

Subsurface Oil Detection and Delineation in Shoreline Sediments

Phase 2—Final Report

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Executive Summary

The result of a survey of subsurface oil detection and delineation tactics has generated a set of recommendations for studies or activities that have a high probability of success and that could significantly advance this capability at low cost and in a relatively short (1- to 2-year) time frame.

Existing proven technologies have the potential to provide continuous or near-continuous detection capabilities that are both rapid and accurate and that are applicable for a range of shoreline, river bank and terrestrial environments.

To a large degree, the primary obstacles to the acceptance of these proven tactics are that they (a) are poorly understood beyond the teams that currently use these tactics and (b) have not been systematically field tested to provide proof of concept.

This report presents recommendations for the development and testing of emerging, but technically proven, technologies which have demonstrated the potential application to subsurface shoreline, river bank and terrestrial oiling issues. These recommendations have a high probability of success and could become operational tools as there are no technological barriers to overcome.

Recommendations for supplemental work on subsurface oil detection and delineation are identified in Section 4.0.

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Subsurface Oil Detection and Delineation in Shoreline Sediments Phase 2a—Final Report

1.0 Introduction

Emergency response to oil spills which impact shorelines or river banks is often complicated by the fact that oil may penetrate or become buried in sediment and may not be detectable from the surface. The standard (and current) practice for detection and delineation of subsurface oil on sediment shorelines consists of visual observations made in pits and/or trenches which are either manually or mechanically excavated. This tactic is labor intensive, slow, and because it relies largely on individual (spot) samples, has limited accuracy and efficiency to delineate the horizontal extent of subsurface oil. Adequate delineation is particularly problematic for low oil concentrations, such as scattered tar balls, and irregular oil distribution, such as oil stranded along swash lines. For example, even intensive pit observations might only cover less than 0.01% of an impacted beach and has a high probability of failing to encounter oil, particularly when oil concentrations are low and distribution is irregular. In addition, the relative cost of assessment per sample area (i.e. square yard of pits or trenches dug) is high compared to methods with broader horizontal delineation. Other commonly used tactics such as coring, gas measurement, water jetting, and geophysics also have sample density issues with varying sensitivities to oil and environmental factors which make their performance erratic. The need for faster and more accurate methods for subsurface oil detection and delineation procedures is well recognized. Fortunately, recent and developing technological advances have produced technologies which promise significant advances in subsurface oil detection.

This study was conducted as part of the American Petroleum Institute (API) Joint Industry Task Force Oil Spill Research and Development Program initiated in 2012 to improve, among other aspects of oil spill preparedness and response, the capabilities for Protection and Restoration of Shorelines. One component of this effort focused on the improvement of shoreline survey techniques for the detection and delineation of subsurface oil in sediment shorelines. Phase 1 of this study described current practice in subsurface oil detection and delineation and identified procedures which have been used with varying effectiveness (API 2013: *Subsurface Oil Detection and Delineation in Sediment Shorelines: Phase 1 – Final Report*, API Technical Report 1149-1)¹.

Phase 2 of the study involved: 1) this document presents recommendations for development and field trials of emerging technologies which have demonstrated potential application to shoreline, river bank and terrestrial oiling issues and 2) the production of a field guide (API 2013b: Technical Report 1149-2b)² for the application of detection and delineation techniques identified in Phase 1.

2.0 Summary of Phase 1 Findings

2.1 Subsurface Oil Detection and Delineation Procedure Objectives

Evaluation of current and developing subsurface oil detection and delineation procedures was based on the following desired objectives:

- Continuous delineation (both horizontal and vertical dimensions);
- Rapid survey speed (as time typically is of the essence, the procedure should be readily available, adaptable to any sediment shoreline conditions, and include real-time analysis, data processing and plotting capability);

¹ <http://www.oilspillprevention.org/oil-spill-research-and-development-cente>

² <http://www.oilspillprevention.org/oil-spill-research-and-development-cente>

- Characterization of the properties of the oil as necessary to evaluate fate and behavior, including design of a shoreline treatment program; and
- Have low relative cost (including capital investment and operational costs).

Table 2.1 summarizes IDEAL attributes of both existing (current) procedures and for developing technologies which show potential for future application. The evident conclusion from this figure is that no single procedure meets all of the ideal objectives. Attributes associated with each procedure are categorized by color, with **green** indicating a favorable application, **yellow** indicating conditional or potential application, and **red** indicating a procedure that is either “not applicable” or has a low probability of success. In the last row, continuous sampling techniques are colored **green** and labeled with a capital C; discontinuous (or “spot”) sampling techniques are colored **red** and labeled with a capital S. Note that the techniques identified in Table 2.1 have favorable application potential that differ from the recommendations given in Table E-1 of the Phase 1 Report³, due to the ongoing development of the authors’ understanding of the detection techniques.

Costs for various procedures are dependent on numerous unpredictable factors (capital investment, field deployment costs and site conditions being major factors) and are discussed in this report only in relative terms. For perspective, planning level operating costs are all basically within the same estimated range of between US\$5,000 to \$25,000 per team per day. The field deployment costs do not reflect the survey design differences between techniques which provide continuous areal coverage versus the techniques which involve spot sampling.

Table 2.1—Existing and Potential Attributes of Subsurface Oil Detection and Delineation Procedures

ATTRIBUTES	Existing Procedures			Developing Technology (Potential)			
	Excavate	Cores	Jetting	Push Probes	Detection Dogs	Geophysical	Surface Gas
Delineation (Horizontal)	Yellow	Red	Red	Red	Yellow	Yellow	Yellow
Delineation (Vertical)	Green	Green	Yellow	Green	Red	Yellow	Red
Survey Speed	Red	Red	Yellow	Yellow	Green	Green	Green
Oil Character	Green	Green	Yellow	Green	Red	Red	Red
Continuous cover (green) vs spot sampling (red)	S	S	S	S	C	C	C

³ <http://www.oilspillprevention.org/oil-spill-research-and-development-cente>

2.2 Current Practice

The Phase 1 evaluation concluded that current practice for detection and delineation of subsurface oil in sediment shorelines and river banks relies primarily on the use of manually or mechanically excavated pits and trenches to allow visual examination and documentation of subsurface conditions and/or sampling for offsite analysis. Visual examination in pits and trenches, when used with a systematic documentation program, such as SCAT, has generally been adequate to meet operational needs (e.g. Owens et al., 1995). However, these procedures are typically labor intensive, excessively time consuming, and are limited in their ability to accurately and efficiently delineate the 3-dimensional extent of subsurface oiling, particularly in the horizontal dimension. This limitation is largely due to the fact that the excavations rely on discontinuous, or spot, samples which are collected either randomly or on fixed sampling grids. The accuracy of delineations using excavations can be improved through collection of additional samples, but only with additional expenditures of time and resources. Even with an intensive excavation survey, pitting and trenching may only cover a small percentage (<0.1%) of the subsurface area. To a large degree, the selection of sample locations is based on the interpretation by an experienced coastal geomorphologist or sedimentologist of beach morphology and the recent history (typically days to weeks) of beach processes that cause erosion and deposition. This professional judgment in itself does not guarantee that subsurface oil will be detected in the sample locations.

Excavations allow visual examination of sedimentary features so that trained observers can interpret and understand recent physical processes that affect the distribution of oil on a beach. Sedimentary features include beach stratigraphy, location and character of depositional zones, nature of penetration of fluid oils, and the location of groundwater levels, all of which are important to understand the depositional environment and in planning and implementing tactical response actions. Excavation and visual observations in some form (trenches are usually most effective) are required to understand the character and vertical distribution of subsurface oil, collect data, and samples, if necessary. Excavation in some form is likely to be required for verification and calibration of many of the developing subsurface oil detection and delineation procedures.

Other procedures, including coring and water jetting have been used historically with varying degrees of success. These procedures also rely on collection of limited point source information, and, although they share similar limiting characteristics and limitations with excavations, they are typically more time consuming. A few of the more novel procedures include:

- Gas measurements have seen limited use on shorelines historically, and, although their use has been promising, no satisfactory field instrumentation has been available and off site laboratory analysis was required, rendering the procedure impractical for emergency response. Advances in field instrumentation, GPS, and analytical software have led to the development of real-time gas monitoring bundles that show promising application to emergency oil spill response.
- Applicable geophysical techniques have been available for at least 20 years, and have been applied successfully to many onshore oil and hazardous material investigations, but have rarely been applied to shoreline situations. In general, geophysics lacks the sensitivity for detection of small quantities or scattered distributions of buried oil, and some tactics are subject to interference by salt water.

2.3 Developing Technology

A number of developing procedures and technologies were identified in the Phase 1 study. These procedures and technologies as described below have the potential to significantly advance current practice, under conditions where their use is appropriate.

2.3.1 Detection Dogs

Description:

Detection dogs are a proven strategy in common use worldwide to detect and locate a wide range of materials including drugs, explosives, contraband food shipments and missing persons. Their importance in certain fields, particularly the detection of narcotics, led to the formation of a US federal government funded Scientific Working Group on Dog & Orthogonal Detector Guidelines (SWGDOG)⁴. This group was established to develop consensus based best practices for the use of detection teams). SWGDOG is a partnership of local, state, federal and international agencies including private vendors, law enforcement and first responders. The group has completed ten approved Guidelines for Best Practices⁵ which provide in-depth descriptions of dog and handler selection, training, team assessment, certification, maintenance training, and documentation. Among others, guidelines which may provide useful benchmarks for developing petroleum detection and delineation tactics include:

Dog Selection (SWGDOG SC 3)

- Screening: aptitude, temperament, and health evaluation
- Tracking evaluation
- Training and vendor responsibilities

Selection of Handlers (SWGDOG SC 5)

- Qualifications: personality, experience
- Training (theory and practice): curriculum
 - Safety
 - Canine care and health
 - Obedience
 - Search techniques
 - Proficiency training
 - Learning and conditioning
 - The senses, properties of scent, drive, response and character traits

In the US the role of detection dogs is also recognized by:

- Military Working Dog programs and Manuals of the armed forces (e.g. Army, Navy, etc.);
- USDA National Detector Dog Manual that defines procedures, health care and training of detection dogs (UDSA, 2012);

⁴ http://swgdog.fiu.edu/about-us/history_goals_of_swgdog.pdf

⁵ <http://swgdog.fiu.edu/approved-guidelines/>

- Auburn University Canine Detection Institute's Olfactory Detection Behavior Laboratory in the School of Veterinary Medicine; and
- Government (non-military) training centers that are maintained by the USDA (National Detector Dog Training Center, Newnan, GA), the DoJ ATF (National Training and Operations Center, Front Royal VA) and the USDHS (Customs and Border Patrol Canine Centers, Front Royal VA and El Paso TX).

Specific field tests to detect oil were conducted in Svalbard (Dickins et al., 2010), funded in part by MMS-BLM (now BOEMRE), and in January 2007 following the M/V *Server* oil spill (Buvik and Brandvik, 2009). These tests demonstrate the ability and extreme sensitivity of a Detection Dog Team to detect and locate subsurface hydrocarbons, sometimes at considerable distances. Detection dogs also are successfully used commercially to detect natural gas and liquid petroleum leaks from buried pipelines⁶.

In evaluating the performance and potential of Detection Dogs it is important to distinguish between the ability to "detect and locate" and to "delineate". Detection dogs are generally trained to detect and locate specific materials. Their detection sensitivity is remarkable and detection levels of parts per trillion are reported⁷ and they are capable of detecting a very wide range of hydrocarbons. Location is achieved by sensing and following airborne concentration gradients to their source or point of high concentration. This information is valuable, particularly for leak detection and location. However, oil which has penetrated or has been incorporated in shoreline or river bank sediments may range from extensive low concentrations to continuous, discontinuous or irregular layers, or scattered tar ball size deposits.

Possible limitations in the delineation of the horizontal extent of buried oil could be related to the process by which a dog senses the oil. As some level of air circulation is normally present above the sediment surface the oil vapor detected by the dog at a given point may have a local or an upwind source, and may or may not be indicative of the presence of subsurface oil at that point of detection. If it is assumed that dogs can sense gradients, then it should be possible for the handler to interpret the behavior and/or develop search protocols to provide delineation of the horizontal extent of buried oil. Test data reviewed in Phase 1 does not conclusively support this capability and additional development work on this topic is recommended.

Accurate delineation of both the vertical and the horizontal extent of subsurface oil are necessary for designing and monitoring a successful shoreline treatment program. Detection Dogs can detect hydrocarbons in the air above the shoreline or river bank surface emanating from subsurface oil but vertical delineation must be conducted by other means (pits, trenches, push probes, etc.).

A Detection Dog Team would be part of the shoreline assessment survey program and work with SCAT (Shoreline Cleanup Assessment Technique) Team Leaders to develop a survey design that would focus, at least initially, on areas where oil potentially could have been buried or penetrated into the subsurface sediments.

At the current state of development, Pros and Cons regarding use of Oil Detection Dog Teams are summarized below:

Pros:

- Dogs have been used for gas and liquid pipeline leak detection, using an injected odorant or specific oil calibration.
- Little training time would be required for an experienced detection dog/handler team, even with no prior oil detection experience, as a "match the sample – sniff and search" technique can be applied.

⁶ <http://www.detectordogservices.com/oil%20and%20gas%20services.html>

⁷ <http://www.pbs.org/wgbh/nova/nature/dogs-sense-of-smell.html>