

Canine Oil Detection (K9-SCAT) Guidelines

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Executive Summary

1. Canine detection searches involve a rapid, straightforward, proven concept that is based on sound scientific principles. Research has demonstrated that the canine sense of smell is at least as sensitive as commercial gas analytical instruments.
2. A trained K9-SCAT detection team that includes a canine, handler, and K9-SCAT Team Lead can provide an efficient, versatile, rapid, reliable, cost-effective, and real-time support tool for a SCAT program to locate surface and subsurface oil in a wide range of environmental settings.
3. Imprinting of a trained detection canine with the target oil is quick (hours) so that an experienced and prepared team can be deployed rapidly during a spill response with minimal additional training.
4. Surface oil searches can survey large areas rapidly or can search in wetlands, dense undergrowth, and rough terrain where pedestrian movement is difficult or undesirable, or the oil is hidden in boulders, riprap, or vegetation. A detection canine senses for an airborne odor cloud working toward the potential or suspected oil source. The canine may use a combination of air and ground scenting as s/he approaches the source of hidden oil, or in low wind conditions.
5. In a search for potential or suspected subsurface oil, a detection canine senses for an airborne odor cloud that has migrated to the surface from the source through sediment, snow, and/or water to create an odor “footprint.” The canine typically uses a combination of air and ground scenting as s/he approaches the odor footprint, or in low wind conditions.
6. Locating a subsurface or hidden oil deposit is not a challenge for a canine in many scenarios. Successful delineation of the surface footprint of a continuous or discontinuous (including lens-type) subsurface oil deposit requires training, experience, coordination, and good communication between the K9-SCAT Team Lead and the handler, and between the handler and the canine.
7. The objective of delineating a subsurface oil deposit is to identify areas for excavation and investigation by a SCAT team who then determine the character of the oil and the exact vertical and horizontal dimensions.
8. The combination of the fast survey speed with real-time GPS tracking is a valuable strategy to search large areas rapidly and to quickly re-survey areas in dynamic situations where oil may be remobilized and redistributed.
9. A K9-SCAT Team can rapidly clear large shoreline/inland areas or pipeline corridors with a high-confidence, low-risk survey to ensure that oil is not present in those areas. This type of survey would be time consuming for a traditional ground observation and excavation team.
10. A skilled and attentive handler is essential to ensure that the safety, health, and welfare of the animal are the first priority at all times.

Shoreline assessment (SCAT) surveys provide information to document the location, characteristics, and environmental conditions present on shorelines or other terrains where spilled oil is present. These assessments typically are time consuming and labor intensive and may need to be repeated periodically as the oil is redistributed (and often buried) by natural processes. In cases where oil penetrates into, or is buried in the, subsurface sediments, accurate location and delineation of the horizontal distribution is based on spot samples and has a limited accuracy. Frequently, the distribution of the oil changes by the time an assessment survey program is completed.

A canine detection team can support a traditional SCAT program in a number of field roles to significantly increase the efficiency of surveys and the level of confidence in oil detection and delineation, and to enable a more timely provision of information for planning and direction of response operations.

The ability of canines to detect and accurately locate a wide variety of odors at extremely low levels is well known and currently in use for the detection of a wide range of materials including drugs, contraband materials, explosives, and a wide variety of other substances. The current state-of-knowledge for oil detection using canines is based on limited testing and a relatively small data set. However, field and laboratory research and the real-world experience with detection canines from many other applications have generated an extensive body of data and knowledge that is applicable to oil detection. These Guidelines present the current known capabilities, potential applications, advantages, and the limitations of using canines in support of SCAT assessments (K9-SCAT). As the application of canines to oil spills is relatively new, it should be considered a developing technology.

Canine oil detection is a relatively straightforward and sound scientific concept that requires the canine to identify and communicate the presence of odor from an oil deposit. This is achieved with:

- a trained detection canine that has been imprinted with the target odor,
- a trained and experienced handler to control the search pattern and reward the canine,
- an experienced SCAT Team Lead to manage and direct the K9-SCAT survey,
- GPS tracking equipment to facilitate tracking the search patterns and observations of the K9-SCAT team,
- an animal health and welfare protocol implemented by the handler and supported by a canine veterinarian(s).

Animal health and welfare protocols are the responsibility of, and implemented by, a trained handler and supported by a canine veterinarian. These protocols are essential to ensure that the canine remains healthy and well conditioned during initial training, maintenance, calibration, transportation, deployment, and post deployment. Animal health and wellbeing is an ethical responsibility and ensures a high-quality and well-maintained “tool” for oil detection.

An important element of planning and deployment of K9-SCAT recognizes that the implementation of a detection team is fundamentally different from a human observation SCAT team survey or gas detection using analytical instruments. In all cases, a field test before a full deployment is important to validate that the detection team can achieve the survey mission application and expectations.

In particular, a K9-SCAT program has the potential to:

- rapidly clear large shoreline/inland areas or pipeline corridors with a high-confidence, low-risk survey to ensure that oil is not present in those areas; a process that otherwise would be time consuming for a traditional ground observation team;
- be effective in areas that would be difficult or hazardous for a ground team, such as large sediment (boulder and riprap), bedrock, or dense undergrowth terrain and deep snow;
- survey in areas where pedestrian movement is undesirable, such as wetlands;
- repeat surveys with a rapid (real-time) data turnaround when oil stranded on shorelines or river banks has been remobilized and redistributed by wave and/or current action;
- detect subsurface oil to depths of at least a meter (several feet) with 100% coverage, versus spot sampling by manual or mechanical excavation.

There are three primary survey missions for which a K9-SCAT program can provide a rapid, reliable, and low risk, high confidence support role:

Table E.1—K9-SCAT Missions

MISSION OBJECTIVE	APPLICATION
CLEARANCE – NO DETECTED OIL (NDO)	During an initial SCAT phase where surface, hidden or subsurface oil is not anticipated, but confirmation is required. For example: • a survey in an area not believed to have been oiled • a routine pipeline inspection.
OIL DETECTION (WITH DELINEATION)	During an initial SCAT phase where hidden or subsurface oil possibly exists, and where confirmation, location (detection) and delineation are required, or where the area is cleared as No Detected Oil (NDO). For example: • a survey where oil is suspected to have penetrated into, or been buried by, sediment or snow • a survey where oil is suspected to be present in a wetland or scrub area and cannot be directly observed from the air or ground, or where human traffic in a wetland can be avoided, or in difficult terrain • rapid localized surveys to precisely locate buried oil on a shoreline in support of active cleanup • a resurvey following high water levels or following a significant event, such as a storm or a river flood period, which probably would remobilize and redistribute, or bury, stranded oil • a routine pipeline survey following a leak warning and/or third-party report. The objective of delineating a continuous or discontinuous subsurface oil deposit is to provide location information so that a SCAT team can excavate the site and the immediately adjacent area to determine the character of the oil and the exact vertical and horizontal dimensions.
CONFIRMATION OF ENDPOINT ACHIEVEMENT	As part of a post-treatment survey where the location of oiling is known, and either: • recommended treatment has been completed, or • a suitable period of natural recovery has transpired.

K9-SCAT requires close interaction and communication between the K9-SCAT Team Lead and the canine handler, and requires a high level of understanding of each other's roles, expectations, protocols, and skills in order to communicate effectively and develop a good working relationship. An effective and successful K9-SCAT Team must fully integrate the two very different disciplines of SCAT and canine detection, with inter-disciplinary training, cooperation, and calibration.

In an ideal situation, a SCAT program may use a combination of techniques for different phases of a survey:

- reconnaissance aerial visual observations or remote sensing using aircraft or drones to locate Heavy or Medium category surface oil deposits;
- ground visual surveys of those locations to document the oiling conditions;
- detection canines to clear areas for NDO, or to locate and delineate:
 - Light or Very Light category surface oils,
 - oil “hidden” in salt marshes, reed beds, peat, river bank shrubs, undergrowth, between boulders or riprap, or covered by snow or blown sand,
 - subsurface oil;
- manual or mechanical excavation to provide vertical delineation and oil characterization where subsurface oil has been located.

Detection canines can be imprinted with multiple targets (oil odors) and trained to discriminate and ignore other, background, oils that may be present, such as tar balls, spilled machine or vehicle oils, etc. They can analyze the variance in the concentration of an odor carried in the air and follow the increasing odor concentration to the surface expression (footprint) of the target; that is, they can detect spilled oil down wind and follow an odor cloud up wind to the source.

Field and laboratory research, and real-world experience over several decades with detection canines from many other applications has generated an extensive body of data and knowledge that is applicable to oil detection, in particular:

- odor detection and discrimination,
- calibration and reward,
- handler/canine communications,
- distraction avoidance,
- search pattern techniques,
- animal welfare,
- many other aspects of a detection team training program and deployment techniques.

Bearing in mind the existing knowledge base and experience for other applications, it is reasonable to expect that trained and calibrated teams can detect oil in a range of situations and conditions well beyond the current tested scenarios, including underwater targets and targets in deep snow.

These Guidelines are provided to aid decision making and planning for, and deployment of, K9-SCAT during an oil spill response, monitoring program, or oil spill exercise or drill.

A summary of the specific key points on the full range of topics covered in these Guidelines is provided as a K9-SCAT Fact Sheet in Annex E.

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Canine Oil Detection (K9-SCAT) Guidelines

1 Introduction

The purpose of these Guidelines is to provide information on the potential for detection canines to support a shoreline or inland oiled area assessment (SCAT) program. This information includes:

- how oil detection dogs use their sense of smell and what they can do to locate and delineate surface and subsurface oil,
- the current state of knowledge regarding situations and types of support surveys that a K9-SCAT team can undertake as part of a SCAT program,
- how to plan and design a K9-SCAT survey and collect the appropriate data to document that mission.

1.1 Objectives

The purpose of these Guidelines is to provide information on the realistic potential for detection canines to support a shoreline or inland oiled area assessment (Shoreline Cleanup Assessment Team: SCAT) program. Although detection canines have been used extensively for many years for a wide range of purposes, there have been only a few occasions when oil detection canines have been studied in research programs or have been used in response operations (Section 2.3).

A K9-SCAT team consists of a trained animal, a professional handler, and a SCAT field assessment expert. This specialist team is a tool in the same way that an experienced, trained human oil observer or a gas detection instrument is a professional tool. These Guidelines present the current known capabilities, the potential applications, and the limitations of a K9-SCAT team.

1.2 Content, Format, and User Guide

What is in this guide:

- How to integrate SCAT and canine oil detection

What is not in this guide:

- How to train and imprint canines
- How to train canine handlers
- How to conduct a traditional (non K9-SCAT) program

The following table provides a quick reference to locate the key topics presented in these Guidelines.

TOPIC	SECTION
How detection canines use their sense of smell	2.2
What detection canines can do	2.3, 2.4, 2.5
Appropriate situations for a K9-SCAT Survey Program	3, 7.1.1
Setting up and planning a K9-SCAT Survey Program	4, 5, 6, 7
Conducting a K9-SCAT Survey Program	7.4, 7.5, 7.7
What data to collect	8.2, 8.3, 8.4

A summary of the section headings is provided on the following page.

A summary of the specific key points on the full range of topics covered in these Guidelines is provided as a K9-SCAT Fact Sheet in Annex E.

2. Background: Canine Oil Detection

- Current Accepted SCAT Survey Detection Practices
- Canine Air Detection Theory and Techniques
- Canine Oil Detection Field Experience
- Applications, Constraints, Limitations: Current State-of-Knowledge
- People, Canines, and Machines: A Comparison

3. The Decision Process

- The Decision Process on Where and When to Deploy K9-SCAT

4. Canine Providers

- Detection Canine Provider Guidelines
- Canine Provider Selection Criteria
- Information required by the Detection Canine Provider
- Detection Team Preparation, Deployment and On-Site Imprinting

5. K9-SCAT Roles and Responsibilities

- Introduction
- K9-SCAT Roles and Responsibilities

6. K9-SCAT Survey Planning

- Mobilization
- Logistics
- The Public and Response Personnel
- Canine Health and Safety
- Equipment Checklist for a K9-SCAT Survey

7. K9-SCAT Survey Design Guidelines

- Survey Objectives
- Information Required for K9-SCAT Survey Planning from the SMT
- Design Decisions that Need to be Made by the K9-SCAT Team
- Scenario Planning Considerations and Search Patterns
- Potential Confounding Issues or Sources of Misidentification
- Confirmation Testing and Vertical Delineation

8. Data Collection and K9-SCAT Data Management

- K9-SCAT Survey Checklist
- Field Survey Documentation Forms
- Photography-Videography Guidelines
- Survey Coverage and Track Lines
- Data Management
- Reporting

Annexes

- ANNEX A: K9-SCAT Survey Plan Outline
- ANNEX B: Creating and Using a Calibration and Reward Target
- ANNEX C: K9-SCAT Survey Forms
- ANNEX D: GPS Guidelines
- ANNEX E: K9-SCAT Fact Sheet



Documents

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2 Background: Canine Oil Detection

- Current oil detection practices are based on physical observations and can be slow and, for subsurface oil, may provide only a partial (<0.01%) coverage.
- Canine surveys for surface oil detection can support ground SCAT teams in difficult or heavily vegetated terrain, or to “clear” large areas with no surface or subsurface oil within the affected area, or where pedestrian movement is undesirable.
- The positive attributes of canine subsurface oil surveys (speed, versatility, reliability, and accuracy for low-risk, high-confidence, real-time horizontal detection) and of excavation tactics (for documentation, vertical delineation, and oil characterization) do not directly overlap, but rather are complementary.

2.1 Current Accepted SCAT Survey Detection Practices

- The current SCAT practice is for experienced observers to locate surface oil and to excavate to detect and delineate subsurface oil.
- Typically, this is a slow and time-consuming process.
- Aerial observations can detect only relatively large surface oil deposits so that ground surveys are required to locate and characterize smaller concentrations; even detecting large surface deposits on the ground may be difficult in heavily vegetated areas.
- The primary detection method for subsurface oil is spot sampling by manual or mechanical excavation.
- Spot sampling for subsurface oil has a limited potential for success, with a high probability of non-detection, particularly for horizontally discontinuous or lens-type oiling.

A primary role of a SCAT program is to describe the oiling conditions following a spill, and this can be achieved by a variety of methods and tools that range from simple, real-time observations and remote sensing to off-site laboratory sample analyses. For the most part, SCAT information is generated by direct, systematic aerial or ground observations to locate and then delineate and characterize the oil (IPIECA, 2014). A typical SCAT program may use a combination of techniques for different components of a survey:

- reconnaissance aerial visual observations (Figure 2.1a) or remote sensing using aircraft or drones to locate Heavy or Medium category surface oil;
- ground visual surveys of those locations to document the oiling conditions (Figure 2.1b);
- manual or mechanical excavation to locate subsurface oil and vertically delineate, observe, and characterize that oil (Figure 2.3).

This section identifies the basic survey techniques in common use and highlights some of the limitations of these current practices that are relevant for evaluating the applicability and value of a K9-SCAT Team to support a survey program.



a)



b)

Figure 2.1—a) Aerial Reconnaissance; b) Ground SCAT Survey

2.1.1 Surface Oil

Surface oil surveys:

- The current SCAT practice is for experienced observers to locate surface oil.
- Visual aerial surveys usually can detect and define Heavy and Moderate Surface Oiling Categories but may not be able to detect low oil concentrations (Light, Very Light, or Trace Oiling Categories).
- Visual ground surveys may not be able to locate surface oil hidden by vegetation in wetlands or river banks, or between boulders or riprap.
- Ground-based survey teams may be very slow in rough and difficult terrain, such as irregular bedrock and coarse sediment (cobble-boulder or riprap) environments, dense vegetation, or snow conditions.
- Typically, a considerable portion of the SCAT program survey effort involves a ground-based determination that no oil is present (No Observed Oil – NOO).

Systematic ground-based surveys may be very slow and tiring in areas of difficult terrain, such as exposed bedrock, cobble, boulder, or riprap substrates, heavily vegetated areas, and in snow conditions. Pedestrian surveys may not be desirable to avoid disturbance in habitats such as wetlands.

A large portion of the reconnaissance-level survey effort typically is undertaken to ensure that oil is not present in the affected area (Table 2.1).

- This type of “clearance” survey is a time-consuming effort for ground-based teams.
- Clearance surveys may tie up resources that may be better deployed elsewhere, particularly during the early phase of a response.

Table 2.1—Surface Oil Survey Data

RESPONSE	TOTAL SHORELINE LENGTH SURVEYED (km)	LENGTH WITH NO OBSERVED OIL (NOO) (km – %)	SOURCE
Deepwater Horizon	7,058	5,285 – 75%	Michel et al., 2013
T/V Exxon Valdez, AK	5,459	3,359 – 61%	Owens, 1991
M/V Selendang Ayu, AK	763	345 – 45%	Owens et al., 2008
M/V Cosco Busan, CA	379	232 – 61%	Unpub. SCAT database

2.1.2 Subsurface Oil

Subsurface oil surveys:

- The current SCAT practice for subsurface oil detection involves manual or mechanical excavation tactics to survey for and locate subsurface oil.
- This is a very labor-intensive and time-consuming tactic.
- This is a spot sampling technique that typically covers only a fraction of the area being surveyed (potentially <0.01%), and has a high probability of non-detection for horizontally discontinuous lenses of subsurface oil.

Current practice for the detection and delineation of subsurface oil in sediment shorelines, river banks and on land (e.g. Figure 2.2) relies primarily on manually (Figure 2.3a) or mechanically (Figures 2.3b and 2.3c) excavated pits and trenches or auguring to allow visual examination and documentation of subsurface conditions and/or sampling for off-site analysis. These procedures are typically labor intensive and very time consuming. Other currently acceptable techniques include coring and water jetting. A range of other potential techniques has been reviewed (API, 2013a), but these are either not proven or have a limited applicability.



a)



b)

**Figure 2.2—a) Continuous Layer of Oil Buried by Sediment Deposition;
b) Discontinuous Subsurface Oil Deposit**



a)



b)



c)

Figure 2.3—Pit and Trench Excavation: a) Manual Excavation of a Pit, b) Mechanical Excavation of a Pit, c) Mechanically Excavated Trenches

The general advantages and limitations of current subsurface oil survey practices are summarized in Figure 2.4. In this presentation:

- **Green** indicates a favorable attribute,
- **Yellow** that the strategy may be effective, depending on circumstances, and
- **Red** that a procedure has important limitations or is “not applicable.”

One clear message from Figure 2.4 is that the positive attributes of Excavation and Canine Detection do not overlap, but rather are complementary. If an alternative detection technique is used, such as jetting or canine detection, then excavation in some form would most likely be required for verification and vertical characterization.

ATTRIBUTES	CURRENT PRACTICES			CANINE DETECTION
	EXCAVATION	CORES	JETTING	
HORIZONTAL DETECTION AND DELINEATION	Yellow	Red	Red	Green
VERTICAL DELINEATION	Green	Green	Yellow	Red
SURVEY SPEED	Red	Red	Yellow	Green
OIL CHARACTER	Green	Green	Yellow	Red

Figure 2.4—Attributes of Current Accepted Subsurface Oil Detection Practices and Canine Detection (after API, 2013b)

Excavation with pits, auguring and trenches is a spot-sampling technique so there are limitations in the ability of the survey to accurately and efficiently delineate the three-dimensional extent of subsurface oiling, particularly in the horizontal dimension. In situations of discontinuous or lens-type oiling, there is a high potential for non-detection where individual deposits or layers have small horizontal dimensions.

The location of an excavation is based on either professional judgment, random selection, or on a fixed sampling grid.

- Even with an intensive excavation survey, pitting, trenching or auguring may only cover a small percentage (potentially <0.01%) of the total subsurface area.
- To a large degree, on shorelines or river banks, the selection of sample locations is based on an interpretation by an experienced coastal geomorphologist or sedimentologist of beach/river morphology and the recent history (typically days to weeks) of the processes that cause erosion and deposition.
- Professional judgment in itself does not guarantee that the actual location(s) of subsurface oil would be detected.
- Intensive sampling is atypical due to the very high level of effort involved.
- Many locations excavated in a subsurface oil survey typically have No Observed Oil (NOO) (Table 2.2).

Table 2.2—Examples of Intensive Excavation Projects to Locate and Delineate Subsurface Oil on Beaches

RESPONSE /PROJECT	PERIOD	NUMBER OF PITS/TRENCHES	COMMENT	SOURCE
Deepwater Horizon: SCAT	May 2010–December 2012	>180,000	NOO in 67%	Michel et al., 2013
Deepwater Horizon: LAASR	January–June 2013	>32,000	NOO in 5 of the 15 selected target areas	OSAT-3, 2014
Deepwater Horizon: BOP	June–August 2013	>8,000	NOO in 86% of the locations	OSAT-3, 2014
Bouchard B-155, Tampa Bay FL	18–19 August 1993	964	1 team, 2 days: pits at a 1-m interval on 119 transects spaced at 160 m	Owens et al., 1995
Refugio, CA	15 June 2015	360	4 teams: 1500 ft × 30 ft area (4,000 m ²) with a 10 ft × 10 ft (3 m × 3 m) grid in 6 hours	J. Michel, pers. comm., 10 July 2015

2.2 Canine Air Detection Theory and Techniques

- Canines can be trained to investigate, analyze, discriminate, and signal the presence of a substance that the animal has been trained to recognize.
- The presence of subsurface oil can be detected as molecules are released and move upwards through sediment, water, or snow. The canine uses either ground or air scent to detect the target odor.
- The canine can be trained to signal the presence of an odor plume or follow that plume to the source (the odor ground “footprint”).
- Wide Area Search off-leash patterns are used to cover large areas rapidly whereas on-leash techniques are used to delineate an odor footprint.

2.2.1 Detection Dogs

- Canines have on the order of 200–300 million highly sensitive olfactory cells, depending on the breed. Goldblatt et al. (2011) provide a detailed discussion of the olfactory system of canines.
- Canines can detect certain odorants to tens of parts per billion (ppb), and even 500 parts per trillion (ppt) (Johnston, 1999).
- Canines use this highly evolved sense of smell to search for odors of interest, such as food, other canines, etc.
- Canines are naturally driven to elicit reward and avoid pain or conflict. This repeatable behavior enables trainers to use positive reinforcement to develop a canine's skills. Detection canines are trained to focus on specific odors, and to follow the handler's communications and "signal" when those odors are detected.
- Certain breeds of canine can be trained to follow a survey pattern to investigate, analyze, discriminate, and signal odors that the animal has been trained to recognize ("imprinted").
- A well-trained canine is skilled, intelligent, efficient, and versatile and, when combined with a proficient handler, forms an effective and rapid survey and real-time detection tool.

2.2.2 Subsurface Odor Detection Theory

- Scent molecules may be present in the environment as ground scent (molecules contained within the surface soil structure) and air scent (molecules carried in the air). Canines use either or both to detect a target odor.
- Ground scent can be detected by a trained canine that has been imprinted for that odor. The surface molecules are attached to grains of soil/sand, etc., and the canine's "sniffing" action either disturbs the molecules for investigation or soil/sand particles containing odor molecules are taken into the nose for investigation.
- An oil odor plume (air scent) that is in the air just above the ground surface can be detected by a trained detection canine that has been imprinted for that odor.
- The air scent of large surface oil deposits can be detected at ranges of hundreds or more meters (Brandvik and Buvik, 2009).
- The concept of subsurface oil detection by canines is based on the release, or venting, of molecules that move through a medium (sediment, snow, or water) to the surface.
- Subsurface odor is detectable at the point the molecules reach the surface of the substrate (ground scent). The odor is also carried on the air (air scent) and can easily reach, and be detected, at 15 m to 20 m under favorable conditions (P. Bunker, pers. comm., June 2015).
- The canine can be trained to either:
 - communicate to the handler once the presence of an odor plume associated with the target odor has been detected, or
 - analyze the directional variance in the concentration of odor carried in the air and follow the increasing odor concentration to the surface expression (footprint) of the target substance.

2.2.3 Search Strategies: Detection vs. Tracking

Canines are trained to search in different ways using scents or odors.

Detection canines use air or ground scent to locate a target.

- The strategy is used to locate missing persons, specific materials (accelerants, explosives, drugs, food, etc.).
- The canine identifies the odor from the material that it has been trained to recognize (“imprinted”).
- The strategy does not require a Last Known Place (LKP) as a starting point for a search.

Tracking or trailing canines, by contrast, search by scent discrimination.

- Requires beginning the search from LKP and may (“trailing”), or may not (“tracking”), use a scent article.
- The strategy is one that follows an animal or human trail using the scent on the ground and in the air and may involve visual clues, such as disturbed vegetation or soil.
- Typically would not be applicable for a SCAT survey.

2.2.4 Air Scent Odor Subsurface Detection Sequence

The sequence involved in the detection process is described in Figure 2.5:

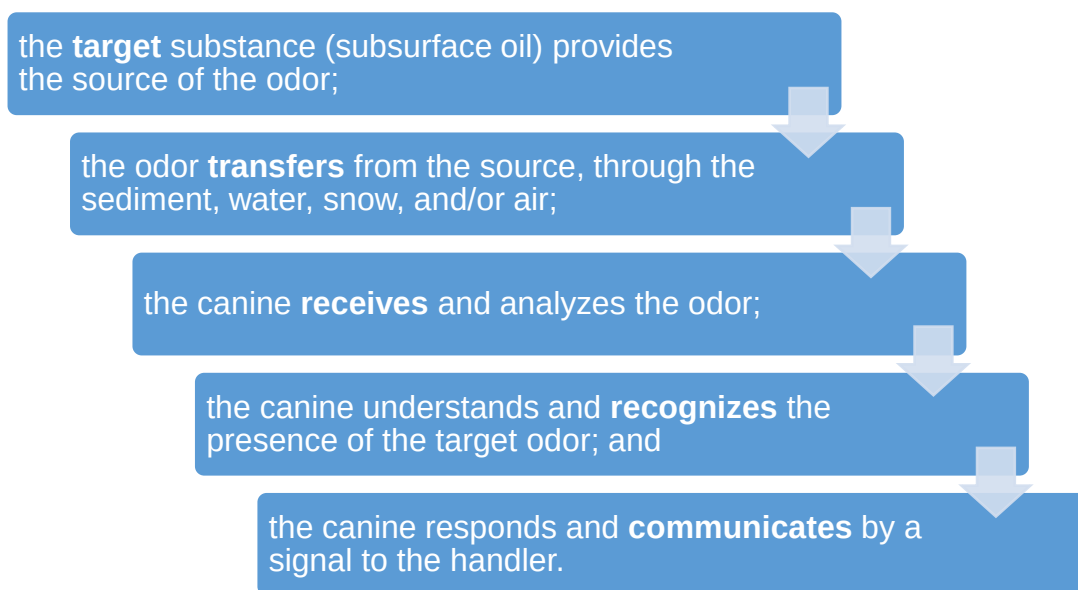


Figure 2.5—Air Scent Odor Subsurface Detection Sequence

2.2.5 Air Scent Detection and Delineation Survey Techniques

- Canines can be used to detect surface oil, and to detect and delineate subsurface oil.
- The distance at which a canine can detect the odor plume from a surface oil deposit, for example, in a wetland or dense vegetated scrub/woodland, or during low visibility or at night, is a function of many parameters and environmental variables, such as oil concentration, degree of weathering, wind speed/direction, air turbulence, humidity, barometric pressure, etc.
- During the Norwegian trials on ice (Section 2.3.1), the odor plume from a large surface snow-covered patch of oil (400 L: 100 gallons) was detected 5 km (3 miles) downwind (Brandvik and Buvik, 2009).
- During the same set of trials, the odor plume from 400 mL (0.1 gallons) of oil buried by snow in ice at 30 cm (12 in.) depth was detected at distances on the order of 400 m (440 yards) from the target.
- There are two basic detection search strategies (see also Section 7.5):
 - Off-leash **Wide Area Search (WAS)** to locate surface or subsurface oil within an area (Figures 2.6, 7.1, 7.2, and 7.3), and
 - On-leash **Delineation Survey** to inspect smaller areas (Figures 2.7 and 7.4); for subsurface oil this typically is used after a site has been located by a WAS.

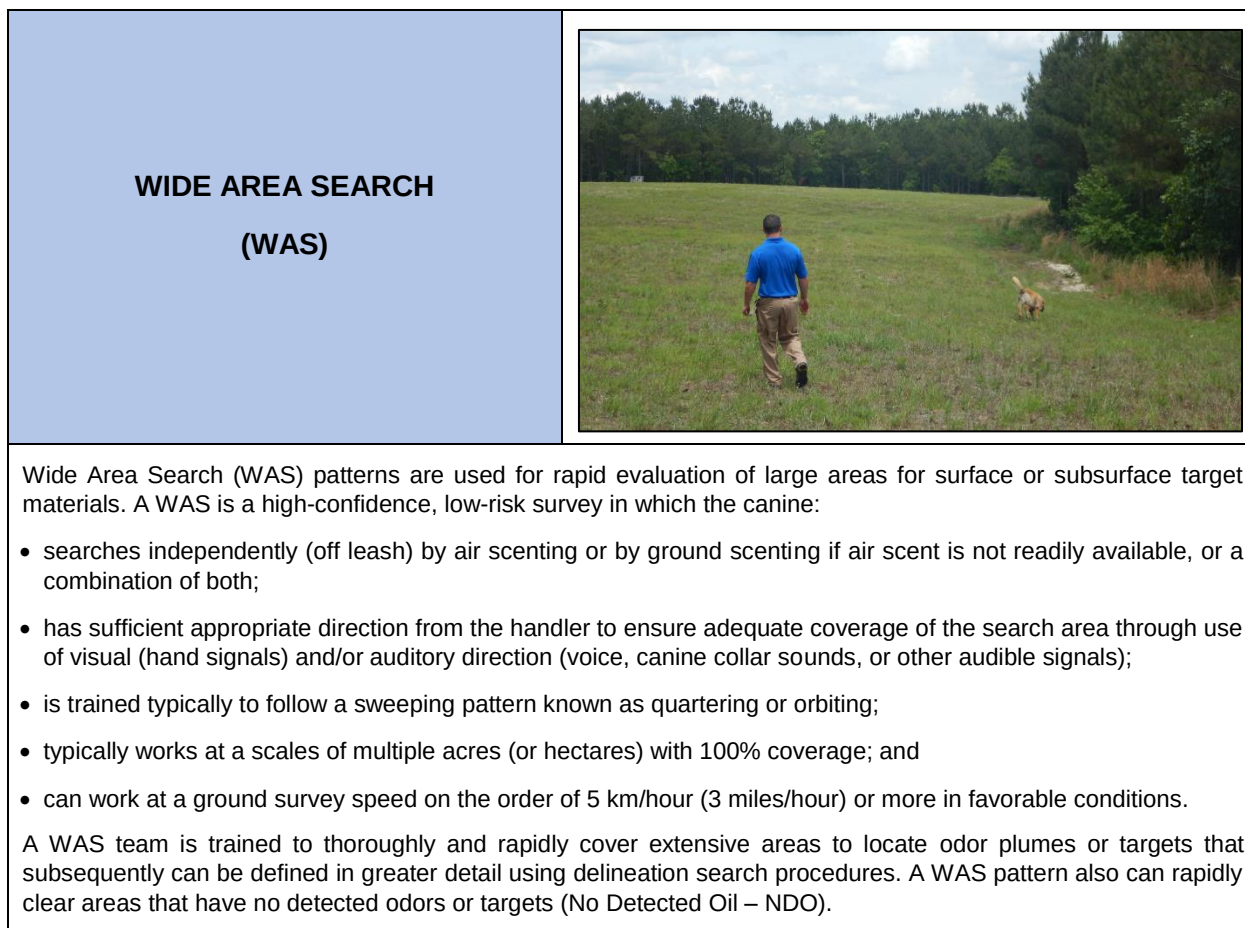


Figure 2.6—Wide Area Search

DELINEATION SURVEY



Delineation Surveys for subsurface oil are used to inspect smaller areas in detail, where the canine focuses on the ground odor in the footprint of the subsurface oil.

- A Delineation Survey may be the next phase after a WAS has detected the presence of a target odor.
- In a Delineation Survey the canine:
 - works on leash as directed by the handler;
 - may involve “bouncing” around the odor footprint (Figure 7.4) if the survey is inspecting a subsurface pipeline or an alongshore beach feature; and
 - can cover an area on the order of 100 m by 10 m (1,000 m²) in approximately 10 minutes (~0.5 hectare/hour or 1.2 acres/hour).

Figure 2.7—Delineation Survey

2.3 Canine Oil Detection Field Experience

- Field research studies conducted with oil detection dogs in Norway and the USA provide proof of concept for a range of situations.
- Large surface oil deposits have been detected at distances over 1,000 m (0.6 mile).
- Subsurface oil has been detected at depths of 90 cm (36 in.) in sediments and 30 cm (12 in.) in packed snow.
- Apart from the Norwegian research, field experience on actual spills is limited to anecdotal information.

The odor detecting skills of dogs have been used extensively for many applications including search and rescue, locating surface, buried or underwater cadavers, wildlife detection, narcotics and food interdiction, explosive and accelerant detection, cancer detection, etc. There is a large body of research literature associated with these applications (e.g. USDA, 2012; Ensminger, 2013), and the military has routinely used canine teams for many years to detect mines and buried ordnance (e.g. Paterni, 2014; US Dept. of the Army, 2005; US Dept. of the Navy, 2012). There exist a large number of manuals and standards that deal with the selection, training, health and wellbeing of detection canines as well as operating procedures (e.g. IMAS, 2013a,b).

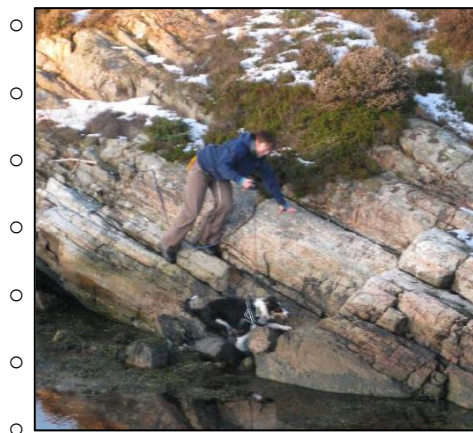
Many studies have reported on various canine issues, such as detection performance and capabilities (Johnston, 1999; Furton and Myers, 2001; Williams and Johnston, 2002; Johnen et al., 2013), duty cycles (Garner et al., 2001), the effects of extraneous odors (Waggoner et al., 1989), validation testing (Rooney et al., 2007), handler influences (Lit et al., 2011), odor discrimination tests (Porritt et al., 2015), etc., but little research has been conducted on the use of canines for subsurface oil or gas detection, and only two well

documented efforts have focused on the subsurface detection of oil in sediments, within ice, and underwater (Sections 2.3.1 and 2.3.2).

2.3.1 SINTEF

SINTEF and the Trondheim Hundeskole (Trondheim Dog Training Academy) have verified, through a series of field tests and informal exercises, that trained canines can detect oil residues in a range of situations:

- Field trials in Svalbard in April 2008 as part of the Arctic JIP program (Dickins et al., 2010) were designed to evaluate the ability of canines to detect oil hidden in snow and ice (Brandvik and Buvik, 2009). The results showed that the canines were able to:
 - detect a small amount of weathered oil (400 mL: 0.1 gallons) that had been buried 30 cm (12 in.) into ice and covered with snow and left for a week;
 - determine the dimensions of large oil deposits by indicating the borders of clusters of smaller amounts of oil at a 10-m (11-yard) spacing;
 - find the location of a larger oil deposit (400 L: 100 gallons) that had been laid down on top of ice and covered by snow, based on the triangulation of detected plume dimensions; with oil detected up to 5 km (3 miles) downwind of the spill location.
- Further field trials funded by Statoil were conducted in Svalbard in September 2008 and in western Norway (Fedje/Austreheim) in November 2008 (Buvik and Brandvik, 2009) to evaluate the ability of canines to detect oil hidden in beach sediments.
 - In the Svalbard survey (Figure 2.8b), an IFO-30 that had been laid down in 1997 as part of a shoreline experiment (Sergy et al., 1998) was detected in upper intertidal zone mixed sand-pebble beach sediments at a depth of 0.8 m (30 in.).
 - At Fedje (Figure 2.8a), on challenging terrain with bedrock and coarse sediment (cobble-boulder) shorelines and with snow and winds gusting to 20 m/s (45 mph), oil from the 2007 M/V *Server* spill was detected in mixed sand-pebble sediments, and in bedrock crevices and cracks. Under these weather conditions the teams worked in two 4–5 hour periods each day. A search speed of 1–5 km/hour (0.6–3.1 mph) was recorded on the challenging terrain with 3–5 km/hour (1.8–3.1 mph) on more favorable terrain.



a)



b)

Figure 2.8—a) Surveying on Rugged Terrain; b) 2008 Svalbard Survey (Buvik and Brandvik, 2009)

- As one of several informal exercises, oil was buried in an intertidal zone at low tide and later detected at high tide from the adjacent beach in a water depth of approximately 40 cm (15 in.) (P.J. Brandvik, pers. comm., March 2011).

2.3.2 API 2015

Field trials to demonstrate and evaluate the applicability of using oil detection canines were conducted in June 2015 as part of an American Petroleum Institute (API) Joint Industry Task Force (JITF) Oil Spill Preparedness and Response program study on Subsurface Oil Detection and Delineation technologies in support of inland and shoreline oil spill response (Figure 2.9).



Figure 2.9—2015 API Field Trials (API, 2016)

The trials were conducted at the K2 Solutions K9 Training Center, Jackson Springs, NC, and involved two detection canines imprinted with a West Texas Intermediate crude oil and a certified handler who had no knowledge of the target locations (API, 2016).

- Seven (7) off-leash **Wide Area Search (WAS)** tests were conducted on open fields to evaluate the ability to rapidly survey a 0.5 ha (1.2 acre) area to either detect a single shallow target or to “clear” the area if no oiled sediment targets had been deployed.
 - In terms of accuracy, the teams (a) detected and located each WAS target during four (4) tests and (b) cleared (with No Detected Oil) the areas searched during the other three (3) tests with no false alerts, equating to **100% accuracy**.
 - In terms of performance, the WAS tests were equivalent to a survey rate of **5 to 10 km/hour**, (~3 to 6 mph), or on the order of 15 to 20 linear km/day (~9 to 12 linear miles/day), for a high-confidence, low-risk survey with 100% coverage of a 50-m-wide (55-yard-wide) shoreline or pipeline Right of Way (ROW).
- Fourteen (14) on-leash **Delineation Survey** tests involved a gridded layout within a 1,250 m² (0.3 acre) area using six (6) different target designs to represent continuous, discontinuous and isolated lenses of subsurface oil distributions, as well as a linear pipeline scenario. Oiled sediment targets were “buried” at various depths between 30 cm and 90 cm (12 in. and 36 in.).
 - Oil was detected at all depths up to 90 cm (36 in.).
 - In terms of accuracy, two (2) of the 700 oiled sediment and non-oiled targets that were deployed in the delineation tests were misidentified for undetermined reasons: twenty (20) targets were

misidentified due to survey or experimental issues that were not attributed to the canines, equating to **99.7% canine accuracy**.

- In terms of performance, the average time for the fourteen 1,250 m² Delineation tests was eleven (11) minutes for 100% ground coverage.

2.3.3 Other Field Experience

Very few other studies or case histories for oil detection canines have been documented. In North America and Europe, a few reported field studies or experiences on actual spills have used canines to locate subsurface pipeline leaks, sometimes with the aid of an odorant injected into the pipeline (Canadian Energy Pipeline Association, 2012; K9 Pipeline Leak Detection, nd; The Sniffers, nd.). In the UK, results of field trials on pipeline leaks report that trained canines were 96% reliable in detecting leaks as small as 0.07 mL (0.004 in.³) (Kerrigan, 2012; Penspen Integrity, 2010).

2.4 Applications, Constraints, Limitations: Current State-of-Knowledge

- Detection dogs are versatile and can locate small surface oil deposits during Wide Area Searches and at depths up to 90 cm (36 in) in sediments, based on research and experience to date.
- Detection dogs have a wider application, as yet untested, to detect oil at greater depths in sediments and snow as well as sunken oil in shallow water, based on research results and experience with detection dogs in other applications.
- Pre-deployment field trials are important to validate that a detection team can meet survey application and expectations.
- Implementation of a detection team survey is less straightforward than with human observers or analytical instruments as animal/human behavioral factors must be considered and successful deployment requires an experienced SCAT Team Lead and an interactive Team Lead, handler, and canine partnership.

The current state-of-knowledge for oil detection is based on a small data set (Section 2.3). However, field and laboratory research and real-world experience with detection dogs from many other applications have generated an extensive body of data and knowledge that is applicable to oil detection (Sections 2.2 and 2.5). In particular:

- odor detection and discrimination, calibration, handler/canine communications, distraction avoidance, search pattern techniques, animal welfare, and many other aspects of a detection team training and deployments are well understood after decades of research and implementation, and
- canine teams are used routinely and effectively:
 - to detect underwater targets, such as cadavers and marine mammals,
 - for human search and rescue operations following landslides and avalanches,
 - in challenging environments in terms of terrain and climate conditions.

Training and imprinting techniques for land mine detection are designed to, and have achieved, a 100% detection rate in independent scientific trials (P. Bunker, pers. comm., December 2015).

Bearing in mind the existing knowledge base and experience for other applications, it is reasonable to expect that trained and calibrated teams can detect oil in a range of situations and conditions well beyond the current tested scenarios.

2.4.1 Applications

Table 2.3 presents a list of those applications for which a K9-SCAT team could, in most situations, be expected to meet survey goals. In all cases, a field test should be conducted before a full deployment to validate that the detection team can achieve the survey application and meet expectations.

Table 2.3—Current Oil Spill Applications Based on Tested Scenarios

For SHORELINES, LAKE SHORES, RIVER BANKS AND TERRESTRIAL ENVIRONMENTS , K9-SCAT teams can:
→ Conduct an off-leash Wide Area Search (WAS) to “clear” areas for surface or subsurface No Detected Oil (NDO) as part of an initial ground survey or as part of a post-cleanup inspection (“completion” or “sign off”) process within a SCAT survey program
→ Locate hidden or subsurface oil with a WAS mission
→ Delineate subsurface oil with on-leash search patterns if oil is located by a WAS mission
→ Operate in wetlands and scrub land, where aerial or ground observers may not be able to detect surface or subsurface oil, or on difficult terrain such as vegetated bedrock, boulders, or riprap.
For ONSHORE AND SHALLOW UNDERWATER PIPELINES , oil detection canines have the potential to support pipeline integrity management, particularly in the following areas:
→ Routine inspection, as part of an integrity management plan
→ Situations where corrosion has been identified by In Line Inspection (ILI), and a verification of “no leak” is required
→ Situations where coating problems have been identified by above-ground surveys
→ Pipelines that cannot be “pigged”
→ Delineation of the area (“footprint”) of a subsurface leak
→ Locations with poor cathodic protection coverage
→ Cases where there are suspected “illegal taps” and theft
→ Following a hydrotest (where water has been scented and the canine can locate any leak)

Canine detection is not identified as a “leak detection” tool in the United States (see PHMSA, 2007; Shaw et al., 2012) and relatively little research has been conducted on the use of canines for subsurface oil or gas detection. By comparison, a large body of research literature deals with the other tools that can be used for subsurface oil or gas detection, particularly to support pipeline operations and leak detection. For example:

- Wang et al. (2001) describe a number of surveillance (visual, dogs, thermal sensors), acoustic, and hydraulic methods, and state that “*dogs can be used to locate the minute odours from leaked fluids and gases. There are some successful cases reported, for example three tracking dogs successfully located 150 leaks in a 150km (93 miles) long gas pipeline in 9 days*”;
- Hirst et al. (2004) report on a real-time optical ethane detection system for oil and gas prospecting that has a range of several kilometers from the source;
- PHMSA (2007) describes current accepted pipeline leak detection technologies and states the agency position that has a high priority on the advancement of leak detection technology;

- Shaw et al. (2012), review the state-of-the-art and accepted best practices for pipeline leak detection, as well as major current technology gaps: they note the difficulties of identifying small leaks (<1% of flow) with flow meters and pressure sensors;
- Liu et al. (2012) review and classify gas detection techniques for a wide range of applications;
- Mandal (2014) reviews and discusses the advantages and disadvantages of the current range of detection methods for gas leaks, including canines.

2.4.2 Constraints and Limitations

An important element of planning and deployment of a K9-SCAT mission is to recognize that the deployment of a detection team is less straightforward than with human observers or analytical instruments (Furton and Myers, 2001).

Canines and their human support partners have limitations. To be successful, a K9-SCAT survey:

- requires a detection-trained animal and an experienced handler,
- requires an experienced SCAT Team Lead partner,
- must be safe for the canine(s), the K9-SCAT team, and responders and the public,
- must take into account animal/human behavioral factors,
- requires defined expectations and a carefully strategized survey design,
- requires samples of the target oil(s) for imprinting.

Some specific constraints or operational limitations on the performance of a canine include:

- a canine that has not been suitably trained and imprinted for air scenting, detection searches or delineation,
- an inexperienced handler and/or SCAT Team Lead support that can influence the animal's performance in terms of survey area locations and survey coverage,
- environmental conditions, such as strong and/or swirling winds patterns, heavy rain, very high temperatures, etc.,
- highly volatile odors, e.g. from gasoline, that can saturate the nasal passages so that the canine's sense of smell is blocked for several minutes,
- high concentrations of hydrogen sulphide (H_2S), which can incapacitate olfactory sensory reception, and more importantly, prevent personnel including K9-SCAT teams from entering areas with dangerous levels of H_2S ,
- large volumes of deep subsurface oil that can saturate the sediments beyond the source area, making it difficult to pinpoint, and therefore accurately delineate, the deposit,
- different oil sources that may confuse the canine, requiring discrimination between target and background oils during imprinting,
- canine performance may be reduced in extreme weather conditions,
- canine performance is reduced if the canine becomes fatigued or bored: factors that are the responsibility of, and can be mitigated by, the handler.

In snow scenarios:

- Snow can absorb vapor. Loose, dry snow is porous and allows vapors to rise to the surface, whereas tightly packed snow is less porous. Wet snow could cause vapor components to go into solution and be absorbed by the snow through capillary action, thus changing the overall scent.
- Potentially, one could expect a detection depth of about 2 m to 4 m (6.6 ft to 13 ft) with fresh snow (based on human detection experience; Gilmore, nd), although with heavy wet snow, which is dense and has a high water content, detection limits may be only to 0.8 m (2.5 ft) depths. On one reported occasion, a canine in Austria found a subject buried under 12 m (40 ft) of snow following an avalanche (Gilmore, nd).

2.5 People, Canines, and Machines: A Comparison

- Humans observe and document; canines and gas instruments detect, analyze, and communicate.
- Visual surface oil detection and documentation surveys can be conducted from the air for Heavy and Moderate oil concentrations, but have the risk of not detecting small amounts of oil, or oil hidden in vegetation or between boulders/riprap.
- Ground canine searches can cover large areas quickly and detect small amounts of surface and/or subsurface oil.
- The combination of human observational skills and canine detection/delineation skills are highly complementary.
- Aerial observations provide rapid coverage for locations with high surface oil concentrations, whereas canines provide rapid ground coverage in areas with low oil concentrations or with thick vegetation that are hard to observe and detect by humans.
- Canines reliably and rapidly generate real-time data and provide a low risk, high confidence strategy to detect and delineate hidden or subsurface oil deposits or to clear areas with No Detected Oil (NDO).

The selection of the appropriate techniques and tool(s) to conduct a SCAT survey evaluates the advantages and disadvantages of each tactic. The proven ability of canines to detect oil targets, even in very small (Trace) amounts, and to provide complete, rapid survey coverage is a significant advantage over systematic ground-, or vessel-based, surveys. Canines are, however, primarily a support tactic and do not replace the traditional SCAT Team surveys, although they may obviate the need for a ground survey in some areas when used in a “clearance” capacity (Section 2.1.1), or for local Operations support during cleanup.

The development of a SCAT program involves evaluating the different human, canine, or instrumental survey tools based on the current knowledge base.

- Human skills are the primary field survey tool and, although these vary from person to person, there are standard procedures and recommended protocols that are intended to ensure a degree of uniformity in the type and quality of observational data that is collected.
- Commercial portable instruments, as well as others under development, could be used in a SCAT program to detect oil in sediments or water (Goldthorp et al., 2014).
- The ability of canines to detect subsurface oil is well documented (in Section 2.3).