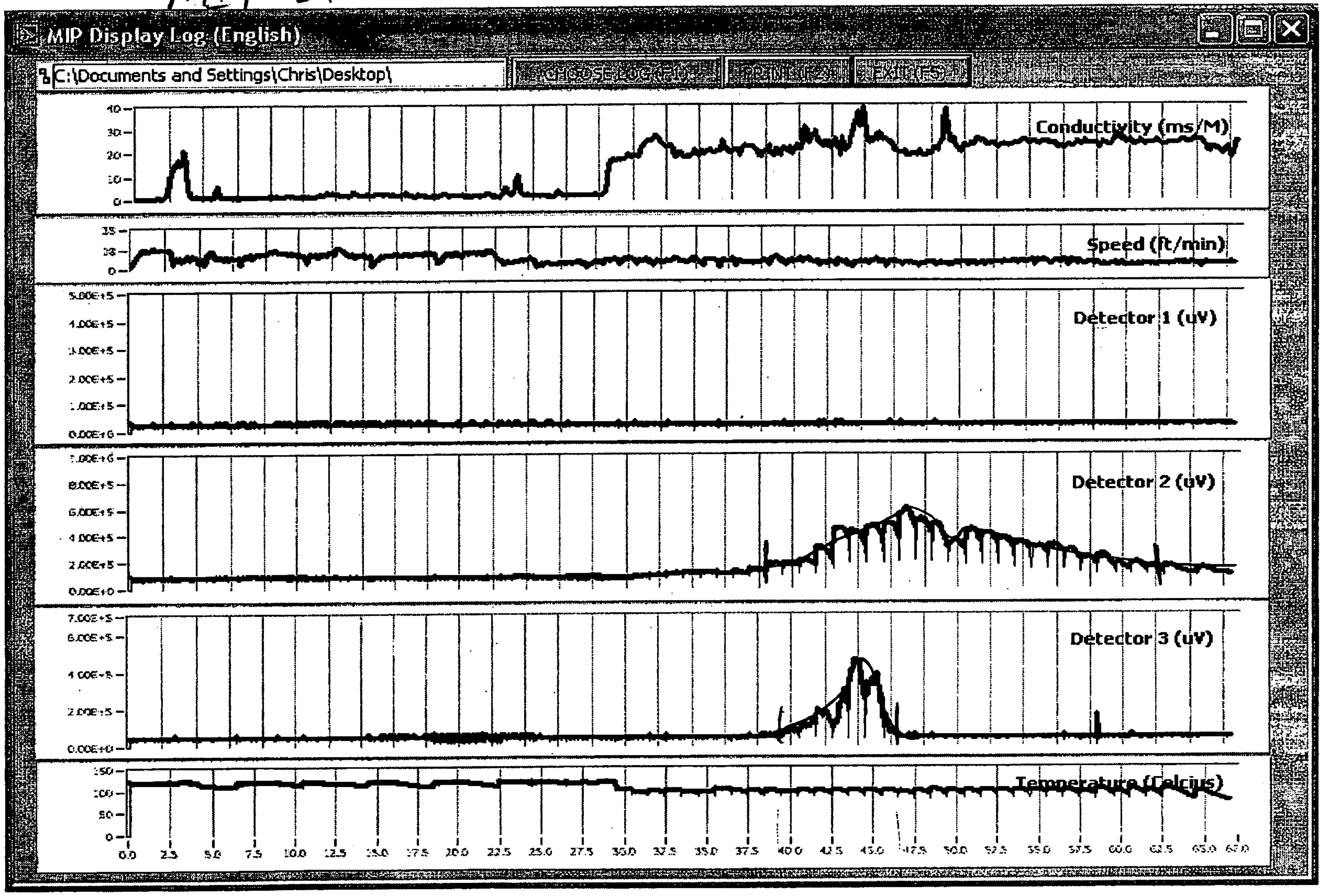
985

MIP-36



File name: 987

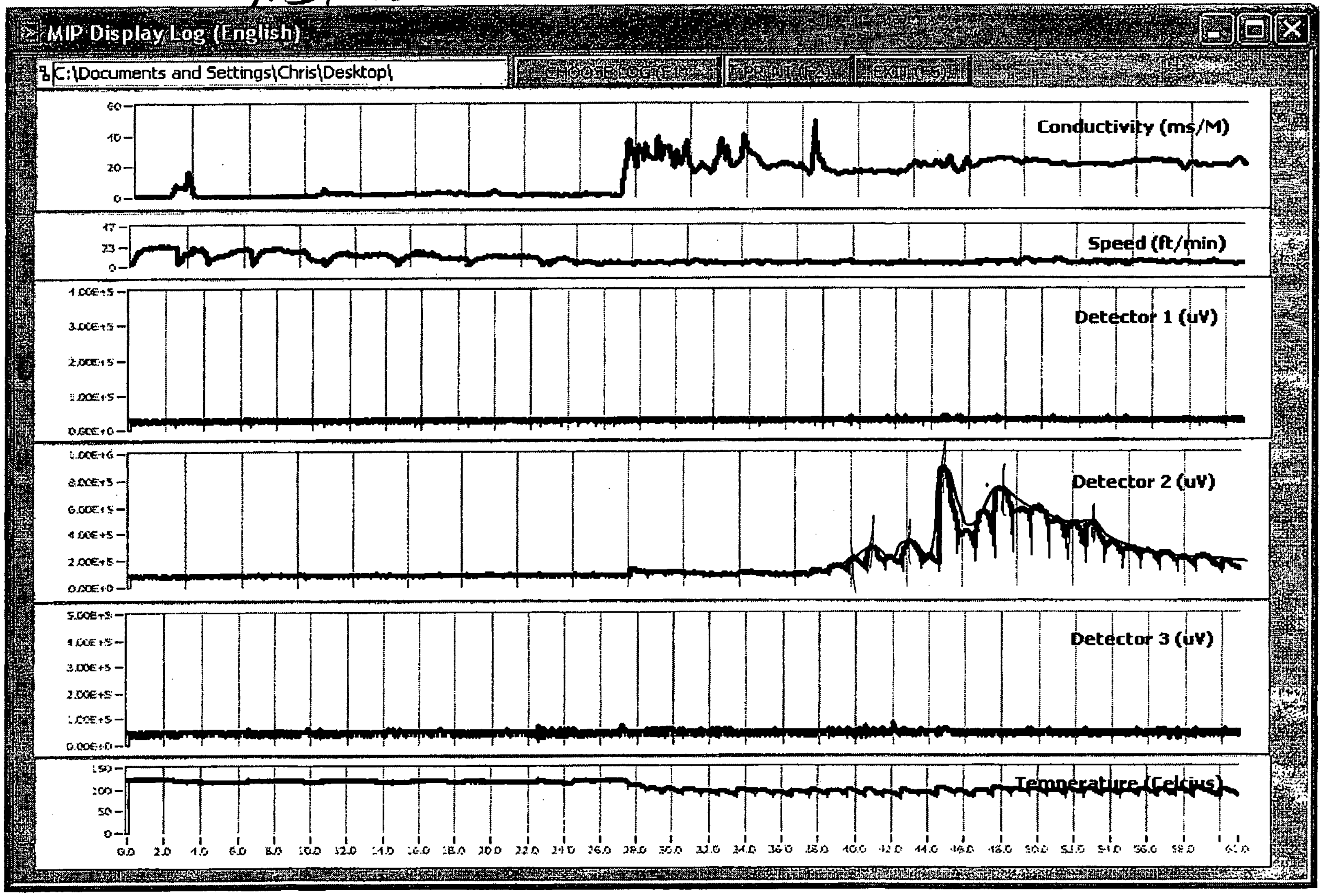
MIP-37



File name:

994

MIP-38



File name:

995

APPENDIX B

BORING LOGS