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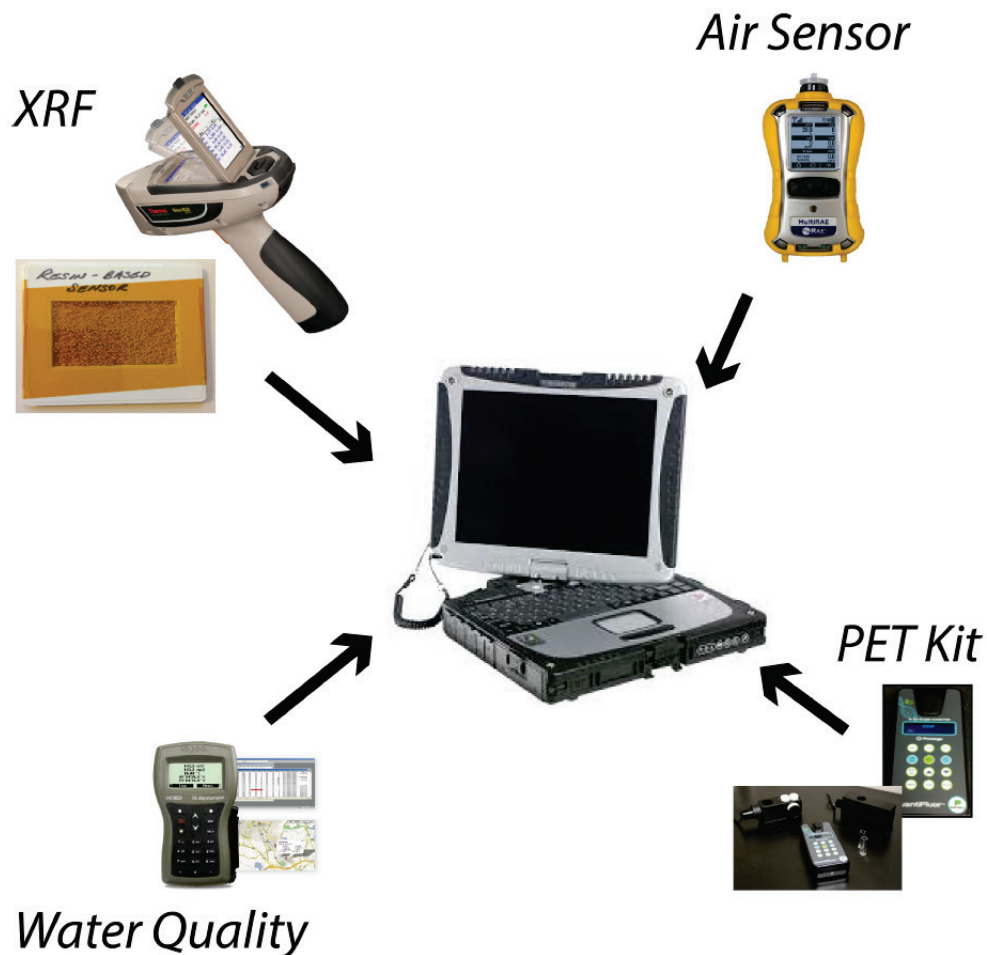


*NDCEE Program*

# **Qualification of Hanna Instruments HI9829 for the Environmental Toolkit for Expeditionary Operations**

Luke A. Gurtowski, Josh LeMonte, Jay Bennett,  
Brandon Lafferty, and Matthew Middleton

September 2022



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# **Qualification of Hanna Instruments HI9829 for the Environmental Toolkit for Expeditionary Operations**

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## Abstract

A new, commercially available, field-portable water sensor was evaluated for efficacy during operation and compatibility with current Environmental Toolkit for Expeditionary Operations (ETEO) software. The ETEO provides sensors to Soldiers to rapidly identify and quantify environmental contamination in soil, air, and water at potential new base sites during initial reconnaissance to ensure safety and minimize unnecessary remediation efforts by the Army. In addition to streamlined environmental baseline survey (EBS) reporting, the ETEO can provide rapid analysis of potential environmental contamination to support various Military applications. The Hanna Instruments HI9829 multiparameter water meter was selected following a survey of commercial off-the-shelf (COTS) technologies and analyzed by researchers from the US Army Engineer Research and Development Center (ERDC) for inclusion in the ETEO design since it can rapidly and accurately measure 14 different properties. Usability tests were conducted with researchers unfamiliar with the technology, and a set of standard operating procedures (SOPs) were developed to operate the device. The software for the tool was successfully integrated into the ETEO system for rapid data analysis. The HI9829 has been demonstrated in various scenarios at ERDC and other locations; including Ft. Leonard Wood, MO, at which several visitors reviewed the operation of the equipment and other ETEO technologies. The Thermo Scientific Gemini, another sensor, which can detect organic constituents in various matrices via Fourier transform infrared (FTIR) spectroscopy and Raman spectroscopy was also investigated but eliminated from the ETEO design as it could not adequately detect a Military-relevant compound in an environmental matrix. Regardless, the addition of the HI9829 provides water quality monitoring to the ETEO design and greatly improves its capability to address various applications.

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## Preface

This study was conducted for the US Army National Defense Center for Energy and Environment (NDCEE) Program under Project EVFY16-007, “Environmental Toolkit for Expeditionary Operations (ETEO).” The technical monitor was Mr. Will Jones.

The work was performed by the Environmental Engineering Branch (EPE) and the Environmental Processes Branch (EPP) of the Environmental Processes and Engineering Division (EP), US Army Engineer Research and Development Center, Environmental Laboratory (ERDC-EL). At the time of publication, Dr. Michael Rowland was Chief, EPE; Dr. Rebecca Crouch was Chief, EPP; Mr. Warren Lorentz was Chief, EP; and Dr. Elizabeth Ferguson, EZT was the Technical Director for Military Materials in the Environment. The Deputy Director of ERDC-EL was Dr. Jack Davis and the Director was Dr. Edmond Russo.

COL Christian Patterson was the Commander of ERDC, and Dr. David W. Pittman was the Director.



# 1 Introduction

## 1.1 Background

Currently, the US Army faces several obstacles accomplishing Environmental Baseline Survey (EBS) reporting. Soldiers often have minimal expertise collecting environmental samples/data and lack the appropriate tools to collect and process data at potential base sites. Therefore, environmental samples collected cannot be analyzed in real time on station, and delays to data analysis occur. These limitations restrict awareness of environmental contamination that could be harmful to the Soldiers' health and readiness. Also, lack of information about baseline environmental contamination leads to additional remediation efforts, as preexisting contamination cannot be effectively differentiated from new contamination when land is transferred back to a host nation. The Environmental Toolkit for Expeditionary Operations (ETEO) has been developed as an intuitive solution to provide the capability of screening for multiple environmental contaminants and enabling Soldiers to easily and comprehensively complete EBS reporting requirements. This ability to rapidly and accurately collect and report contamination information enables commanders to account for environmental considerations when basing units and ultimately prevent medical and environmental treatment costs.

The ETEO was initially funded by the Assistant Secretary of the Army (Acquisition, Logistics and Technology) (ASA[ALT]) as a four-year project led by the US Army Research and Development Center's (ERDC) Environmental Laboratory (EL). In that work, several sensors capable of detecting environmental contamination in various matrices were procured, modified, or developed. These devices were evaluated to determine their potential value to the intended application. The selection criteria included the function, ruggedness, and ease of use for each tool. The overarching principles used in the selection of sensors for the ETEO were: (1) sensors must be rugged, (2) sensors must be easy to use, and (3) the ETEO should analyze the highest number of environmental contaminants using the lowest possible number of sensors/tests.

## 1.2 Additional applications for the ETEO technology

In addition to EBS reporting, the versatile technology associated with ETEO could be used for a variety of applications. Specifically, the tools included could be used to perform routine environmental analysis at CONUS installations, including training ranges and the Army Industrial Base (IB). The ETEO technology could also be used to address potential environmental contamination at Base Realignment and Closure (BRAC) sites or Formerly Used Defense Sites (FUDS). This could be included in Military operations other than war (MOOTW) in terms of disaster relief and humanitarian assistance when potential environmental concerns are present. Depending upon the intended application, the entire ETEO set or specific sensor technologies may be appropriate.

## 1.3 Current ETEO capabilities

The existing ETEO configuration consists of three sensors. A commercial off-the-shelf (COTS) Niton™ XL34t X-ray Fluorescence (XRF) Analyzer is included for heavy metal analysis in soil. This portable XRF provides rapid detection of 25 elements (sulfur [S] to uranium [U], including many heavy metals) with quantitative accuracy. The COTS MultiRAE PGM-6228 is included for its capability to monitor air quality and quantify potential harmful gases, such as hydrogen sulfide (H<sub>2</sub>S), oxygen (O<sub>2</sub>), carbon monoxide (CO), combustible gas (lower explosive limit [LEL]), and volatile organic compounds (VOC) quickly and efficiently. The last sensor included is the Petroleum Hydrocarbon Field Screening Kit (PET kit) which analyzes for petroleum in water and soil. The PET kit uses a sample extraction technique and utilizes an ERDC-developed visual analyzer for rapid detection of hydrocarbons and COTS QuantiFluor®-P fluorometer (Promega) for expedient quantitation. These sensors (Figure 1-1) are included in one COTS transit case for efficient transport and enhanced durability in use.

ETEO software streamlines environmental reporting via efficient data transfer from the sensors to the EBS template. Sensors evaluated for ETEO are compatible with this software, and data from these devices are easily transferred to an EBS template via automatic upload or manual entry. The software also provides GPS mapping for documentation of each location when preparing an EBS. A rugged laptop included in each ETEO set powers this software for immediate access in use.

Figure 1-1. ETEO sensors; A) XRF, B) gas monitor, and C) flurometer.



#### 1.4 ETEO capability gaps

There are opportunities in the current ETEO configuration for improvement. If these capability gaps were addressed, the ETEO would provide more applications to benefit the Warfighter or intended user.

Specifically, the current sets lack the ability to identify or quantify organic constituents other than petroleum in various matrices, including soil and water. Considering that the Army utilizes various organic energetic materials in routine operation, the capability to rapidly detect these materials would provide great benefit to potential users of the ETEO.

Other sensors have been considered for inclusion in the ETEO but were ultimately eliminated from the recommended design. The Water Diagnostics Operations Gear (WaterDOG), a prototype sensor developed by ERDC's Geospatial Research Laboratory (GRL), was developed for the ETEO. This device can measure multiple water quality properties, including turbidity and pH, to assess potability. It can also map the locations of water evaluations for efficient documentation. However, this device is not sufficiently portable for the ETEO application, as shown in Figure 1-2. Therefore, the WaterDOG was not included in the recommended design, thus eliminating water quality meter capabilities in this iteration of the ETEO.

Figure 1-2. WaterDOG in operation (Elder 2015).



The National Defense Center for Energy & Environment (NDCEE) funded the evaluation and demonstration of the ETEO to quickly add a new sensor for enhanced capability. Considering the absence of an organic detector or water quality meter in the design at the conclusion of the ASA(ALT)-funded project, these tools in ETEO were chosen to be investigated for inclusion during this project. Adding at least one of these capabilities is crucial to accomplish the intended application of protecting the Warfighter and reduce costs and labor for extraneous remediation efforts.

## 1.5 Objectives

The primary objective was to demonstrate the capability of the ETEO software to integrate an additional sensor quickly and with minimal programming. Water quality monitoring was the primary capability to be attained for ETEO from the new sensor. The objective was achieved by completing the following five tasks:

1. Define success criteria for the capability improvements,
2. Survey and procure commercially available sensors,
3. Evaluate acquired sensors for functionality and accuracy,
4. Incorporate selected technology into the ETEO software procedures, and
5. Demonstrate the capability of the tool in a field scenario.

## 1.6 Scope

This study involved the review of two COTS technologies for potential inclusion in the ETEO to address capability gaps. Specific capabilities to be addressed included organic compound identification and water quality evaluation. Technologies were assessed based on their features and performance.

## 2 Capability Investigation

### 2.1 Opportunities for ETEO capability enhancement

The ETEO can be enhanced with the addition of specific capabilities not currently provided by previous versions of the prototype set. Improvements to the capabilities would enhance the versatility and value.

Specifically, the ability to detect and characterize organic contaminants in various matrices would greatly enhance the capability of the ETEO. This proficiency would allow the Warfighter to determine potential contamination associated with energetic compounds, such as 2,4,6-trinitrotoluene (TNT) and hexahydro-1,3,5-trinitro-s-triazine (RDX), in addition to inorganic metal quantification provided by XRF. Considering partition, dissolution, and mobility of organic contamination in environmental matrices, detection, and characterization of organic materials in both soil and water would allow for full understanding the environmental state of evaluated areas.

Previous versions of the ETEO lacked instrumentation to effectively determine water quality, so the addition of this capability would allow the nearby water bodies to be analyzed for potential contamination associated with Military activities. Furthermore, analysis of the water quality could help qualify water sources for potential applications. Water quality assessment could also determine the effectiveness of treatment technologies employed by the Military, such as the reverse osmosis purification unit (ROPU), in addition to those being currently developed for future application. Simultaneous analysis of multiple properties would be preferred to maximum efficiency and value for the sensor.

Each of these capabilities would provide unique but meaningful benefits to the ETEO. Therefore, each technology was investigated for potential inclusion in the set.

### 2.2 Evaluation criteria for investigated sensors

The sensors included in this study were evaluated using eight criteria:

1. **Commercial availability** to enable rapid demonstration

2. **Performance factors**, including capability and analytical accuracy using standard procedures per vendor recommendations
3. **Compatibility with existing software**
4. **Ease of use** to ensure minimal necessary training for operation, demonstration, and potential transition
5. **Size**
6. **Weight**
7. **Ruggedness** to ensure adequate portability and durability
8. **Cost** to support use of the ETEO for intended applications.

The priority assigned to each attribute for selection is shown in Table 2-1.

For organics analysis, the selected sensor was evaluated based upon its ability to characterize compounds in both soil and liquid matrices. The water quality sensor was assessed based upon its ability to measure multiple properties simultaneously.

**Table 2-1. Selection criteria for evaluated sensor.**

Priority	Technology Attribute	Success Criteria
1	Commercial availability	Rapid acquisition of COTS technology
2	Performance factors	Capable of rapidly providing accurate data for the intended operation
3	Compatibility with ETEO software	Efficient transfer of data to ETEO software
4	Ease of use	Minimal training required
5	Size of instrument	Sufficient portability
6	Weight of instrument	Sufficient portability
7	Ruggedness and durability of instrument	Suitable for field use
8	Cost of instrument	Minimal cost

## 3 Organics Sensing Technology Assessment

### 3.1 Survey of available instrumentation

An online survey was conducted to determine which COTS sensors would be capable of evaluating organic contaminants in various environmental matrices. Various handheld devices could provide organics characterization via different mechanisms, including Fourier-transform infrared spectroscopy (FTIR) or Raman spectroscopy. However, the Gemini, provided by Thermo Scientific, was the only device reviewed in this survey that provided both FTIR and Raman spectroscopy for analysis. Therefore, it was selected for evaluation at ERDC (Figure 3-1).

Figure 3-1. Thermo Scientific Gemini (ThermoFisher Scientific 2019).



## 3.2 Technology description – Thermo Scientific Gemini

The Gemini is handheld device capable of providing rapid characterization and identification of organic compounds in both solid-state and liquid matrices. This sensor helps identify unknown substances and allows environmental samples to be tested for the presence of potential contaminants. Successful function of the Gemini would provide effective screening of soil and water samples for relevant organic compounds, including, but not limited to, energetics. This capability would further assess environmental conditions of selected areas at various times.

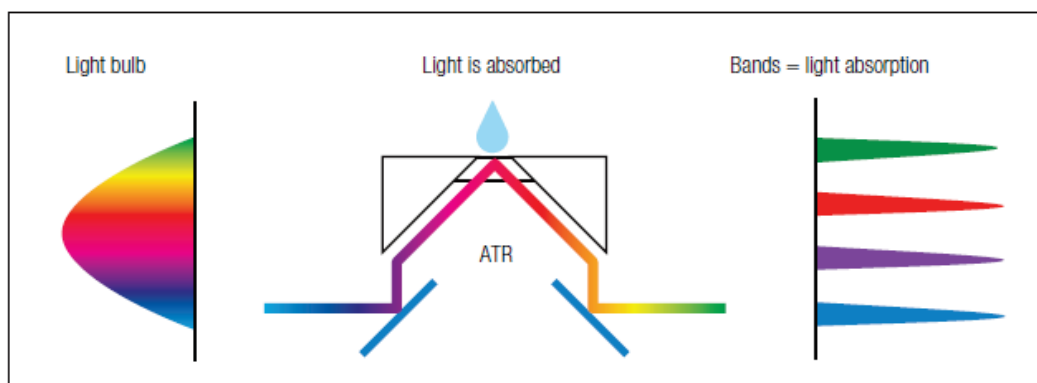
The use of FTIR or Raman enhances the sensor's characterization ability. Depending upon the sample analyzed; FTIR, Raman, or both techniques would be used for characterization.

### 3.2.1 Analytical technologies

#### 3.2.1.1 FTIR

FTIR is a method of absorption spectroscopy in which a sample is exposed to mid-infrared light. During this process, certain molecular bonds absorb specific amounts of energy at wavelengths; the remainder of the light passes through the sample. This process is depicted in Figure 3-2.

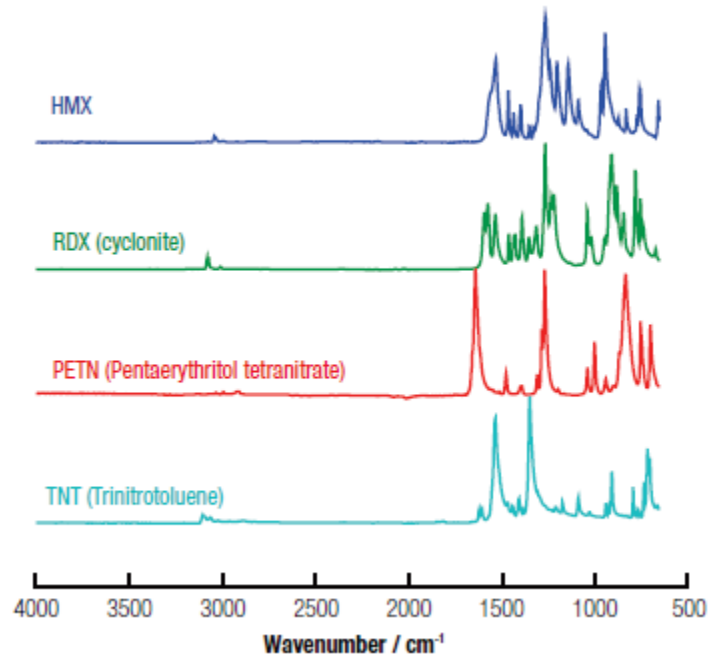
Figure 3-2. FTIR operation (Thermo Scientific 2015).



The reduction in energy results in a peak at a specific wavenumber. The location and relative magnitude of each peak provides a unique fingerprint for various compounds that can allow their reproducible identification under various conditions. Representative spectra of energetic compounds are shown in Figure 3-3.



Figure 3-3. FTIR spectra of representative energetic compounds (Thermo Scientific 2015).



### 3.2.1.2 Raman

Raman spectroscopy operates by introducing a single-wavelength laser to a sample that excites molecular bonds and produces scattered light unique to compound analyzed (Figure 3-4). The resulting signature from the compound – example spectra are shown in Figure 3-5 – can be repeatedly produced under this method of analysis and provide efficient identification of unknown substances.

Figure 3-4. Raman spectroscopy operation (Thermo Scientific 2015).

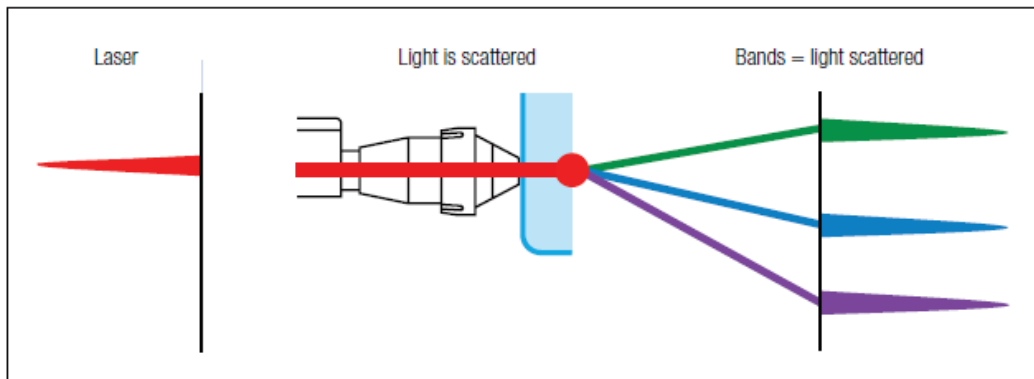
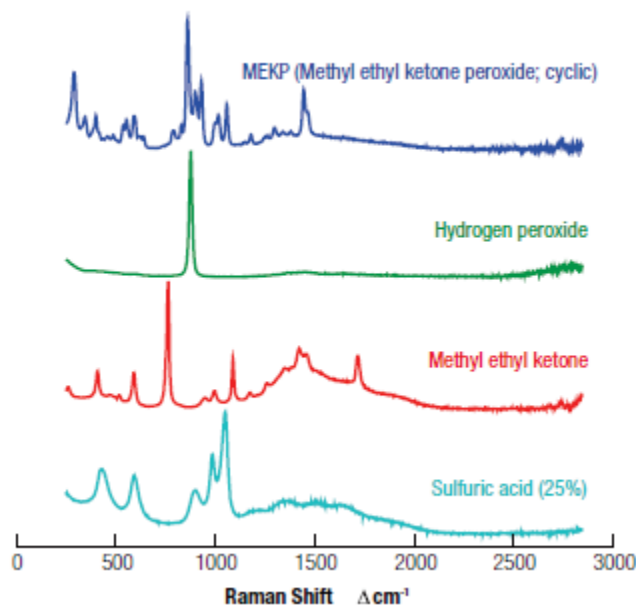


Figure 3-5. Raman spectra of example compounds (Thermo Scientific 2015).



### 3.2.1.3 Combined FTIR-Raman capabilities

Both FTIR and Raman analysis provide specific advantages and disadvantages inherent to analysis. Therefore, the use of either technology complements analysis and provides a great range of assessable compounds.

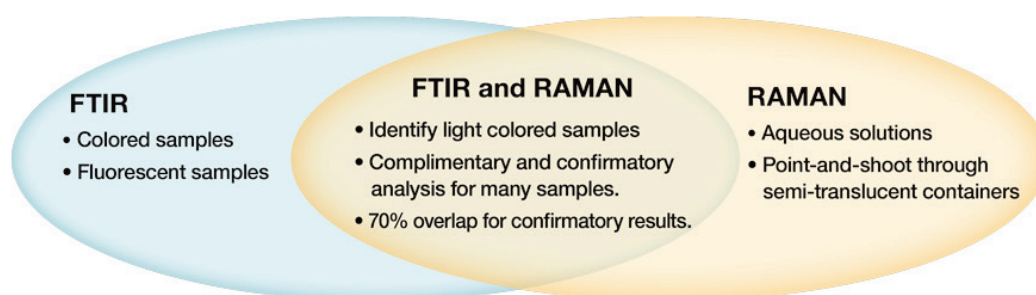
FTIR can analyze substances that cannot be safely or effectively analyzed by Raman spectroscopy. Specifically, FTIR is highly effective at analyzing solid and liquid samples of various tones and shades, including dark colored materials. These compounds are not recommended for Raman spectroscopy as the laser used for this analysis may cause ignition of the material. FTIR is also recommended for energetic materials to prevent ignition or accidental detonation associated with Raman analysis. Additionally, the Raman laser causes fluorescence for certain samples that interferes with results, which is why FTIR is recommended for fluorescent samples, as well.

Conversely, Raman spectroscopy provides advantages relative to FTIR. Raman analysis can detect samples within sealed, transparent containers. Therefore, handling of unknown and potentially hazardous materials is prevented using this form of spectroscopy; FTIR requires sample extraction. Additionally, aqueous solutions can easily be analyzed via

Raman spectroscopy based upon the weak Raman signal associated with water.

Regardless, both can identify unknown white or light-colored samples. Analysis with both technologies provides greater confidence in identification as spectra can be produced and interpreted for comparison from each method. These benefits, in addition to those added by each technology separately, are shown in Figure 3-6.

Figure 3-6. Capabilities of FTIR and Raman analysis (Thermo Scientific 2015).



### 3.2.2 Technical specifications

Specifications regarding size, weight, and durability for the Gemini are shown in Table 3-1.

Table 3-1. Gemini technical specifications (MRIGlobal 2018).

Property	Specification
Dimensions	10.1 in. x 5.7 in. x 2.4 in.
Weight	4 lb.
Operating Temperature Range	-4 to 122°F
Durability Rating	IP-67
Survivability	MIL-810-G Compliant
Shelf Life	10 years

The size (10.1 in. x 5.7 in. x 2.4 in.) and weight (4 lb) of the Gemini allow it to be transported efficiently. Technical specifications regarding its durability ensure its operation in various environments. Specifically, the device is qualified for operation in most temperatures anticipated in the field. It has a durability rating of IP-67 and is dust-resistant and waterproof up to depths of 1 m for approximately 30 min (IEC 60529). The Gemini is also compliant to the US Military Standard, MIL-STD-810,

for survivability in various conditions including, but not limited to, shock and vibration. The shelf life of 10 yr provides the sustained use of this device after procurement.

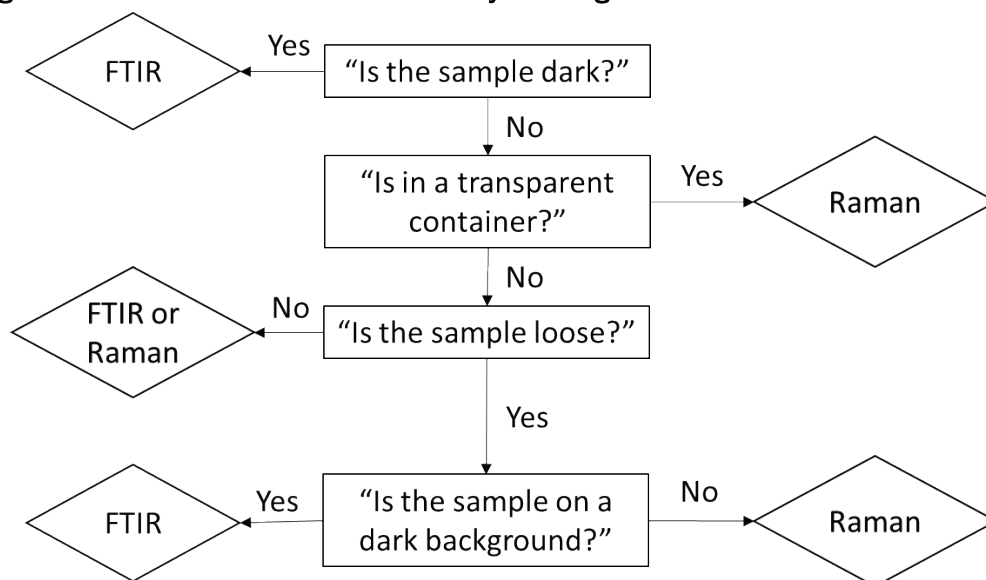
### 3.2.3 Ease of use

The Gemini is equipped with a touchscreen, a keypad with only seven buttons, and two additional movable parts to limit complication during operation. Additionally, a four-page instruction guide discussing the operation and safety features of the unit are provided by the supplier. A detailed manual is also included for further instruction to ensure its ease of use.

## 3.3 Operation

The Gemini uses rechargeable lithium-ion batteries. Once powered on with sufficient charge, the device undergoes a two-minute initiation procedure. Once fully operational, a self-test can be performed using supplied standard materials to ensure calibration. After the calibration, analysis via FTIR or Raman spectroscopy can be performed for the intended sample(s). The flowchart shown in Figure 3-7 can be used to determine which method is appropriate for the given sample(s). The questions shown in Figure 3-7 are also included in the instrument's software within its "Scan Assist" module to help guide the user.

Figure 3-7. Flowchart for selection of analysis using the Gemini "Scan Assist" module.



### **3.3.1 FTIR operation**

FTIR can be used for solids, volatile and nonvolatile liquids, and pastes. Solid samples require the use of an anvil adjacent to the sample area. This anvil compresses the solid sample to ensure adequate interaction with the light emitted from beneath the sample area. Liquids and pastes do not require the use of the anvil as the material is evenly distributed when spread thinly across the sample area. The option to use the anvil can be selected prior to analyzing each sample.

Prior to using the FTIR unit, the sampling area must be cleaned to prevent error in results. Alcohol wipes are recommended for this procedure.

Then, a sample “blank” must be analyzed in which the sample matrix is analyzed in the absence of the materials of interest. The blank provides a background for the sample to ensure the sample matrix does not interfere with results; peaks produced from this matrix will be removed from further scans.

Once the sample and Gemini have been prepared for analysis, the sample can be tested using the same procedure followed for the blank. The display screen on the instrument will show the progress of the scan and indicate when analysis has completed; typical scans require approximately one minute to provide accurate results. Following the scan, the instrument will automatically review its internal library for a matching scan to identify the material.

### **3.3.2 Raman operation**

Raman spectroscopy can be used for materials provided in a variety of orientations. For samples provided in large transparent containers, such as plastic or glass bottles and jars, the wand containing the laser can be extended from the device so the aperture can be placed directly onto the container’s surface for penetration to the sample of interest. Materials in opaque containers cannot be analyzed using this procedure, as the laser cannot penetrate these surfaces. Open liquid and solid samples can be tested accurately via Raman spectroscopy. For these samples, the laser must be placed on the surface of the material itself; the laser cannot contact the underlying surface during this analysis because this material will interfere with the anticipated results.

Materials can also be collected in small vials and evaluated using the sample orifice on the face of the Gemini. For these samples, the wand can be returned to its standard location within the Gemini to provide adequate distance between the laser and material on interest. Liquid and solid samples can be analyzed using this method.

The intensity of the laser can be adjusted manually prior to analysis. Once intensity has been set, the laser can be utilized to evaluate the sample. The display screen of the Gemini will show the progress of the analysis; typical evaluation requires approximately one minute per sample. As with the FTIR, the Gemini will automatically review its library to identify the sample.

### **3.3.3 Sample identification**

Regardless of the analytical method used, the system will provide five options when displaying results. The Gemini will provide one positive match when one compound has been identified with high confidence in the sample. The Gemini can also provide matches for a mixture of numerous compounds identified with high confidence. For this scenario, the Gemini will display the relative percentages to the total mixture each sample contributes.

When the Gemini provides results with moderate confidence, multiple positive matches are displayed. In these cases, more than one potential match is shown on the display for the compound of interest, and the operator must use judgment to correctly identify the material. Additionally, when the analyzed material produces results that are similar to those in the Gemini's library but do not provide an exact match, the device will show the compound that most closely resembles that of the analyzed compound. The operator must use judgment when reviewing these results to determine if the appropriate compound has been identified.

Lastly, when the scan provides unrecognizable results, the Gemini will alert the operator that no match has been found. Another sample could be collected and analyzed to improve material identification.

Regardless, the spectra from each scan will be stored in the instrument's software. Potential matches can be compared to these spectra for

confirmation. The library can also be updated manually to allow identification of other compounds, including emerging contaminants.

### **3.4 ERDC evaluation of Gemini**

The Gemini was evaluated by ERDC researchers to determine its efficacy for Military-relevant compounds and ultimately determine if it should be included in the ETEO. The Gemini's FTIR system was used to evaluate 2,4,6-trinitrotoluene (TNT), an organic energetic material included in traditional munition formulations for various applications by the US Army. TNT could be present in soil and waters at Military training bases in which explosive rounds are tested or in potential OCONUS locations where munitions were manufactured or previously used.

#### **3.4.1 Evaluation of FTIR analysis**

The FTIR system was evaluated against TNT in soil matrices. Standard operating procedures provided by the manufacturer were followed to determine the instrument's efficacy against this compound.

When mixed in soil, however, the FTIR system of the Gemini could not detect TNT, regardless of the concentration. Interference associated with the soil baselines prevented adequate identification of the material. Considering that TNT is one of the most relevant organic compounds for Military installations, further evaluation of the Gemini's FTIR was ceased, as the device was not capable of overcoming soil interferences.

#### **3.4.2 Evaluation of Raman analysis**

The Raman system of the Gemini was not tested against TNT during this evaluation for safety reasons. Raman spectroscopy is not recommended for energetic analysis as the laser inherent to the system has potential to excite the compounds during evaluation and cause harm to the operator or damage to the equipment. For this reason, the Raman system of the Gemini was not qualified for use against TNT or other Military-relevant munition constituents despite its potential application for non-energetic materials. Regardless, the Raman system of this instrument was not further assessed.

### **3.5 Results**

Because the Gemini was incapable of detecting the compounds evaluated by ERDC in this study, this instrument was not recommended for inclusion in ETEO. Further evaluation of other technologies should be considered in future efforts to address the need of adequately identifying Military-relevant organic materials, including but not limited to, munition constituents.



## 4 Evaluation of Water Quality Sensors

### 4.1 Initial survey and assessment

An online market survey was conducted to identify technologies potentially suitable for water quality evaluation. Leading vendors in water quality monitoring technologies were consulted regarding available instrumentation. Hanna Instruments, Hach Company, YSI, Fisher Scientific, Omega Engineering, and the Horiba Group offered commercially available technologies consistent with ETEO objectives. One multiparameter water quality meter was procured from each vendor for ETEO consideration.

Each instrument was evaluated per vendor recommendations using supplied solutions. Additionally, standard solutions prepared by ERDC were also tested to ensure consistency among water meters. Based upon its ability to meet the success criteria, the Hanna Instruments HI9829 (Figure 4-1) was selected for further evaluation and potential adoption into the ETEO.

Figure 4-1. Hanna Instruments HI9829 multiparameter meter and probe (Hanna Instruments 2019).

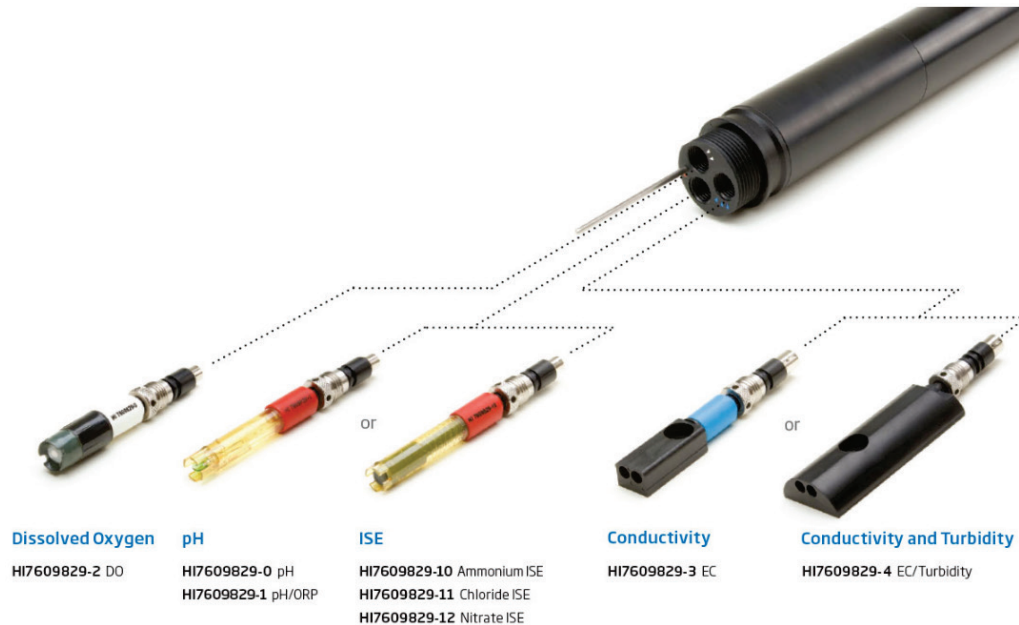


### 4.2 Technology description

The HI9829 is a multiparameter water meter capable of measuring up to 14 different water quality properties. Specifically, this device can measure dissolved oxygen (% or ppm DO), pH, oxidation reduction potential (ORP,

mV), electroconductivity (EC, mS/cm), turbidity, temperature, atmospheric pressure, resistivity, seawater sigma, salinity (PSU), and total dissolved solids (ppm TDS) via the installation of three probes, as shown in Figure 4-2. Additional probes can be installed to measure ammonium, nitrate, and chloride in place of pH/ORP measurement.

Figure 4-2. HI9829 analytical probes (Hanna Instruments 2019).



The handheld (8.7 in. x 4.5 in. x 2.2 in.) meter is equipped with a hand-strap for support in use. The HI9829 is also dust tight and waterproof up to depths of 1 m for approximately 30 min (IEC 60529). The touchpad on the meter provides access to all the device's functions. The brightness of the screen can be adjusted, as well. This meter has a mass of less than 2 lb, the detachable probe has a cord length of 13 ft, the life of the rechargeable battery is 95 hr and the total cost for this unit is \$2,550.00 (Hanna Instruments 2019).

### 4.3 Operation of the HI9829

Once the probe is submerged into the evaluated sample, the water meter can record data from each measured property at time increments from one second to three hours. This data can be plotted against time to display trends and averages during analysis; up to 44,000 individual data points can be stored on the device. Single-point data collection can also be performed. Data can be collected quickly and constantly with measurements for up to 12 properties displayed on one screen. Individual

properties can also be displayed and toggled on the main screen, as needed. The date and time of sample analysis are recorded, and remarks can be added for further documentation within the meter's user interface.

Calibration can be performed using supplied or custom solutions and standard operating procedures for each water quality parameter. The meter signals the user when certain properties require calibration by flashing the units of the parameter. Additionally, the measured data flashes when it is out of the defined calibration range. Both signals ensure quality control of data acquisition and analysis.

The HI9829 can also be connected to a Microsoft-based computer via USB. Software associated with HI9829 allows collected data to be imported by various spreadsheet programs for further analysis (Hanna Instruments 2017).

#### **4.4 Laboratory evaluations**

The HI9829 was procured by ERDC-EL for confirmation of preliminary results. Approximately 40 hr of effort were required to evaluate the HI9829's capability and accuracy using supplied calibration standards and ERDC-prepared standard solutions for pH and conductivity. These efforts successfully qualified the HI9829 in terms of performance. The portability and durability of the device was confirmed via brief inspections of the handheld, rugged unit. Additional tests for the HI9829 verified its ease of use during data collection.

#### **4.5 Usability assessments**

To assess the ease of use by non-experts, the Hanna meter was distributed to ERDC employees unfamiliar with the technology. These researchers recorded the procedures necessary to operate the instrument and collect data. This effort resulted in a one-page, 24-step standard operating procedure (SOP) comprising protocols for initiating, utilizing, and powering down the device. This SOP, included in Appendix A in addition to those for other ETEO devices, was successfully followed by other ERDC employees previously unfamiliar with the sensor, and water quality data was collected from various sources. Approximately 160 hr were required to prepare and test the SOP by the ERDC team.

### 4.6 Software integration

Once the HI9829 was selected for ETEO consideration, software integration efforts were executed. This instrument could successfully connect to ETEO laptops via USB for data analysis. The HI9829 software allowed the raw data, as shown in Figure 4-3, to be exported to a readable format that could be imported by the ETEO software application; example results are displayed in Figure 4-4. This inclusion allowed rapid and efficient data transport. An SOP further detailing software integration and data transport is included in Appendix B.

Figure 4-3. Raw data from HI9829.

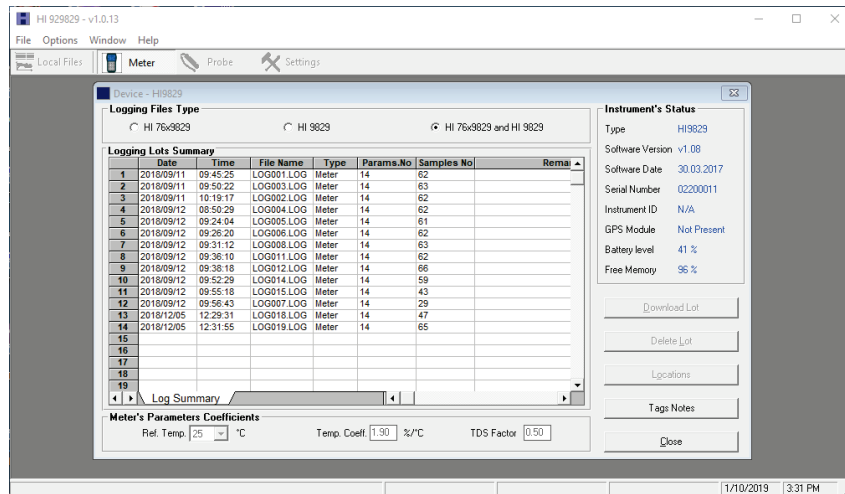
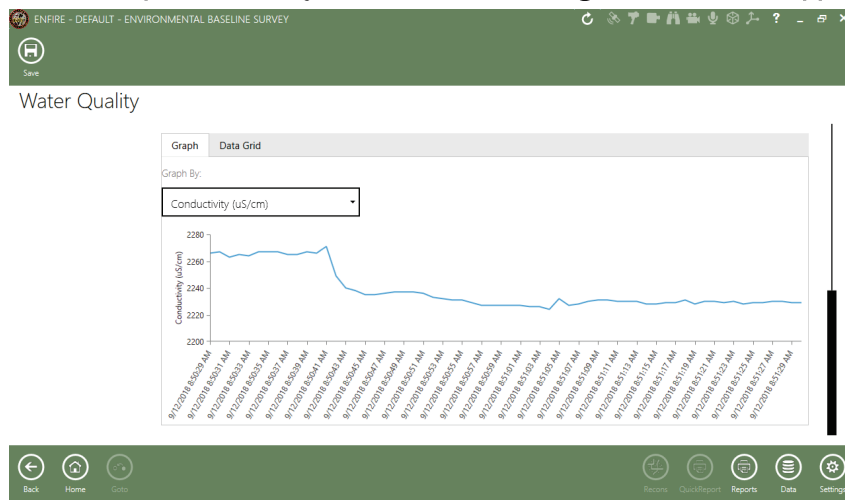


Figure 4-4. Example data analysis from HI9829 using ETEO software application.



Although the HI9829 is not GPS-enabled, geographic location of analyzed samples can be added manually following data collection and export. This coordinate data would be included in the EBS.

Approximately 2,000 labor hours were dedicated to software integration. These efforts were led by ERDC experts in sensor and software development.

## 5 Technology Demonstration

The HI9289 was included in a field demonstration at Ft. Leonard Wood, MO, in September 2018 in which the ETEO was displayed and discussed to visitors from various DoD organizations, including the National Guard, SOUTHCOM, and NDCEE. This demonstration also included the XRF, PET kit, and MultiRAE at separate areas using test samples to further communicate the benefits of ETEO and the enhanced capability the HI9289 provides. During this demonstration, the visitors were initially briefed on the objectives, benefits, and status of the ETEO. Then, the visitors were divided into separate groups and rotated among four exhibit booths, each displaying one ETEO sensor, for in-depth discussion and demonstration on the technologies.

Water samples were collected from the field and compared to tap water onsite in terms of TDS to demonstrate the HI9289's capability and accuracy. The HI9289 successfully measured a much higher TDS for the field samples compared to tap water throughout a one-minute duration. The recorded plots were displayed during analysis to confirm its pace and accuracy to the visitors. The SOP developed for the HI9289 was discussed to demonstrate its ease of use.

The XRF was demonstrated using various soils provided by ERDC. The benefits and operation of the sensor were discussed to the visiting groups prior to its use. Soil samples labeled with a known concentration of a metal were evaluated, and the visitors were shown the consistency between the results from the XRF and the anticipated concentrations.

The PET kit was demonstrated via the analysis of water and sediment samples contaminated with petroleum-based materials. The visiting staff was shown the two technologies associated with the PET kit to demonstrate the rapid identification of petroleum and the subsequent quantification of the contaminants.

The MultiRAE gas sensor was demonstrated to the visiting staff using household materials (hot coffee and a portable butane lighter) that provide low concentrations of VOCs or carbon dioxide (CO<sub>2</sub>). The coffee emitted low concentrations of VOCs that were measurable at its surface and the butane lighter also emitted VOCs when unlit fuel was released. Furthermore, the lighter emitted CO<sub>2</sub> when the butane was ignited.

Because the MultiRAE remains silent under conditions safe to human health, demonstration of the technology required the sensor to be placed exceptionally close to the pollutant to ensure analysis would cause the system's alarm to be sounded.

As with the HI9829, the SOPs for each device were discussed with the visitors. These procedures, which are shown in Appendix A, were included with a fact sheet discussing the capabilities and benefits of the ETEO in a bound booklet that will accompany the tools in future demonstrations and applications.

Following demonstration of sample analysis, the HI9829 was connected to a compatible Microsoft laptop via USB. The data from the demonstration was imported to the ETEO software and included in an EBS. The coordinates of the site were included in addition to the date and time for documentation.

Additional demonstrations were conducted at the Forward Engineer Support Team (FEST) – Advance and Environmental Support Team (EnvST) trainings under the direction of US Army Maneuver Support Center of Excellence (MSCOE) and USACE HQ Environmental Support Branch in Mobile, AL, in April 2018 and USACE ERDC in Vicksburg, MS, multiple times for various audiences.

## 6 Conclusions and Recommendations

The Hanna Instruments HI9829 successfully addressed a key capability gap for the ETEO by providing analysis of 14 water quality properties. This commercially available tool was selected after a market survey based upon its performance attributes, usability, and cost. Following performance evaluations, this technology was successfully adapted to the ETEO software package for efficient EBS reporting. The HI9829 and software integration capability was successfully demonstrated at Ft. Leonard Wood. Integrating the HI9829 into the existing toolkit demonstrated the capability of the ETEO to rapidly integrate new sensors with minimal programming.

The performance of the HI9829 could be further investigated through additional evaluations. Specifically, field samples from various locations could be analyzed to confirm the efficacy of the probes in different matrices. Additionally, wider ranges of laboratory-prepared solutions could have been evaluated to further determine the accuracy of the probes. Evaluations of adjustments to multiple properties within standard solution sets would also be beneficial in terms of determining potential interference of one property on another. Repeatability and reproducibility studies could be performed by analyzing various sample solutions in sequence to evaluate and validate the precision of the equipment. Lastly, usability studies could be performed by non-technical individuals equipped with the HI9829, the SOP, and test samples during trial scenarios. Although these investigations could be performed to further confirm the capability of the HI9829, the technology has been selected for use in ETEO.

The Gemini by Thermo Scientific was not selected for inclusion in the ETEO design based on its lack of ability to detect TNT accurately and safely in soil via FTIR or Raman spectroscopy. Though this specific tool was eliminated for this application, other potential sensors for organic detection and quantification should be investigated for the ETEO in future efforts.

Regardless, the capability of the ETEO improved greatly with the inclusion of a water quality meter. The current design of this set includes sensor technologies for three environmental matrices – soil, water, and air – that could be monitored for environmental reporting or hazard identification. The software currently available for ETEO can utilize the data from each



sensor included in this design to efficient analysis and reporting. Although these sensors and software are sufficient for the current applications for ETEO, improvements to the capabilities and operation should be continuously made to further support the Warfighter and intended users.

## References

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## Appendix A: ETEO Instrument SOPs

### A.1 Water quality – Hanna Instruments HI9829

1. Connect probe to the socket at the bottom of the water meter. Align the pins and key, then push the plug into socket and tighten the thread.
2. On the probe, loosen the bottom protective cover. Remove the clear plastic cap from the pH probe and set aside. Twist the protective cover back into place.
3. Press and hold the power button to turn on the device.
4. Select “Param.,” and then select “Enable All.”  
  
\*If the meter reads “Disable All,” select “Disable All” then select “Enable All.” This will ensure all parameters are selected for the analysis.
5. Press “ESC” twice, and select “Menu,” then select “System setup.”
6. Select “Meter setup.”
7. Ensure the Time and Date are correct.  
  
\*If they are incorrect select “Modify” and revise to the correct time/date. Then select “Accept.”
8. Once finished, press “ESC” three (3) times to return to the main screen.
9. On the meter, select “Log.”
10. Arrow down to “Start meter log” and select “Options.”
11. Ensure the Log interval reads “00:00:01.”  
  
\*If it does not, select “Modify” and revise the time to read “00:00:01” and select “Accept” to return to the previous screen.
12. Select “ESC.”
13. Place the probe into the water sample, ensuring that all probes are submerged into the water.
14. Arrow down to “Start meter log” and choose “Select,” then “New.”
15. Using the keypad, type in a sample ID, and select “Accept.”
16. Select “OK,” then “No,” and then “Skip.”
17. The meter will begin to record the sample parameters, and the elapsed time in sec will display on the bottom right-hand side of the screen.
18. Leave the probe in the water sample for approximately 60 sec.
19. Select “Log,” then “Stop meter log.”
20. Remove the probe from the water and rinse with clean water.
21. Repeat Steps 8 – 20 for each additional sample reading.
22. Once finished, press and hold the power button to turn off device.

23. On the probe, loosen the bottom protective cover. Ensure that 1/3 the clear plastic cap is filled with KCl, and place back on the pH probe.  
Twist the protective cover back into place.
24. Disconnect the probe from the socket at the bottom of the water meter.

## **A.2 Petroleum analysis – Promega QuantiFluor®-P Fluorometer**

1. Collect the water/sediment sample in a clean container.
2. If necessary, allow wet sediment to settle.
3. Once settled, pour liquid layer into a separate clean container to give both a sediment and water sample.
4. Perform the extraction procedures in Step 5 for water sample and/or Step 6 for sediment sample. If needed, reference the “PET Kit Reference Vials” kit for the extractions.
5. Water Sample Extraction:
  - a. Fill a new/clean Water Vial with hexane up to the bottom arrow “B.”
  - b. Slowly pour water from the sample into the Water Vial until the liquid level reaches the top arrow “A.”
  - c. Replace the lid on the vial tightly and shake vigorously for 1 min.
  - d. Allow the mixture to sit until there are two separate layers.
  - e. Label the Water Vial with date, time, and location.
6. Sediment Sample Extraction:
  - a. Using the 1/2 tablespoon soil measuring device and spatula found in the Fluorometer toolkit, measure a level of 1/2 tablespoon sediment/soil from the sample.
  - b. Transfer the sediment sample into Sediment Vial 1, which should already contain sodium sulfate.
  - c. Mix the two solids thoroughly using the spatula.
  - d. Fill Sediment Vial 2, one that does not contain sodium sulfate, with hexane up to the arrow.
  - e. Once complete, pour the contents of Sediment Vial 2 into Sediment Vial 1.
  - f. Replace the lid on Sediment Vial 1 tightly.
  - g. Shake Sediment Vial 1 vigorously for 10 sec, then allow the vial to sit for 10 sec. Repeat this shake/site process for a total of three (3) times.
  - h. Let Sediment Vial 1 sit for 1 min.
  - i. Transfer as much of the liquid in Sediment Vial 1 into Sediment Vial 2 using the plastic pipette. Care should be taken to transfer as little of the solid as possible.

- j. Label Sediment Vial 1 and Sediment Vial 2 with date, time, and location.
7. Turn on the device by pressing the “ON/OFF” button and wait 5 sec for the instrument to warm up.
8. Press “DATA” twice, then “ENTER” to start logging.
9. Press “ESC” to return to the analysis screen. “Logging” should now appear on the screen.
10. Using a pipette contained in the Fluorometer toolkit, transfer the water sample from Steps 4 and/or 5 on Page 1 into a cuvette, also found in the Fluorometer toolkit. Fill to the top line on the cuvette.
11. Ensure the outside of the cuvette is clean prior to analysis.
12. Open the cover on the top of the Fluorometer, above the analysis screen.
13. Insert the cuvette into the holder.
14. Close the top cover and press “READ.”
15. Wait until a numeric value is displayed on the screen. The measurement should take roughly 10 sec.  
  
\*The value displayed corresponds to a crude oil concentration in mg/L for water sample or mg/kg for soil/sediment.
16. Remove the analyzed sample by opening the top cover.
17. Pour the sample back into the vial it was extracted from.
18. Repeat steps 7-14 for each collected water and sediment sample.
19. Once finished, close the top cover.
20. Press “DATA” twice and “ENTER” to stop logging.
21. Press “ESC” to return to the analysis screen. “Logging” should no longer appear on the screen.
22. Turn off the device by pressing “ON/OFF” button.

### **A.3 Soil analysis – Niton™ XL34t XRF**

1. Power on the analyzer by pressing and holding the “ON/OFF/ESCAPE” button until the touch screen turns on.
2. Wait until the system finishes initializing, then tap anywhere on the screen.
3. Acknowledge the radiation warning by selecting “yes.”
4. Enter password “1234,” followed by pressing “Enter.”
5. Select the “System” icon followed by the “Date & Time” icon.
6. Verify correct date and time settings for accurate and verifiable data collection.
7. Select “Save” and hit the “Return” icon to return to the main menu.

8. Select the “System Check” icon and hit “Yes.”  
\*It is recommended that this be performed every working day as part of the startup procedure.
9. Wait until the system finishes performing the check. Once finished, the screen should read “System OK.” Hit “Close.”
10. Attach the metal test guard over the front nose of the analyzer. Secure the guard by firmly clipping into place.
11. Press the “Sample” icon, then select “Soils and Minerals,” then “Soils.”  
\*This will put the analyzer in soils mode and show a “Ready to Test” screen.
12. Select the “Data Entry” tab and touch the keyboard icon to the right of the sample tab.
13. Enter sample name by using the keyboard and press return.
14. Position the analyzer on the desired analysis spot, ensuring the nose of the analyzer is making direct contact with the soil.
15. Pull and hold the trigger for 60 sec to initiate the reading. **DO NOT LET GO OF TRIGGER WHEN ANALYZER BEEPS.**
16. Once finished, press the center button to return to the data entry screen.
17. Remove and clean any soil residue from the metal guard.
18. Repeat steps 12 – 17 for each sample analyzed.
19. After analyzing all samples, press the arrow button on the bottom left-hand corner of the screen, and then the “ON/OFF/ESCAPE” to return to the main menu.
20. To power off, select the “Logoff” icon, then press and hold the “ON/OFF/ESCAPE” button until the screen turns off.

#### **A.4 Air quality – MultiRAE PGM-6228**

1. Press and hold the power button to turn on the device.
2. Once on, the meter will begin measuring oxygen, lower explosive limit (LEL), hydrogen sulfide (H<sub>2</sub>S), carbon monoxide (CO), and volatile organic compounds (VOC) levels.
3. Turn off the device by holding the power button for 5 sec.

#### **A.5 Data transfer instructions**

1. Connect USB data transfer cable for the Water Meter to the meter and to the yellow color-coded port on back of laptop.

2. Press and hold the power button to turn on the Water Meter. The unit should display “PC Connected.”
3. Open HI929829 software icon on the computer desktop.
4. From the top toolbar, select “Meter.” This will display all the recorded readings.
5. Select the recorded reading, then press “Download Lot” and “OK.”
6. Save as a TXT file type to the computer.
7. For multiple recorded samples, repeat steps 5 – 6.
8. Press “Close,” then press “Close” again, and “Yes” to disconnect the device.
9. Close out of the HI929829 software program.
10. Disconnect the data transfer cable from the computer and meter and press the power button to turn off the device.
11. Connect USB data transfer cable for the XRF to the yellow color-coded port of laptop and the XRF device.
12. Turn on the XRF by pressing the “ON/OFF/ESCAPE” button until the touch screen turns on.
13. Tap anywhere on the screen, then press “Yes.”
14. Enter password: 1234, and press “Enter.”
15. Open the NDT software icon on the computer desktop.
16. From the top toolbar, select “Download.”
17. Select “Settings,” and choose “COM4 <USB Serial Device>” and hit “OK.”
18. Select “Connect” on the bottom left, and then “Test.” The screen should say “Hardware Successfully Communicating.” Press “OK.”  
  
\*If the connection fails, disconnect then reconnect the transfer cable from the XRF and repeat steps 17 – 18. Additionally, one may have to repeat step 17 and choose a different COM port.
19. Press “Query Readings,” and select the recorded samples to be downloaded by checking the box on the left-hand side of the desired sample(s).
20. On the left-hand side, choose a Destination folder and File name.
21. If not already selected, check the box for “Simultaneous Download to MS Excel.”
22. Press “Download,” then select “Done”
23. From the top toolbar, select “Export.” The CSV file will open, and the CSV data file will save to the Destination folder.
24. Close the Excel program and the NDT software program.

25. Select the “Logoff” icon on the XRF, and then press and hold the “ON/OFF/ESCAPE” button to turn off the device.
26. Disconnect the data transfer cables from the computer and XRF unit.

## **A.6 Upload data to ENFIRE**

1. Connect the serial cable for the Fluorometer to the green color-coded port on laptop.
2. Turn on the device by pressing the “ON/OFF” button.
3. Launch the ENFIRE software program and wait for the program to finish loading.
4. Once finished, select “Recons” on the bottom toolbar, and then select “Environmental Baseline Survey.”
5. From the top toolbar, select “Create EBS.”
6. On the map, draw a box around the sample area. An EBS should open.
7. From the left toolbar, choose “Fluorometer” and click on “+” symbol.
8. Label the New Reading.
9. Set the COM port to proper port for device (commonly this is COM1) and leave baud rate at 9600.
10. Press “Connect to Device.”
11. On the Fluorometer, press “Data” three (3) times, then press “Enter” five (5) times.
12. Data from the Fluorometer should now appear on the Graph and Data Grid tabs under Data Views.
13. From the left toolbar, select “XRF” and then click “+.”
14. Label the New Reading.
15. Under “Import Data,” press “Import Data From File” and choose the CSV file previously saved under the Data Transfer Instructions. The data should now appear on the Graph and Data Grid tabs under Data Views.
16. From the left toolbar, select “Water Quality” and click on “+” symbol.
17. Label the New Reading.
18. Under “Import Data,” press “Import Data From File” and choose the TXT file previously saved.
19. Repeat steps 16-18 for all the recorded water meter readings.
20. Select “Save” on the top toolbar to save the Environmental Baseline Survey.
21. Turn off the Fluorometer device by pressing the “ON/OFF” button and disconnect the data transfer cables.



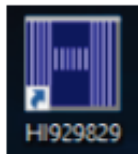
## Appendix B: HI9829 Software SOPs

### Introduction

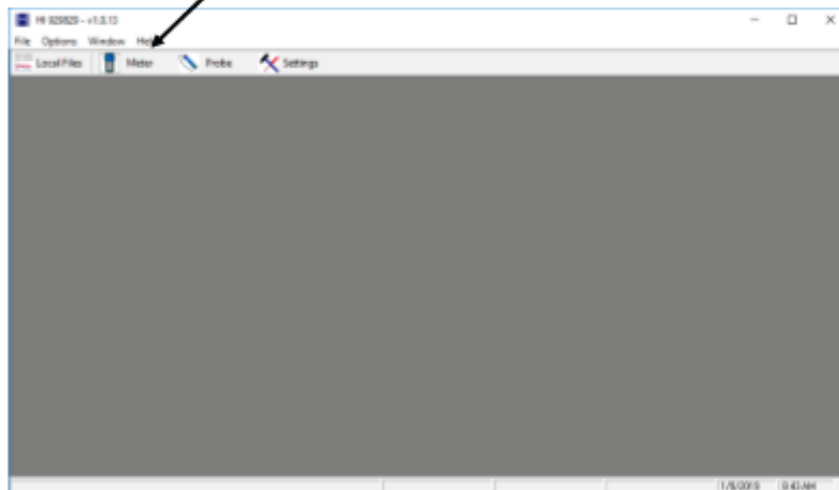
The Environmental Toolkit for Expeditionary Operations (ETEO) water meter data transfer is described below. The description covers the transfer of collected data for a Hanna water meter sensor systems to the ENFIRE system.

### Transferring the Data onto the Computer System

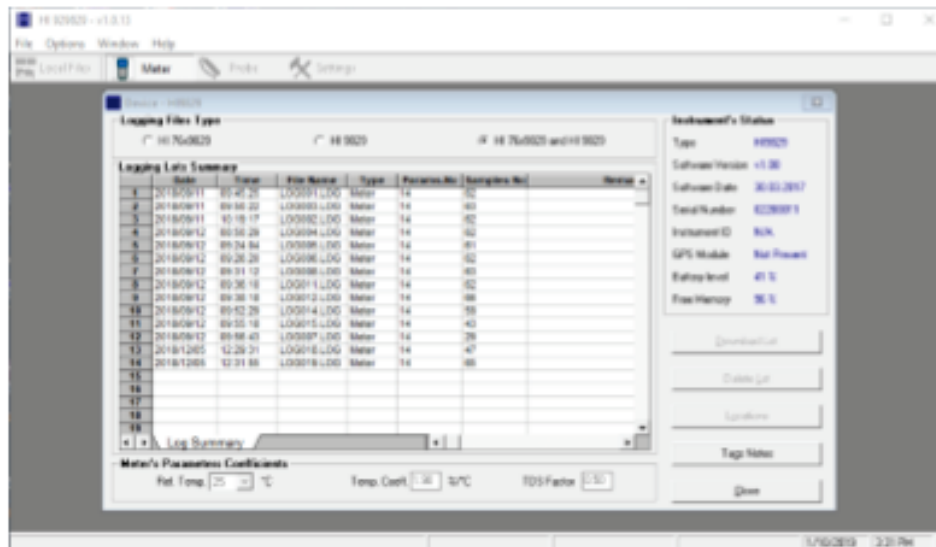
- Click on the “Hanna Meter software interface” ICON on your desktop to start the Hanna Graphical User Interface (GUI).



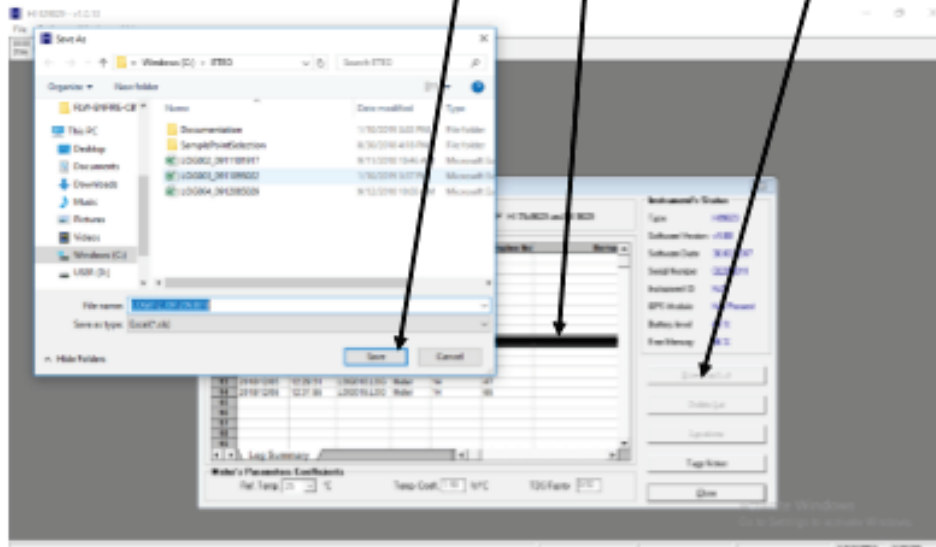
- The following Hanna GUI will appear.
- Click on the “Meter” button in the upper left-hand corner of the GUI.



- A spreadsheet representation of the recorded readings will be displayed as shown below.



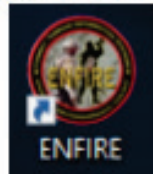
- Select the recorded reading from the list. Click the "Download Lot" button. Navigate to the desired directory in the "Save As" window and Click on the "Save" button.



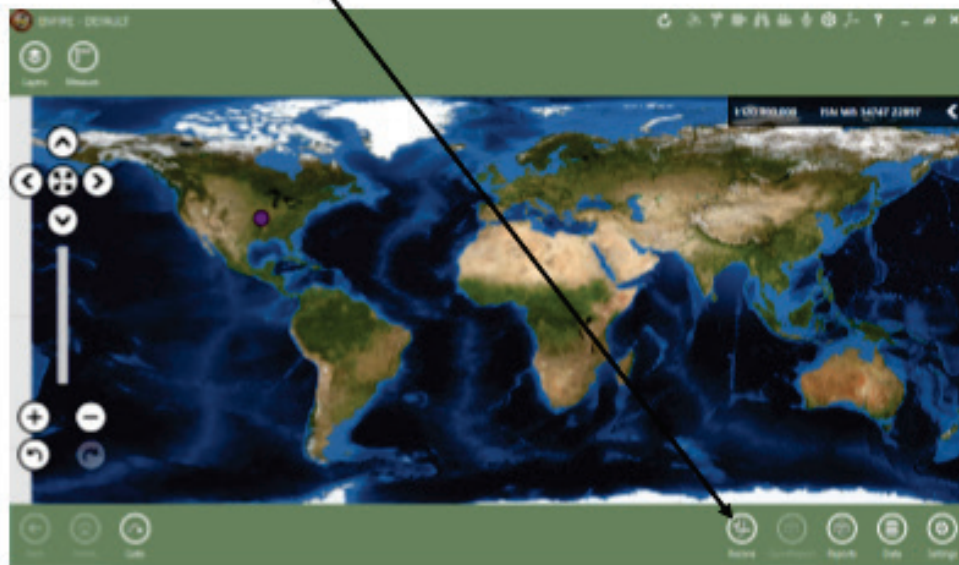
- The selected recorded reading is now saved as an text document in the desired directory.

## Opening ENFIRE and Selecting Recon

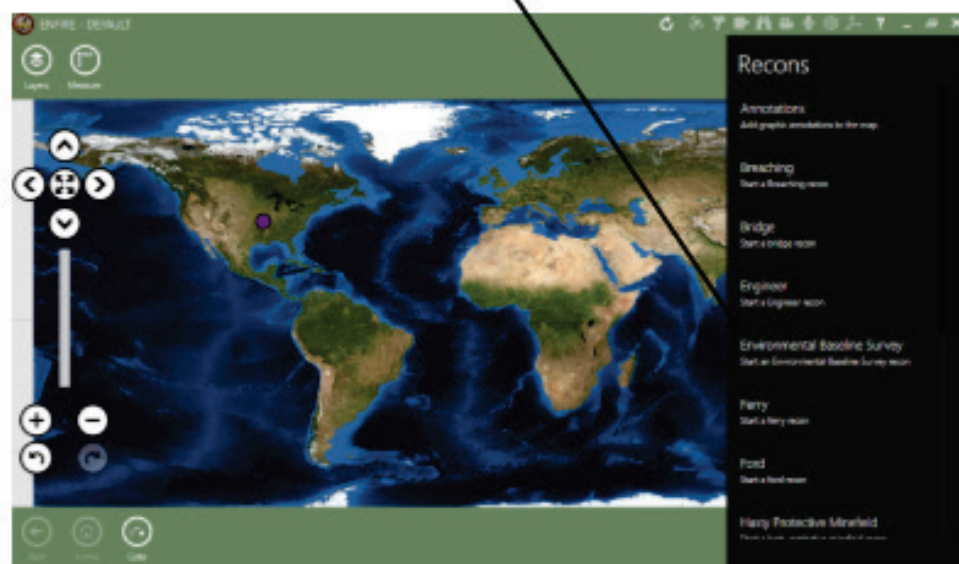
- Click on the “ENFIRE” ICON on your desktop to start the EN-FIRE GUI.



- The following ENFIRE GUI will appear.
- Click on the “Recons” button in the lower right-hand corner of the GUI.



- Click on the “Environmental Baseline Survey” recon.



## Selecting the Environmental Baseline Survey

- Click on the "EBS Reports" button.



- Now, select the desired Environmental Baseline Survey (EBS) report from the list.





## Labeling the Water Quality Sample Site

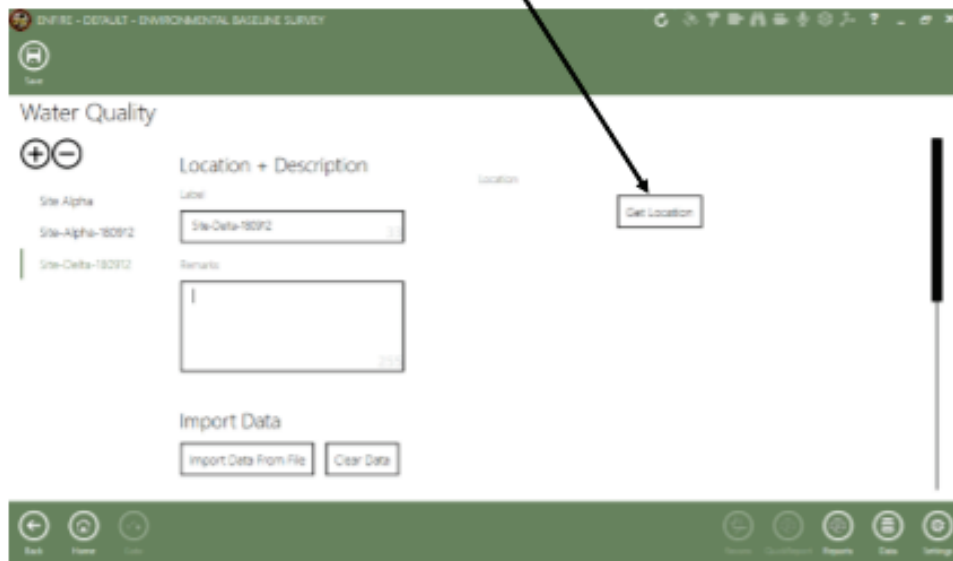
- The EBS report will be displayed on the screen as shown below. Click on the “Water Quality” button to open the Water Quality data entry screen.



- The following data entry window for water quality will open. Click in the “Label” box and replace the “New Reading” text with the name and date of the sample site.

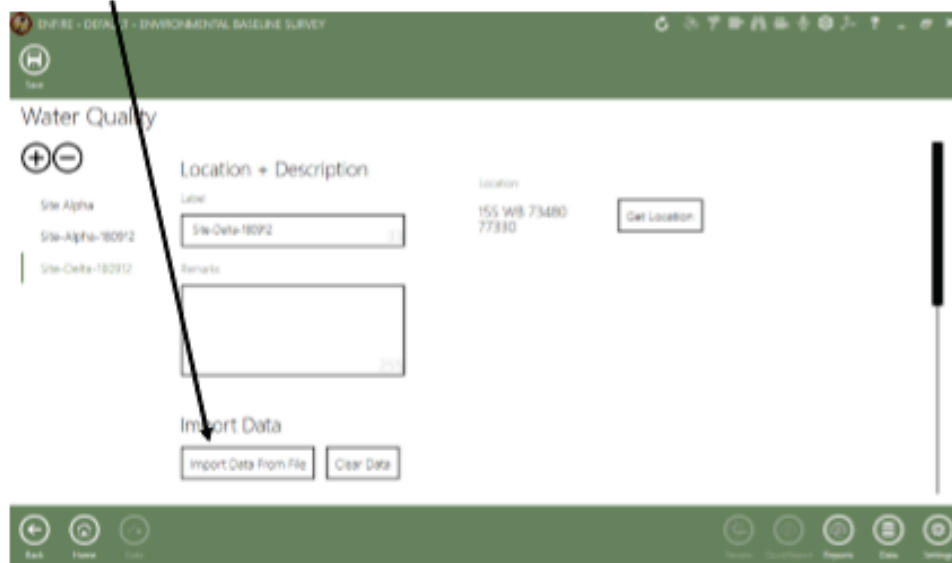
## Entering the Location of the Water Quality Sample Site

- Now, click on the “Get Location” button and enter the MGS coordinates for the sample site.



The screenshot shows the 'Water Quality' data entry screen. The title bar reads 'ENRIS - DEFAULT - ENVIRONMENTAL BASELINE SURVEY'. Below the title bar, there is a 'Home' button and a 'Water Quality' header. The main content area is divided into sections: 'Location + Description', 'Import Data', and a bottom navigation bar. In the 'Location + Description' section, there are three 'Site Alpha' options: 'Site Alpha', 'Site Alpha-180912', and 'Site Delta-180912'. The 'Label' field contains 'Site-Delta-180912'. The 'Remarks' field is empty. To the right of the 'Label' field, the word 'Location' is displayed. A 'Get Location' button is highlighted with a black arrow. Below the 'Location + Description' section is the 'Import Data' section, which contains two buttons: 'Import Data From File' and 'Clear Data'. The bottom navigation bar includes 'Back', 'Home', 'List', 'Tools', 'Location', 'Reports', 'Data', and 'Settings'.

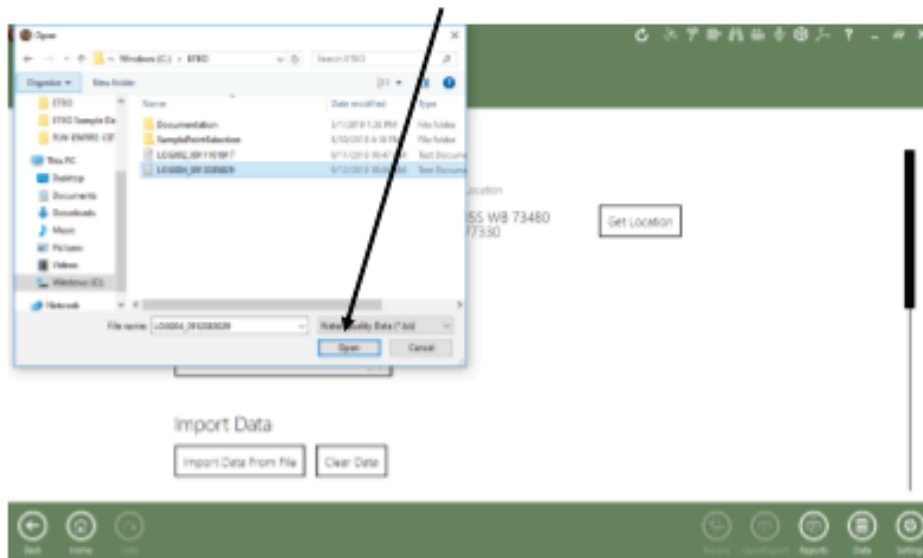
- The displayed Water Quality data entry screen will now have the label and the location displayed as shown below. Click on the “Import Data From File” button to load data.



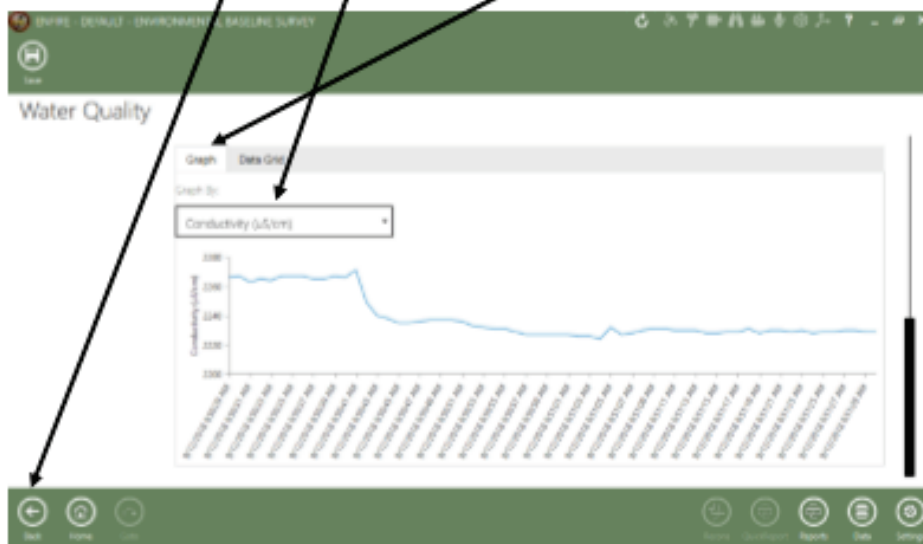
The screenshot shows the 'Water Quality' data entry screen after the location has been entered. The title bar reads 'ENRIS - DEFAULT - ENVIRONMENTAL BASELINE SURVEY'. Below the title bar, there is a 'Home' button and a 'Water Quality' header. The main content area is divided into sections: 'Location + Description', 'Import Data', and a bottom navigation bar. In the 'Location + Description' section, there are three 'Site Alpha' options: 'Site Alpha', 'Site Alpha-180912', and 'Site Delta-180912'. The 'Label' field contains 'Site-Delta-180912'. The 'Remarks' field is empty. To the right of the 'Label' field, the word 'Location' is displayed, followed by the coordinates '155 WB 73480' and '77310'. A 'Get Location' button is visible. Below the 'Location + Description' section is the 'Import Data' section, which contains two buttons: 'Import Data From File' and 'Clear Data'. The 'Import Data From File' button is highlighted with a black arrow. The bottom navigation bar includes 'Back', 'Home', 'List', 'Tools', 'Location', 'Reports', 'Data', and 'Settings'.

## Importing Water Quality Data

- The “Open” window will be displayed as shown below. Navigate to the directory containing the water quality data file, select the file, and click the “Open” button.



- Once the data is loaded, view the data to verify the data transferred correctly. In the example below, the “Graph” tab was chosen and the “Conductivity (uS/cm)” data type was selected. Click on the “Back” button to return to the EBS report display.



## Generating EBS Document

- The EBS report will be displayed on the screen as shown below and will display the new water quality data site. Click on the "Reports" button to bring up a list of EBS reports.



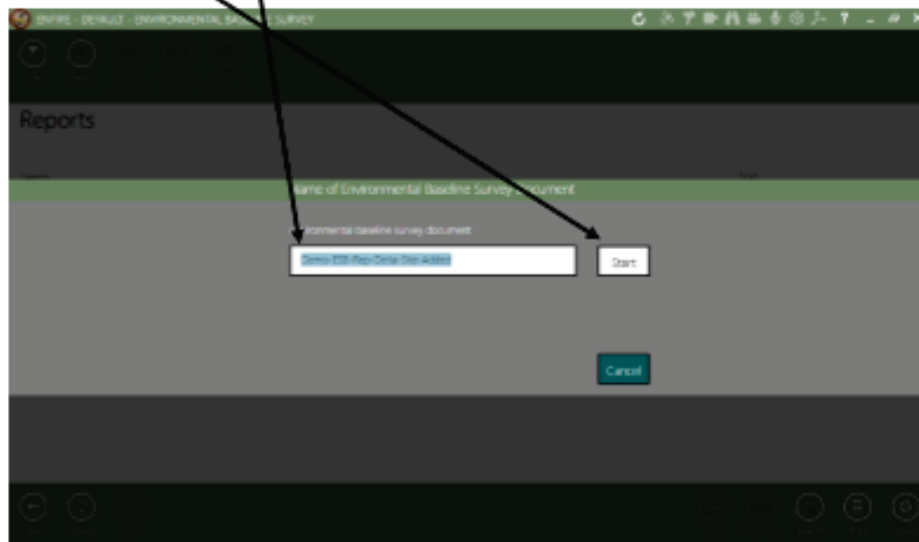
- The list of EBS reports is displayed as shown below. Select the report for generating the EBS document.



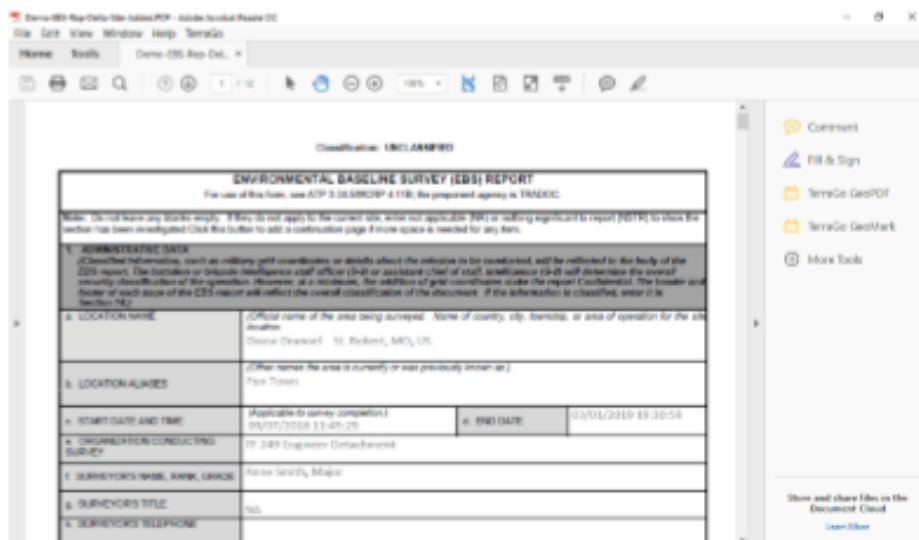


## Generating EBS Document (continued)

- Enter the name for the EBS document you are generating. The document will be created in the user's Documents directory. Click the "Start" button.



- The Adobe Acrobat Reader will open and display the new EBS document.



## Reviewing the Site Data

- Search on the name of the site and review the site data, as shown below.



## Acronyms

AL	Alabama
ASA(ALT)	Assistant Secretary of the Army (Acquisition, Logistics, and Technology)
BRAC	Base Realignment and Closure
CO	Carbon monoxide
COTS	Commercial off-the-shelf
DoD	Department of Defense
EBS	Environmental Baseline Survey
EL	Environmental Laboratory
ENFIRE	Instrument Set, Reconnaissance and Surveying
EnvST	Environmental Support Team
EPA	Environmental Protection Agency
ERDC	Engineer Research and Development Center
ETEO	Environmental Toolkit for Expeditionary Operations
FEST	Forward Engineer Support Team
FTIR	Fourier transform infrared (spectroscopy)
FTLW	Ft. Leonard Wood, MO
FUDS	Formerly Used Defense Sites
GRL	Geospatial Research Laboratory
hr	Hour
HQ	Headquarters
H <sub>2</sub> S	Hydrogen sulfide
IB	Industrial Base
IR	Infrared (spectroscopy)
LEL	Lower explosive limit
min	Minute
MOOTW	Military operations other than war
MS	Mississippi
NDCEE	National Defense Center for Energy and Environment
NH <sub>4</sub>	Ammonium

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NO <sub>3</sub>	Nitrate
NO <sub>2</sub>	Nitrite
O <sub>2</sub>	Oxygen
Pa	Pascals
PET	Petroleum test
ppb	Parts per billion, µg/L
ppm	Parts per million, mg/L
psi	Pounds per square inch
S	Sulfur
TNT	2,4,6-Trinitrotoluene
VOC	Volatile organic compounds
WaterDOG	Water Diagnostics Operations Gear
XRF	X-ray fluorescence
U	Uranium
UV	Ultraviolet
UV/Vis	Ultraviolet/Visible

# REPORT DOCUMENTATION PAGE

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<b>1. REPORT DATE (DD-MM-YYYY)</b> September 2022		<b>2. REPORT TYPE</b> Final		<b>3. DATES COVERED (From - To)</b>	
<b>4. TITLE AND SUBTITLE</b> Qualification of Hanna Instruments HI9829 for the Environmental Toolkit for Expeditionary Operations				<b>5a. CONTRACT NUMBER</b>	
				<b>5b. GRANT NUMBER</b>	
				<b>5c. PROGRAM ELEMENT NUMBER</b> 643779E21	
<b>6. AUTHOR(S)</b> Luke A. Gurtowski, Josh LeMonte, Jay Bennett, Brandon Lafferty, and Matthew Middleton				<b>5d. PROJECT NUMBER</b> 485389	
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<b>9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b> US Army Corps of Engineers Washington, DC 20314-1000				<b>10. SPONSOR/MONITOR'S ACRONYM(S)</b>	
				<b>11. SPONSOR/MONITOR'S REPORT NUMBER(S)</b>	
<b>12. DISTRIBUTION / AVAILABILITY STATEMENT</b> Approved for public release; distribution is unlimited.					
<b>13. SUPPLEMENTARY NOTES</b> NDCEE					
<b>14. ABSTRACT</b> A new, commercially available, field-portable water sensor was evaluated for efficacy during operation and compatibility with current Environmental Toolkit for Expeditionary Operations (ETEO) software. The ETEO provides sensors to Soldiers to rapidly identify and quantify environmental contamination in soil, air, and water at potential new base sites during initial reconnaissance to ensure safety and minimize unnecessary remediation efforts by the Army. In addition to streamlined environmental baseline survey (EBS) reporting, the ETEO can provide rapid analysis of potential environmental contamination to support various Military applications. The Hanna Instruments HI9829 multiparameter water meter was selected following a survey of commercial off-the-shelf (COTS) technologies and analyzed by researchers from the US Army Engineer Research and Development Center (ERDC) for inclusion in the ETEO design since it can rapidly and accurately measure 14 different properties. Usability tests were conducted with researchers unfamiliar with the technology, and a set of standard operating procedures (SOPs) were developed to operate the device. The software for the tool was successfully integrated into the ETEO system for rapid data analysis. The HI9829 has been demonstrated in various scenarios at ERDC and other locations; including Ft. Leonard Wood, MO, at which several visitors reviewed the operation of the equipment and other ETEO technologies. The Thermo Scientific Gemini, another sensor, which can detect organic constituents in various matrices via Fourier transform infrared (FTIR) spectroscopy and Raman spectroscopy was also investigated but eliminated from the ETEO design as it could not adequately detect a Military-relevant compound in an environmental matrix. Regardless, the addition of the HI9829 provides water quality monitoring to the ETEO design and greatly improves its capability to address various applications.					
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