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DETECTION OF FUEL SPILLS IN WASTEWATER COLLECTION SYSTEMS

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DETECTION OF FUEL SPILLS IN WASTEWATER COLLECTION SYSTEMS

1. Purpose.

a. The purpose of this Public Works Technical Bulletin (PWTB) is to transmit the results of a technology demonstration conducted at Fort Bragg, NC. That study successfully demonstrated that fuel spills entering a sanitary sewer system could be automatically detected and reported to Directorate of Public Works (DPW) personnel by the use of specialized equipment placed in a manhole downstream of the spill.

b. All PWTBs are available electronically (in Adobe® Acrobat® portable document format [PDF]) through the World Wide Web (WWW) at the National Institute of Building Sciences' Whole Building Design Guide web page, which is accessible through URL:

http://www.wbdg.org/ccb/browse_cat.php?o=31&c=215

2. Applicability. This PWTB applies to all U.S. Army facilities where engineering activities have the responsibility to meet: pretreatment requirements for an industrial or domestic wastewater treatment system; the requirements of a Slug Control Plan; the requirements of a Spill Control and Countermeasure Plan; or, the requirements of a National Pollution Discharge Elimination System (NPDES) permit.

3. References.

a. Army Regulation (AR) 200-1: Environmental Protection and Enhancement, 13 December 2007

b. Title 40, Code of Federal Regulations (CFR), part 403: EPA's General Pretreatment Regulations for Existing and New Sources of Pollution.

4. Discussion.

a. AR 200-1 requires that Army installations comply with Federal environmental regulations, including standards for the pretreatment of industrial wastewater, established by the USEPA under the authority of the Clean Water Act (CWA).

b. 40 CFR 403 describes both general and specific limitations on the discharge of wastewater from industrial users to publicly owned treatment works (POTW). These limitations also apply to industrial discharges flowing to Federally Owned Treatment Works (FOTW). According to the general limitations defined in the CFR, no industrial user can introduce into a treatment works any pollutant that will cause interference with the operation of a wastewater treatment plant (WWTP).

c. It is valuable for DPW personnel at Army installations, to have the capability to detect fuel in their wastewater collection systems. Fuel spills that occur at motor pools can enter the wastewater collection system and then, cause upset conditions at the receiving WWTP. In turn, this could cause the plant to be non-compliant with its NPDES permit and also could lead to a Notice of Violation (NOV) being given to the FOTW that serves the installation. Or, because Army installation wastewater is often discharged to a publicly or privately owned treatment works, these fuel spills could result in financial claims against the Army. Therefore, a method to detect accidental fuel discharges into the collection system would help to minimize their impacts on downstream treatment systems.

i. Recognizing the need to detect fuel slugs in sanitary sewers, environmental personnel at Fort Bragg proposed a study be conducted under the Waste Minimization and Pollution Prevention (WMPP) program managed by the Engineer Research and Development Center – Construction Engineering Research Laboratory (ERDC-CERL) in Champaign, IL. As a result, a study was funded through WMPP to determine if fuel detectors could be used to notify operators of the Fort Bragg sewage treatment plant that a significant quantity of fuel had entered the collection system. The study was conducted in 2006 by MSE Technology Applications, Inc. (MSE), of Butte, MT, the prime contractor for executing the WMPP program.

ii. MSE evaluated fuel detector literature, then selected and tested a system that was capable of identifying the fuel vapors in a lift station headspace. The capable system would not be affected by methane or other gases normal to the environment. Bench scale testing determined that a photoionization detector (PID) from RAE Systems, Inc. would provide the desired response. Field tests were then conducted to test the PID sensors in the WWTP system at Fort Bragg. During the testing, methane gas levels and pump status were monitored to determine their effects on the PID sensor. Results showed that the PID sensor effectively detected fuel hydrocarbon vapors in the lift station vaults.

iii. MSE recommended that Fort Bragg install the RAEGuard PID fixed units at key lift stations and use them to detect fuel entering the wastewater collection system. Detection of fuel spills would be relayed to the WWTP and environmental personnel by an existing Supervisory Control and Data Acquisition (SCADA) system. The resulting system would provide early warning, allowing Fort Bragg spill response personnel to react quickly, preventing the incoming fuel from upsetting the treatment plant. The detection system would also provide information that would help to identify the source of a spill and allow rapid investigation of each incident.

iv. MSE also pointed out specific interferences and shortcomings when using the RAEGuard equipment and recommended ways in which these could be overcome.

v. Due to changes in personnel within the Fort Bragg DPW Environmental Division after the completion of this study, funding has not yet been sought to install a spill detection system with the sanitary sewer system.

d. See Appendix A, Detection Of Fuel Spills In The Fort Bragg Wastewater Collection System, for further information regarding the Fort Bragg study. Appendix A is the final report submitted by MSE to ERDC-CERL, edited for format and clarity.

e. A glossary of abbreviations is located in Appendix B.

5. Points of Contact (POCs). Headquarters, U.S. Army Corps of Engineers(HQUSACE) is the proponent for this document. The POC at HQUSACE is Mr. Malcolm E. McLeod, CEMP-II, 202-761-0632, or e-mail: Malcolm.E.Mcleod@hq02.usace.army.mil.

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Appendix A:
Detection of Fuel Spills in the Fort Bragg Wastewater Collection System

Foreword

This project was funded through the Waste Minimization and Pollution Prevention Program (WMPPP) by the U.S. Department of Army Office of the Assistant Chief of Staff for Installation Management (OACSIM). The WMPP was administered by the U.S. Army Engineer Research and Development Center–Construction Engineering Research Laboratory (ERDC–CERL). The study was conducted by MSE Technology Applications, Inc. (MSE), of Butte, Montana.

The major contributors to this project include:

- Mr. Joe Mullaney, MSE Project Engineer
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- Mr. David Franklin, MSE Project Manager
- Mr. Scott Lear, MSE Project Engineer
- Mr. Steve Antonioli, MSE Program Manager
- Ms. Lynne Vaughn, Fort Bragg, North Carolina, Military Reservation
- Mr. Gary Gerdes, ERDC-CERL WMPP Program Manager

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Introduction

Background

Fort Bragg, NC, operates its own wastewater collection and treatment system, which also serves the adjoining Pope Air Force Base (AFB). Occasionally, accidental fuel spills at vehicle maintenance or other facilities enter the wastewater collection system. This might occur when spills enter floor drains leading directly to a sanitary sewer, or if a spill exceeds the storage capacity of an oil/water separator that discharges to a sanitary sewer. When this fuel reaches the wastewater treatment plant (WWTP), it causes upset conditions that are costly and difficult to remedy. In order to minimize impacts from fuel discharges, Fort Bragg needed a method to detect the discharge source in the collection system, prior to the fuel reaching the WWTP. Environmental personnel at Fort Bragg requested that the Waste Minimization and Pollution Prevention (WMPP)Program conduct a study to determine the feasibility of implementing spill detection upstream of their wastewater treatment plant. The WMPP Program subsequently selected that study for funding, and the study was executed by MSE Technology Application, Inc. (MSE), of Butte, MT. (MSE serves as the prime contractor for the WMPP Program.)

Objectives

The primary objective of the project was to determine if fuel vapor sensing equipment could be used to detect fuel spills entering lift stations in the Fort Bragg wastewater collection system.

Approach

MSE evaluated various types of sensors to determine which would be technically suited to detect fuel in the Fort Bragg WWTP collection system. After first selecting a type of sensor, and then a specific device, MSE performed bench scale and field tests of the selected sensor equipment.

Sensor Selection

MSE performed a literature search of technologies capable of detecting fuel vapors in enclosed spaces such as lift stations, manholes, or piping systems. Sources of information included the Internet, university research publications, manufacturers' literature, and military and other government publications. The operational characteristics and process information of the WWTP and lift stations at Fort Bragg were obtained from the post.

The most important criterion in evaluating potential technologies was the capability to differentiate between methane (normal in a sewer collection system) and hazardous hydrocarbons (i.e., jet fuel, gasoline, oil, etc). Preliminary research and industry trends indicated that a number of commercial off-the-shelf devices might have the capability to accurately measure and evaluate fuel vapors.

Technologies Evaluated

Three types of volatile organic compound (VOC) sensors were investigated: (1) lower explosion limit (LEL) sensors, (2) flame ionization detectors (FIDs), and (3) photoionization detectors (PIDs) equipped with 10.6-electronvolt (eV) lamps.

LEL sensors are often used to detect a wide variety of combustible gases and vapors. These sensors use a diffusion barrier to limit the gas flux to the catalytic bead and tend to be very sensitive to high-diffusivity compounds; consequently, they are more sensitive to small molecules like hydrogen and methane than they are to heavy components like Jet Propellant 8 (JP-8) (RAE Systems n.d.). Because of their sensitivity to methane found in the wastewater, LEL sensors were determined unsuitable for this project (Rae Systems 2002).

FID sensors are "carbon-counters" that use a hydrogen-air flame to ionize the sample gas and then detect carbon concentration via measuring the electric current produced by the combusted organic matter (MSE Technology 2006). These detectors are most sensitive to aromatics and long-chain compounds; however, FIDs cannot differentiate methane from other hydrocarbons. Another problem with FID sensors is that they require a continuous supply of hydrogen (ibid.). Thus, FIDs were also determined unsuitable for this project.

PID sensors use an ultraviolet (UV) light source of specific energy (eV) to ionize a gas sample and to detect its concentration. The target gas molecule absorbs the UV photon, resulting in an ejected electron and a positively charged molecular ion. The charged particles produce an electric current that is measured at the sensor electrodes (ibid.). Photoionization detectors are effective in detecting JP-8 and are not sensitive to methane. A disadvantage of PIDs is that they react to moisture. This can be overcome by the use of a moisture filter placed between the air being tested and the sensor. A correction factor must be used (when recording a reading) to compensate for the affect of the filter. The PID technology was determined suitable for this application and was selected for the field test.

Equipment Selected for Field Test

During the research of PID sensors, one model was found that was being used to measure JP-8 in wing tank entries (RAE Systems 2004) and thus, the RAEGuard Fixed PID was chosen for the demonstration. This particular device is designed to be permanently installed and offers two VOC sensors — an LEL and an oxygen sensor. The RAEGuard Fixed PID provides a 4- to 20-milliamp (mA) output that can be used to send data to the existing Supervisory Control and Data Acquisition (SCADA) system, which then sends data to Fort Bragg's central monitoring system. The RAEGuard Fixed PID requires calibration monthly. Since only the sensor part of the device was being tested, a portable version (the miniRAE 2000, which uses the same sensor as the RAEGuard) was used to conserve calibration costs.

Because the device's built-in pump provides internal pumping only and will not pull a sample from several feet of sample tubing, a supplemental sampling unit was used in conjunction with the RAEGuard PID. The CROWCON Environmental Sampling Unit 87ESU is often used with the RAEGuard PID sensor, to assist in dealing with water vapor issues (Crowcon n.d.). A CROWCON sampling unit was used during both the bench and field tests.

To be effective, the detector/sensor head assembly must be mounted (facing downward) on anti-corrosive and rigid material located at the site of maximum probable vapor concentration. The control unit should be mounted in a location that is free from shock and vibration, and is easily accessible for maintenance and calibration (Los Angeles County n.d.).

Testing the Sensor

MSE conducted tests to demonstrate that the sensor could effectively detect fuel vapors in concentrations that would indicate a spill had occurred. Those tests included bench scale testing at the MSE Testing Facility in Butte, Montana, and a field test at Fort Bragg lift stations.

Bench Test

Bench tests were performed on 17–18 May 2006 at MSE's Butte, Montana, Testing Facility to determine the effectiveness of the

RAE sensor in detecting kerosene (representative of JP-8) and gasoline. Results of this bench test are shown in Table A-1.

Table A-1. Bench testing results.

Date	Volume Water (gal)	Volume of Fuel (tsp)	Type of Fuel	Turbulent or Laminar Flow	Fuel Vapor Concentration in Parts per Million (ppm)	Comments
5/18/06	5	none	none	Laminar	0.6 – 1	Baseline
5/18/06	5	1/2	gasoline	Agitation for 2 min	560	Agitation increased the vapor concentration.
5/18/06	5	1/2	gasoline	Laminar	18	No agitation reduced the vapor concentration.
5/18/06	5	1/2	gasoline	Light agitation	88-100	Agitation increased the vapor concentration.
5/18/06	10	1/2	gasoline	Light agitation	16	Agitation increased the vapor concentration; increased water volume reduced the vapor concentration.
5/18/06	10	1-1/2	gasoline	Light agitation	300	Agitation increased the vapor concentration; increased fuel volume increased the vapor concentration.
5/18/06	10	2-1/2	gasoline	Light agitation	662	Agitation increased the vapor concentration; increased volume of fuel increased the vapor concentration.
5/18/06	5	1/2	kerosene	Light agitation	11	Kerosene not as easy to detect as gasoline.
5/18/06	5	1	kerosene	Light agitation	22	
5/18/06	5	2	kerosene	Light agitation	38	
5/18/06	5	5	kerosene	Light agitation	100	

The results of the tests indicated that the sensor effectively detected fuel hydrocarbon vapors. The test mixtures were agitated to mimic lift station turbulence; as agitation increased, the measured concentration of fuel vapors increased as well. This proved that agitation released more hydrocarbon vapors into the air and that the sensor could measure increasing concentrations. The results of the bench scale tests were used to establish fuel-to-water ratios for the testing at Fort Bragg.

Fort Bragg Field Testing

Fuel detection tests were performed at three lift stations: LS A-2205 (Fort Bragg), LS 150 (Pope), and LS 1-3774 (the Old Bowley School at Fort Bragg). Stations A-2205 and 150 were suspected to be points of entry for spilled fuel into the wastewater system because they have a strong odor of jet fuel, and they receive wastewater from motor pools and maintenance areas. One LS at the Old Bowley School (LS 1-3774) was selected as a control site because normal activities at this location would not create fuel spills.

The Fort Bragg/Pope AFB testing was performed in two sessions. The first session occurred during June 2006, and the second session occurred during August 2006. Sensor output was not connected to the Ft Bragg SCADA system; however, personnel ensured that the sensor used was capable of providing a 4- to 20-mA output that could be connected to a SCADA system in the future. The testing sessions began by measuring baseline concentration, followed by releasing a controlled volume of JP-8 upstream from the lift station. Fuel vapor concentrations were measured and recorded as the slug of fuel arrived at the lift station.

The PIDs were allowed to collect air samples overnight, and various data were collected and analyzed the following morning. There were concerns about the sensitivity of the PID and whether it could detect small concentrations of JP-8 that came from a large volume of water. For this reason, testing began by using a RAE sensor with a parts per billion (ppb)range, instead of a parts per million (ppm) range. A baseline for LS 1-3774 (the Old Bowley School) was established using the ppb-range miniRAE sensor (Figure A-1). The baseline reading was higher than anticipated, although it typically did not exceed 500 ppb.

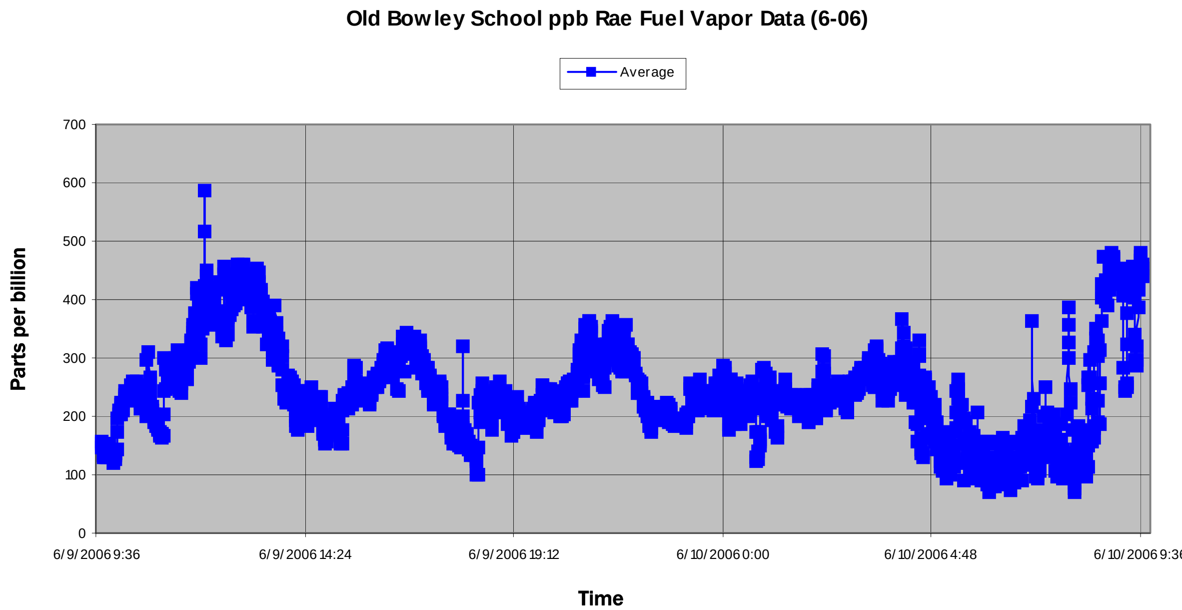

Figure A-1. LS 1-3774 baseline VOC readings.

Due to the strong fuel odor in LS A-2205 and LS 150, the remaining baseline tests were conducted with ppm-range sensor, the miniRae 2000. Figure A-2 shows a significantly higher fuel-vapor concentration baseline at LS 150, probably caused by residual fuel hydrocarbons that had previously passed through the lift station. Higher baseline concentrations (approximately 80 ppm) were not surprising, given the odor of fuel emanating from the lift station at various times.

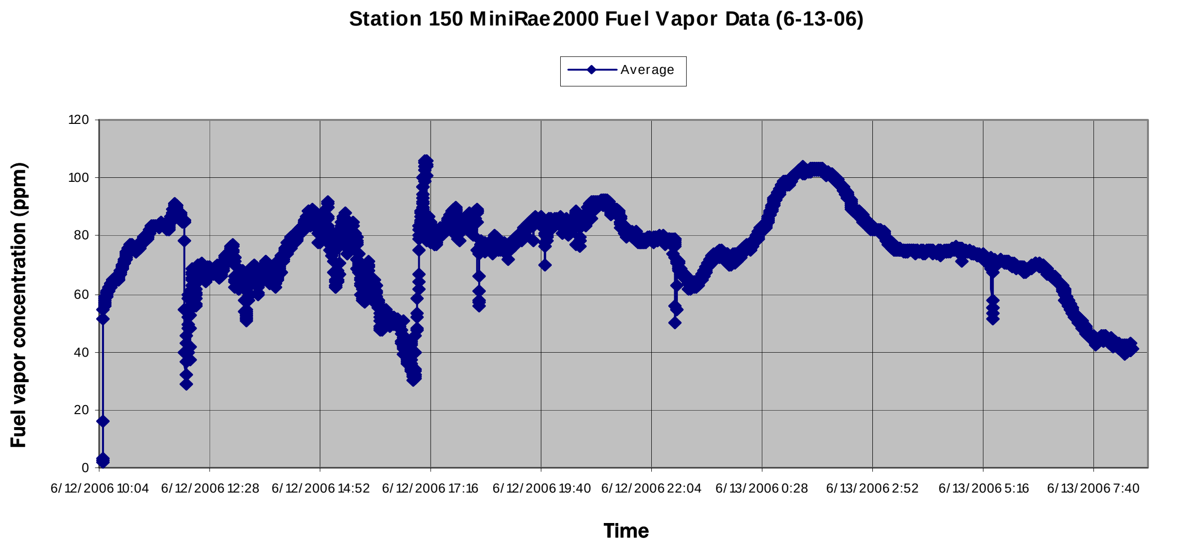

Figure A-2. Station 150 baseline fuel vapor concentration.

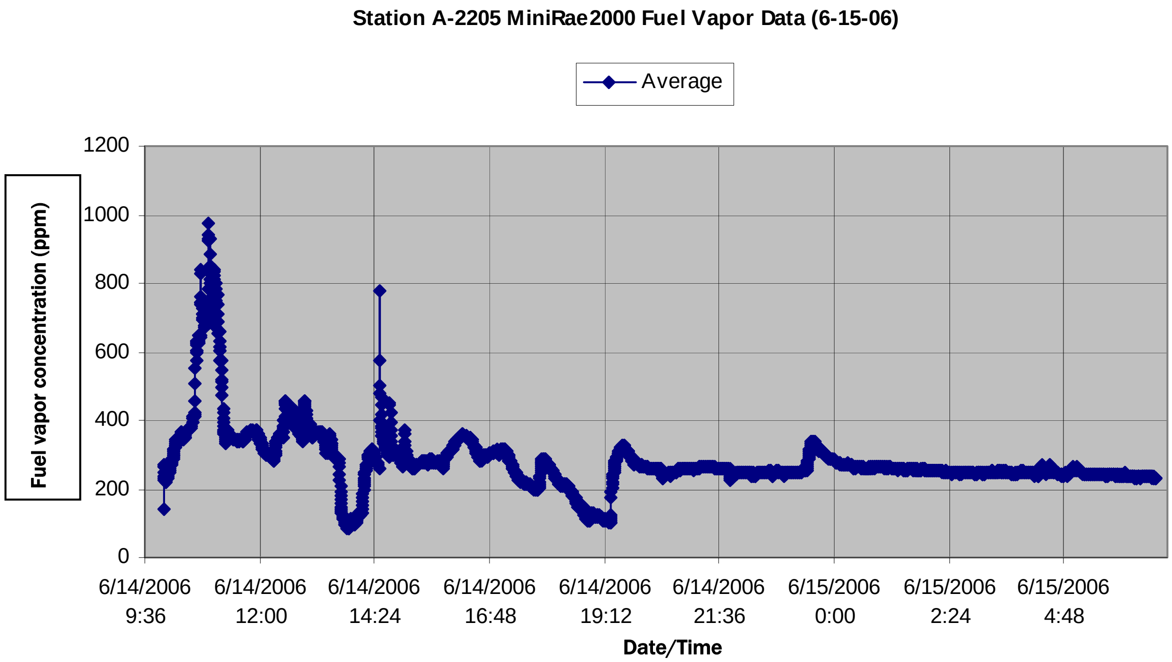

Figure A-3. LS A-2205 baseline fuel vapor concentration.

Figure A-3 shows that LS A-2205 was the most notorious for emitting a strong fuel odor and showed the highest baseline of the three stations.

With baselines established for each station, LS A-2205 was selected for a controlled fuel dump on 15 June 2006. With the permission and oversight of Fort Bragg personnel, 5 gal of JP-8 was introduced in 2.5-gal increments into a manhole, approximately 10 ft upstream of the lift station. The first dump was at 10:03 a.m., and the second dump was 1 minute later. The graph in Figure A-4 reflects the significant rise in fuel concentrations, beginning shortly after the fuel dump.

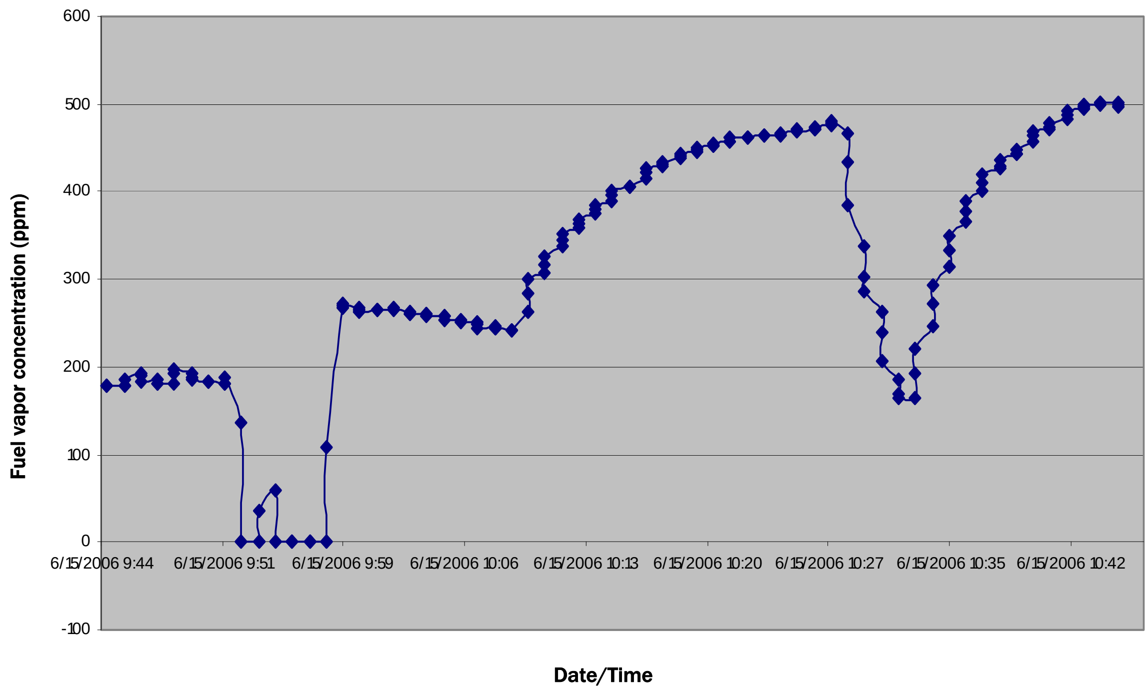

Figure A-4. Fuel vapor concentration in LS A-2205 following 2.5-gal JP-8 dumps at 10:03 and 10:04.

Prior to dumping the JP-8 at LS A-2205, the fuel vapor concentration measured approximately 200-300 ppm. The graph in Figure A-4 shows the fuel vapor concentration after the dump leveled out near 475 ppm; then, about 10:25 a.m., a Fort Bragg operator arrived at the station to check on a slow pump. The operator opened the lid, causing the air/fuel concentration to be temporarily diluted. After the lid was closed, concentrations rebounded rapidly to approximately 500 ppm.

A second fuel dump of 25 gal was done at LS A-2205 on 23 June 2006. Fuel was introduced in 5-gal increments. The pre-dump concentration was recorded at 342 ppm (Figure A-5).

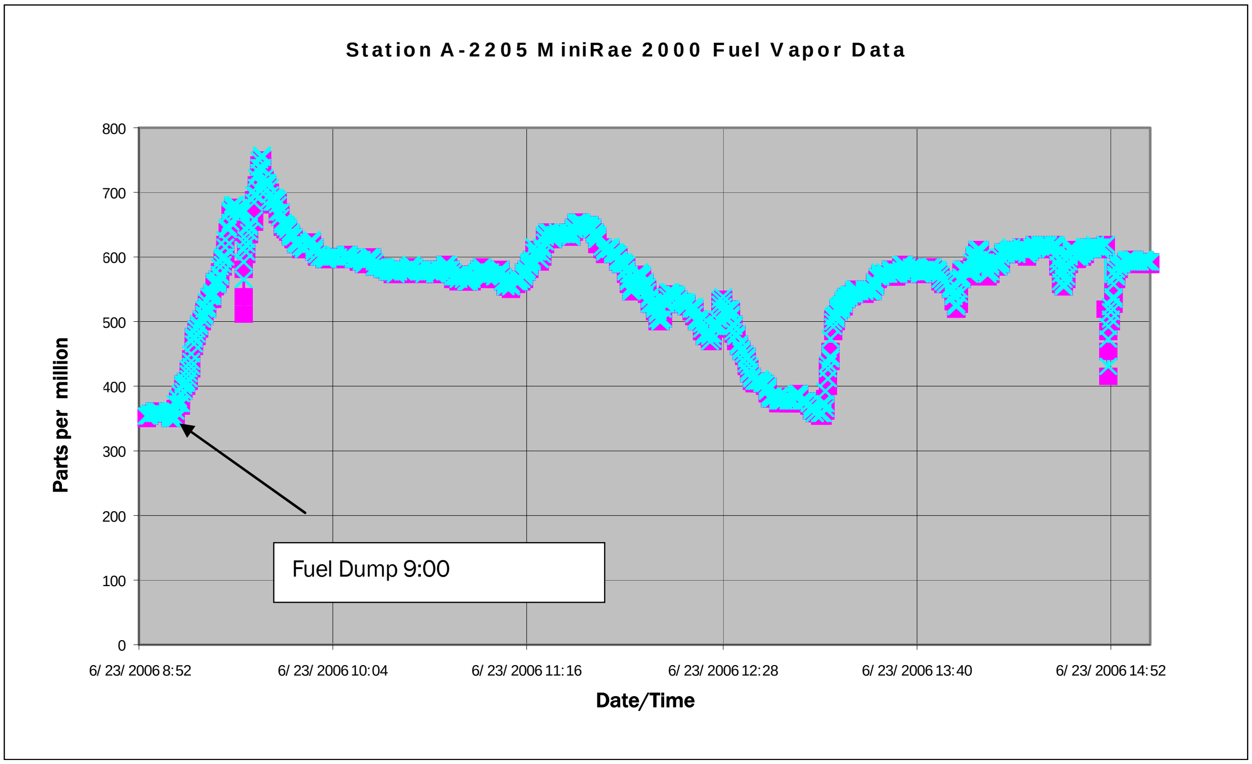

Figure A-5. Fuel vapor concentration in LS A-2205 following 25-gal JP-8 dump.

Dumping of the 5-gal increments began at 9:05 a.m., and continued until 9:15 a.m. The fuel vapor concentration subsequently peaked above 750 ppm. Concentrations gradually declined until 12:34 p.m. The sharp drop in concentrations after 12:28 p.m. was similar in pattern to the 15 June test. Subsequent analysis of data showed fuel vapor concentrations decreased when the lift station pumps came on.

To further investigate the effects of lift station pumps on vapor concentration, personnel compared the operating status of the pumps to the fuel vapor concentration data. Since Fort Bragg's existing wastewater system did not accurately log continuous pump ON/OFF status for each lift station, a monitoring device was installed at the pump control panel to capture this information.

On 18 August 2006, a datalogger was installed at LS 1-3774 (Old Bowley School SCADA panel), and a second datalogger was installed at LS A-2205. These dataloggers were programmed to record the time each wastewater lift station pump came on so that information could be compared to fuel vapor measurements.

Following installation of the dataloggers, the second series of tests began. Baseline measurements were taken at A-2205, prior to a 20-gal fuel dump. That fuel dump occurred about 12:36 p.m. on 23 August 2006. Since this next test was to determine how pump status affects fuel vapor concentrations, the pumps were forced on and off by sending water into the lift station (Figure A-6). The water supply in the motor pool upstream of the lift station was turned full-on and allowed to run into the drain, forcing the lift station pumps to cycle on and off.

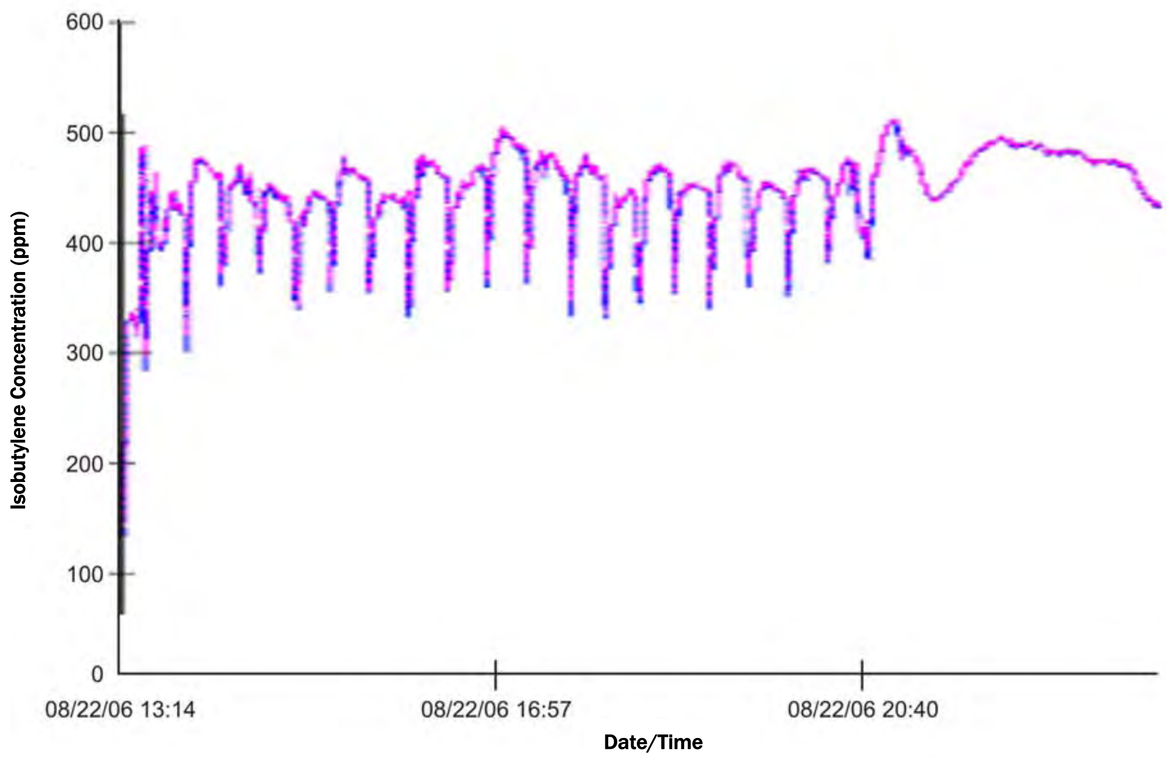

Figure A-6. Effect of pump operation on fuel vapor concentration in LS A-2205.

Figure A-6 shows rapid and repeated reductions in vapor concentrations, which correspond to the pump status. Each downward spike correlated to the time a pump turned on. When the pump turned on, it apparently pulled fresh air into the lift station, diluting the fuel vapor concentration.

Near 22:00 hours (about 10 p.m.), the sensor’s small pump became plugged with water condensate. Fuel vapor concentration data from that time until the water filter was replaced the next morning must be considered invalid.

Economic Evaluation

The costs of installing permanent sensors at the Fort Bragg lift stations include: equipment purchase, system design and engineering, installation of the sensors, and continued maintenance. These costs must be weighed against the costs associated with fuel spills interfering with the wastewater treatment plant, which include cost of clean-up at the plant and any fines or penalties associated with regulatory violations. When the Ft Bragg WWTP is privatized, it is anticipated that the new owner will not hesitate to pass the cost of fuel spill interferences on to the Army. While the exact penalty for causing a violation cannot be predicted, each occurrence could cost from $2,000 to more than $30,000, dependent on the severity of the violation. Clean-up cost is also impossible to predict. Although, the cost to clean up a fuel spill contained at a lift station undoubtedly would be less than the cost to clean up the contamination caused by the same amount of fuel at the wastewater treatment plant. Table A-2 shows the estimated cost for implementing the detection system for 10 lift stations at Fort Bragg.

Table A-2. Estimated cost to implement spill monitoring system at Fort Bragg.

	Estimated cost for 10 Lift Stations ($ equip.)	**Estimated annual cost (assume 10-yr equipment life) (2006$)**
Equipment	53,500	5,350
Engineering	26,500	2,650
Installation	22,500	2,250
Maintenance per month (Labor @$500 per month)	60,000	6,000
Total	162,500	16,250

Unfortunately, because the cost of a spill cannot be predetermined, it is not possible to compare the cost of implementing a spill detection system to the cost of spills without the system. Fort Bragg does not have historical cost data on previous spill cleanups. Thus, it cannot be documented whether it is cost-effective to install the sensors at Fort Bragg. It is possible, though, that the avoidance of even one large spill per year reaching the WWTP would outweigh the total cost of the sensors. A large spill could require the temporary shutdown of the treatment plant in order to contain the spill within the plant. The contaminated wastewater might have to be transferred to a temporary storage area in order to bring the wastewater treatment plant back online. The transferred wastewater would then require treatment to remove the fuel contamination, or would need to be disposed of as a hazardous waste. The cost to deal with a spill’s interference with the WWTP would be site-specific. (i.e., dependent on the availability of equipment, storage, and trained personnel necessary to handle the situation). If the spill could be detected and captured within the collection system, disruption of the treatment processes could be prevented.

There is also merit in simply having a system that will help pinpoint the source location of a spill. Awareness of that capability may intensify personnel’s diligence in spill prevention.

Discussion of Findings and Recommendations

Testing at Fort Bragg has shown that the sensor can detect fuel vapor in a wastewater lift station atmosphere. The vendor literature states that the sensor tested is not adversely affected by the methane in the lift stations, and it appeared that this was true.

Testing proved the effectiveness of the sensor in detecting when a slug of fuel enters a wastewater collection system. Testing also provided valuable information regarding the effects the lift station pump operations have on the measurements. Operational issues encountered during testing included water vapor plugging and battery depletion, and these are considered peculiar to the portable unit and should be resolved with installation of the fixed unit.

The RAE Systems sensor is available in a fixed permanent unit that provides data outputs that could be tied into Fort Bragg’s existing SCADA system. This will allow both remote monitoring and automated warning, which will greatly enhance rapid spill response. To implement a monitoring/warning system, the following actions are suggested:

- Develop a baseline concentration range over time for each monitored lift station. Concentrations exceeding the baseline range would then trigger an alarm.

- Program a controller to ignore minor fluctuations within an acceptable range, but send an alarm for a major concentration increase of some duration. This alarm could go out to the Fort Bragg (PWC) and/or the WWTP.

- Enter each sensor's output automatically into Lookout™ or a similar program. A Fort Bragg operator could monitor this data, or an alarm may be programmed in Lookout™ to notify the operator of a problem.

Because operation of the pump will cause severe fluctuation in fuel vapor concentrations, pump status must be monitored. Sensor readings during and shortly after pump operation should not be allowed to trigger a spill warning.

It is recommended that Fort Bragg install RAEGuard PID fixed units at the suspect lift stations. Monitoring the wastewater system to detect unwanted fuel will allow the WWTP to change operating conditions to adequately treat any incoming fuel. Monitoring will also give Fort Bragg quick information regarding any fuel spills or dumping, and allow rapid investigation of each incident. The fact that fuel dumping will be monitored may also act as a deterrent. This aggressive approach to monitoring unwanted hydrocarbons in the wastewater should prove to be beneficial to Fort Bragg's Environmental Management System.

Any permanent installation of sensors will require periodic maintenance and calibration of the sensors. MSE recommends monthly calibration and function testing for each permanent unit installed. The maintenance and calibration records should be kept for a period of 3 years, and copies should be regularly submitted to Fort Bragg's DPW no less than semi-annually (e.g., January 31 and July 31). During calibration, the span check adjustment should be performed on a regular basis to ensure proper operation and continued accuracy. The calibrations performed should be recorded on the calibration form and kept with the maintenance record (USEPA 2001).

Throughout this project, condensate plugging was a problem, and water traps were repeatedly filled and replaced. This plugging issue needs to be resolved for a permanent PID installation, and MSE recommends that a supplemental sampling unit pull the sample, in conjunction with the RAEGuard PID.

Appendix B:
Acronyms and Abbreviations

Term	Spellout
AFB	Air Force Base
AR	Army Regulation
CERL	Construction Engineering Research Laboratory
CFR	Code of the Federal Regulations
CWA	Clean Water Act
DA	Department of the Army
DPW	Directorate of Public Works
EPA	Environmental Protection Agency; also USEPA
ERDC	Engineer Research and Development Center
eV	electron volt
FID	Flame Ionization Detector
FOTW	Federally Owned Treatment Works
HQUSACE	Headquarters, U.S. Army Corps of Engineers
JP	jet propellant
LEL	lower explosion limit
LS	lift station
mA	milliamp
MSE	MSE Technology Application, Inc
NOV	Notice of Violation (NOV)
NPDES	National Pollutant Discharge Elimination System
OACSIM	Office of the Assistant Chief of Staff for Installation Management
PDF	Portable Document Format
PID	photoionization detector
POC	point of contact
POTW	Publicly Owned Treatment Works
PPM	parts per million
PWC	Public Works Commission
PWTB	Public Works Technical Bulletin
SCADA	Supervisory Control And Data Acquisition
SIS	Specialized Information Services
TN	Technical Note
URL	Universal Resource Locator
UV	Ultraviolet
VOC	volatile organic compound
WMPP	Waste Minimization and Pollution Prevention
WWTP	Wastewater Treatment Plant
WWW	World Wide Web

Appendix C:
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