Canine Oil Detection: Field Trials Report

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Executive Summary

- Field Trials were undertaken in June 2015 to evaluate the applicability of canine oil detection teams (referred to as K9-SCAT) to support assessment surveys to locate and delineate the horizontal extent of subsurface oil for shoreline and inland spills response operations. The study is part of the American Petroleum Institute (API) Joint Industry Task Force (JITF) Shoreline Protection & Clean-Up Technical Working Group within the Oil Spill Preparedness and Response program.

- The trials involved:

    - o two detection canines imprinted with a West Texas Intermediate crude oil,

    - o a certified handler who had no knowledge of the target locations,

    - o evaluation of two survey techniques: an off-leash Wide Area Search (WAS) procedure and an on-leash Delineation procedure, and

    - o recording using documentation forms and by videotape.

- Seven (7) 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.

    - o In terms of accuracy, the teams detected and located each WAS target during four (4) tests and cleared (No Oil Detected) the areas searched during the other three (3) tests with no false alerts, equating to **100% accuracy**.

    - o In terms of performance, the WAS tests were equivalent to a survey rate of **2 km/hour**, or on the order of 15–25 linear km/day, for a High Confidence-Low Risk survey with 100% coverage of a 50-m wide shoreline or pipeline Right of Way.

- Fourteen (14) Delineation search tests involved a gridded layout within a 1,250 m^2 area using six (6) different target designs to represent continuous, discontinuous and isolated subsurface oil distributions, as well as a linear pipeline scenario. Oiled sediment targets were "buried" at depths between 30 and 90 cm (12 and 36 in.).

    - o Oil was detected at all depths up to 90 cm (36 in.).

    - o In terms of accuracy, two (2) of the 704 oiled sediment and non-oiled targets that were deployed 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% accuracy**.

    - o In terms of performance, the average time for the fourteen 1,250 m^2 Delineation tests was eleven (11) minutes for 100% ground coverage.

- Trained canine detection teams are a non-labor intensive tactic. The study demonstrated the ability to rapidly detect and delineate subsurface oil, and their potential application for subsurface leak detection (including pipelines).

- The survey speed for subsurface oil detection searches or for area clearance is orders of magnitude faster and has greater coverage than can be achieved by pedestrian or vehicle-mobile SCAT teams.

- Canine oil detection teams could be deployed in support of shoreline or inland (lake, river, and terrestrial) assessment (SCAT) programs. Maximum effectiveness can be achieved through coordination with SCAT personnel who are familiar with subsurface oil documentation and canine search procedures and requirements. K9-SCAT is proposed as a designation for the combined canine oil detection/delineation survey capability.

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1 Introduction

1.1 Study Program

The Shoreline Protection & Clean-Up Technical Working Group of the American Petroleum Institute (API) Joint Industry Task Force (JITF) Oil Spill Preparedness and Response program has completed several studies to evaluate the current state-of-the-art in Subsurface Oil Detection and Delineation technologies in support of inland and shoreline oil spill response. The field trials documented in this report are part of Phase 3 of this program.

Phase1

- Described the current best practices for subsurface oil detection in shoreline sediments and identified promising detection and delineation techniques (API, 2013a).

Phase 2

- Developed *Field Guide to the Detection and Delineation of Subsurface Oil in Shoreline Segments* (API, 2013b).

- Developed recommendations for the development and testing of emerging technologies that have a demonstrated application to shoreline, river and terrestrial oiling issues (API, 2014).

Phase 3

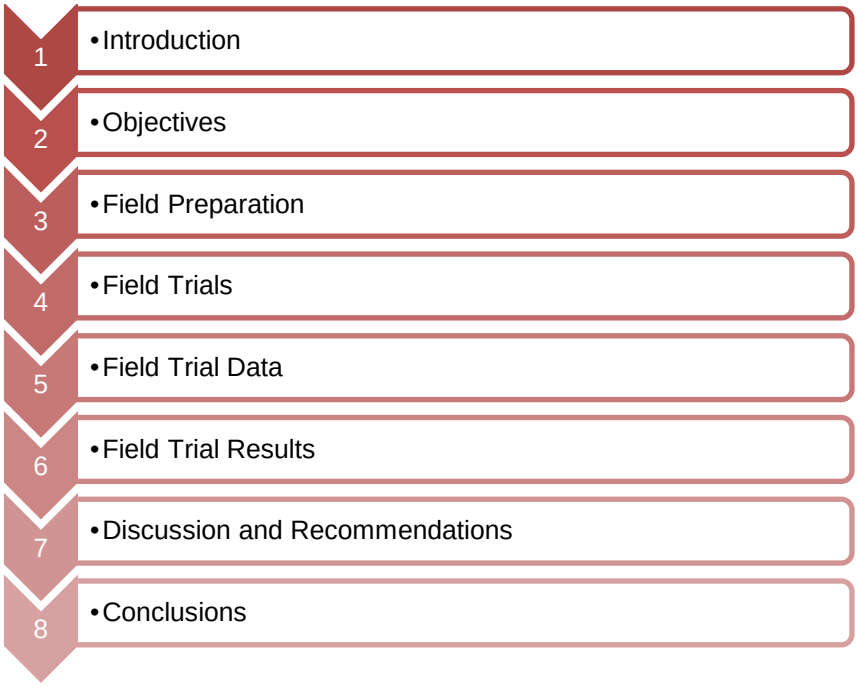
- (*this project*) Conducted field trials to demonstrate and evaluate the applicability of using oil detection canines and to identify further development options.

- (*in preparation*) Develop a Canine Spilled Oil Detection Guidance report for planners and decision makers.

The Phase 2 recommendations identified significant potential for the use of oil detection canines to support Shoreline Cleanup Assessment Technique (SCAT) teams. This recommendation was implemented by way of the field trials that were conducted on 2–4 June 2015. The canine training and field trials were conducted at the K2 Solutions Inc. K9 Training Center in Jackson Springs, NC. A Visitor Program on 4 June enabled interested government and industry representatives to observe the detection teams in action.

The Field Trials were conducted under the direction of OCC with support by RCE Inc. and K2 Solutions.

The content and format of this report are summarized below:



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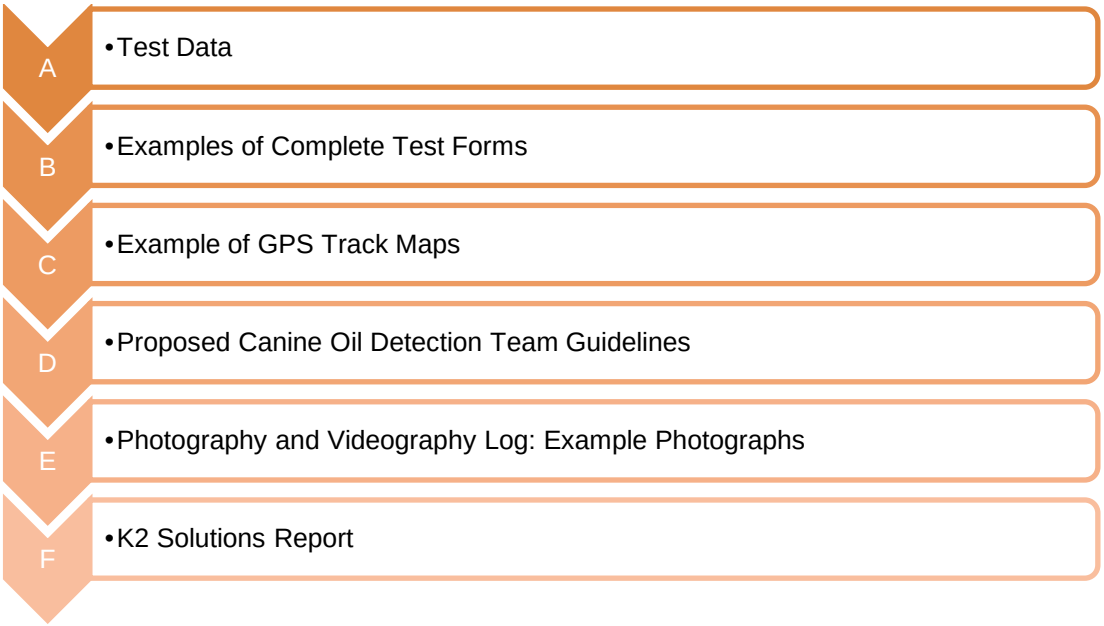


1.2 Previous Studies

Canine detection teams are used to locate a wide range of materials (e.g. drugs, accelerants, cadavers, and foods) (e.g. USDA, 2012; Ensminger, 2013), and the US 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). An Internet search yields many references to the use of canines in a wide range of detection and tracking applications and many books have been published on the topic (e.g. Warren, 2015).

Detection canines have successfully located oil buried in sediments, and buried within ice and underwater during a series of field trials. The most rigorous field tests were conducted in Svalbard (Dickins et al., 2010) and were funded in part by MMS-BLM (now BOEMRE).

Since 2006, SINTEF and Trondheim Hundeskole (Trondheim Dog Training Academy) have verified that trained canines can detect oil residues in beach sediments or hidden in snow/ice (Brandvik and Buvik, 2007; Brandvik and Buvik, 2009; Buvik and Brandvik, 2009). The canines have been used in several spill response operational situations in Norway (Brandvik, 2009).

In North America and Europe, detection canines have located subsurface leaks, sometimes with the aid of an odorant injected into the pipeline (Canadian Energy Pipeline Association, 2012; K9 Pipeline Leak Detection, nd; The Sniffer, nd). In the UK, results of field trials on pipeline leaks report that trained canines were 96 per cent reliable in detecting leaks as small as 0.07 ml (Kerrigan, 2012; Penspen Integrity, 2010).

Research comparing detection canines with mechanical detection techniques identifies a number of advantages and limitations of both techniques, but concludes that canines are at least as accurate as mechanical tools and are more efficient and versatile (Furton and Myers, 2001). Quote: "*Overall, detector dogs still represent the fastest, most versatile, reliable real-time explosive detection device available. Instrumental methods, while they continue to improve, generally suffer from a lack of efficient sampling systems, selectivity problems in the presence of interfering odor chemicals and limited mobility/tracking ability*."

With this information in mind, a recommendation was made to the API Shoreline Protection & Clean-Up Technical Working Group for a Phase 3 study to evaluate the applicability of a canine oil survey team to locate and delineate subsurface oil in support of a SCAT program.

1.3 Acknowledgements

The concept of canines to support shoreline oiling assessment surveys was initiated and pioneered by Per Johan Brandvik with SINTEF and Turid Buvik at the Trondheim Hundeskole (Trondheim Dog Training Academy).

At K2 Solutions, Paul Bunker was the program manager. Lindsey Dixson and Neil Copeland trained the two Labradors, Patton and Sam, who, along with their handler Neil, did all the work.

2 Objectives

2.1 Study Objective

The primary objective of the field trials for Phase 3 of the program was to:

- demonstrate and evaluate the applicability of canine oil detection teams to support assessment surveys to locate and delineate subsurface oil for shoreline and inland spills response operations.

Key elements of the trials were to:

- work and cross-train with the canine detection professionals at K2 Solutions,
- develop lessons learned for inclusion in a parallel API study in the same program to create a Canine Oil Detection Guidelines document for planners and decision makers, and
- based on the results of the trials, propose appropriate situations for which a Canine Oil Detection (K9-SCAT) team could usefully support an assessment (SCAT) survey related to pipeline or other land spills, river spills, marine shoreline spills, lake shoreline spills, or spills under ice or snow.

2.2 Specific Field Trial Objectives

The specific objectives of the canine oil detection team field trials included (not listed in any priority):

1. Demonstrating successful imprinting of a crude oil odor on two search-trained canines.
2. Evaluating trained canine teams to detect subsurface oil and clear non-oiled areas by Wide Area Search (off leash) surveys.
3. Evaluating the accuracy of delineation of various detailed configurations of subsurface oil using on-leash survey procedures for continuous, discontinuous, isolated and linear (pipeline) configurations.
4. Demonstrating the repeatability of the range of tests.
5. Documenting the activities with survey/evaluation forms for each test, GPS tracking, videography, and still photography.
6. Evaluating the coordination and training required between canine detection teams (canine and handler) and SCAT personnel.
7. Enabling government and industry representatives to observe the field demonstration of a Wide Area Search pattern and three Delineation tests, and allowing the team to receive input and answer questions from these stakeholders.

3 Field Preparation

3.1 Schedule

The schedule of the planning and execution of the field trials is provided in Table 3.1.

Table 3.1—Field Trial Schedule

2015	
28 April	Kick-off conference call meeting between OCC and K2 Solutions
Week of 4 May	K2 commenced oil imprinting of ready-trained detection canines
Week of 4 May	K2 mixed oil and sediment to allow weathering
Week of 11 May	K2 buried and set in place outer PVC tubes (Section 3.3.3)
Week of 11 May	K2 filled target (inner) PVC tubes—oiled and blanks (Sections 3.3.2 and 3.3.3)
1 June	Pre-trial team brief at K2 Solutions offices
2–4 June	Field Trials
4 June	Visitor Program (morning)

3.2 Planning Meetings

Two extensive planning meetings were held between OCC and K2:

- A Kick-off meeting (conference call) on 28 April 2015, during which the field trial schedule was confirmed, and the site layout, target set-up, and test documentation were agreed between the teams.
- A pre-trial brief at K2 Solutions facility on 1 June 2015, during which OCC and K2 shared knowledge of SCAT, subsurface oil detection, and the use of canines for detection. Test procedures, documentation and deliverables were confirmed during the meeting.

3.3 Field Site Preparation

3.3.1 Oil Mixing and Weathering

A commercially available Texas Intermediate Crude (www.texasrawcrude.com) was mixed with native (sandy) sediment from the K2 training facility at a ratio of 1:10, producing a 9% oil mix (Figure 3.1). The mix was allowed to weather naturally in the open for 24 hours prior to loading in the target tubes (see Sections 3.3.2 and 3.3.3).

Figure 3.1—Target 9% Oil in Sediment Mix

3.3.2 Wide Area Search

Two open fields within the K2 training facility grounds were chosen by K2 for the Wide Area Search (WAS) tests (WAS-1 and WAS-2 in Figure 3.2).

Figure 3.2—K2 Training Facility

The targets were prepared by placing 5 ml of the 9% oil/sediment mix at the bottom of two closed PVC 6 in. long “target” pipes (1½ in. diameter), which were then filled to the top with clean native sediment. An open “outer” (2 in. diameter) pipe was cut to aid the burial of the oiled target (Figure 3.3).

Figure 3.3—Inner and Outer PVC Pipes for the Wide Area Search Tests

3.3.3 Delineation Tests

Fifty (50) 2 in. internal diameter PVC “outer” tubes were buried in a 10 × 5 diagonal grid, spaced 5 m apart (Figures 3.4, 3.5, and 3.6) in the Delineation Test Area (DTA) field (Figure 3.2). The five end tubes (A1, C1, E1, B10, and D10) were 36 in. deep; the remainder was 24 in. deep. These outer tubes were open ended to allow drainage and prevent accumulation of rainwater.

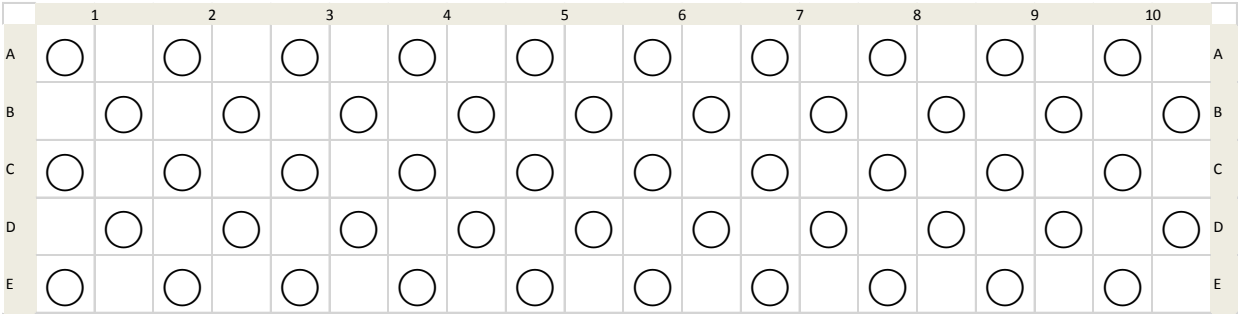


Figure 3.4—Target Grid for Delineation Tests—Schematic

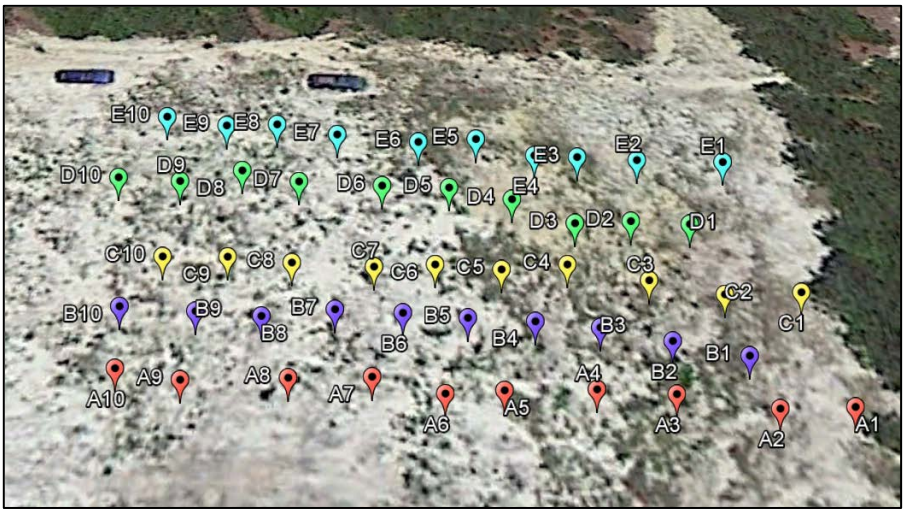


Figure 3.5—Target Grid for Delineation—GPS Waypoints (Map Data: 2015 Google)

Inner “target” PVC (1½ in. internal diameter) tubes were cut to 24 in. and 36 in. lengths, sealed at the bottom and filled with a range of different oiled sediment depth configurations and blanks (clean sediment) (Figure 3.8):

- Blank targets: 36 in. and 24 in. length tubes filled only with clean native sediment (no oil)
- 36 in. depth targets: 36 in. length tubes with 10 ml of 9% oil-sediment mix at the bottom and covered to the top with clean native sediment
- 24 in. depth targets: 24 in. length tubes with 10 ml of 9% oil-sediment mix at the bottom and covered to the top with clean native sediment
- 18 in. depth targets: 24 in. length tubes with 6 in. of clean native sediment, then 10 ml of 9% oil-sediment mix, and covered to the top with clean native sediment
- 12 in. depth targets: 24 in. length tubes with 12 in. of clean native sediment, then 10 ml of 9% oil-sediment mix, and covered to the top with clean native sediment.

The “target” tubes fit snugly into the buried “outer” tubes so that they could be easily and quickly deployed in different designs (see Section 4.4). Half of the target tubes were capped and half of the tubes were left open for 3 weeks prior to the field trials to allow further weathering. All tubes were stored outside. Loaded “target” tubes were capped during deployment handling to prevent cross contamination and spillage.

Figure 3.6—Buried “Outer” Tube

Figure 3.7—24 in. Length “Target" Tube

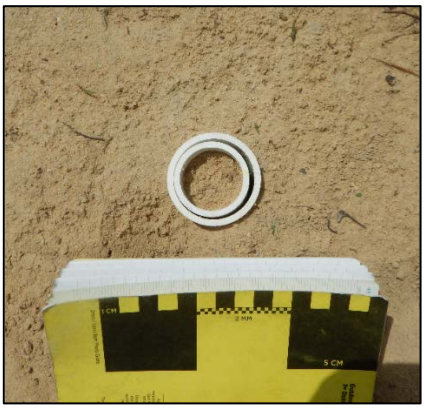


Figure 3.8—“Target” Tube Loaded in “Outer” Tube

3.4 Checklists and Forms

A series of checklists and forms were designed for use during the field trials:

- Canine Oil Detection Field Trial Checklist: A checklist of actions needed from planning to completion (Figure 3.9)
- Equipment Checklist: A checklist for equipment required for the canine trials (Figure 3.10)
- Canine Oil Detection Field Trial Survey Form: Wide Area Search (Figure 3.11)
- Canine Oil Detection Field Trial Survey Form: Delineation (Figures 3.12 and 3.13).

These checklists and forms will be revised for the API Canine Oil Detection Guidelines report based on lessons learned during their use on these trials.

Canine Oil Detection Field Trial Checklist	
1. PLANNING	
	Determine search type (Wide Area Search and/or delineation)
	Determine number of test designs
	Determine individual test designs and details (locations, materials, volumes, depths, substrate, etc.)
	Create/revise Survey Forms
2. INITIAL SET-UP	
	Dig and set target pipes in advance (to allow settlement)
	Record GPS waypoints/coordinates of each target pipe recorded (Target Form)
	Allow oils to weather (if desired)
	Load test materials into inner (training pipes) according to test designs, recording and labeling: • Training pipe number • Oil type • Oil volume/amount • Depth of oiling layer (cm–cm) • Cover material (sediment type, water, etc.)
3. DAY OF TRIAL - PREPARATION	
	Assign roles: • Observation and recording using Canine Oil Detection Field Trial Survey Form • Photography • Videography
	Synchronize the times on tracking GPS(s), camera and video-camera
4. INDIVIDUAL TEST PREPARATION	
	Set training pipes according to test design
	Record target locations (3) and descriptions (4) on Survey Form (can be done in advance if the layout design is already known)
	Allow to cook/settle (time?)
	Set up and locate video camera so that the search will be fully captured
5. INDIVIDUAL TEST EXECUTION	
	Attach GPS tracking device to canine, note device number
	Record general, weather (1) and team (2) information on Survey Form prior to test
	START TEST (note time on form)
	Note all alerts (including false alerts)
	Continue search until team indicates completion
	END TEST (note time on form)
	In comments box (5), note success/no success, any false alerts, missed targets, and other observations, photographs/videos taken, and who completed the form
	Repeat 4 through 5 for each test design
POST TEST	
	Download GPS device track lines
	Download photos/videos
	Collect and collate forms/data
FINALLY	
	Dispose of the oil and oiled materials appropriately (safely, legally)
	Produce Trial Report

Figure 3.9—Canine Oil Detection Field Trial Checklist

EQUIPMENT CHECKLIST: Canine Oil Detection Field Trials

INITIAL SET-UP

- ☐ Target (outer) pipes cut to specified lengths
- ☐ Training (inner) pipes cut to specified lengths
- ☐ End caps for pipes
- ☐ Test material (i.e. oil, sediment for mixing, etc.)
- ☐ Cover materials (soil, sand, water, etc.)
- ☐ Nitrile gloves (for handling oil target tubes)

TRIALS

- ☐ Handheld GPS
- ☐ GPS Tracking device (fitted to canine collar)
- ☐ Camera
- ☐ Video camera
- ☐ Spare batteries for GPS, camera, video camera
- ☐ Tripod for video camera

- ☐ Smart phone with local weather information
- ☐ Canine Oil Detection Field Trial Survey Forms
- ☐ Clipboard
- ☐ Notebook (waterproof)
- ☐ Pens/pencils
- ☐ Survey flags to mark alerts

- ☐ Sturdy footwear (e.g. hiking boots)
- ☐ Sunglasses
- ☐ Hat
- ☐ Foul weather gear
- ☐ First aid kit
- ☐ Water

CANINE REQUIREMENTS

- ☐ Water
- ☐ Food
- ☐ Rewards
- ☐ Shelter
- ☐ Harness/leash

Figure 3.10—Equipment Checklist

CANINE OIL DETECTION FIELD TRIAL SURVEY FORM: WIDE AREA SEARCH

1.GENERAL INFORMATION

Date: (dd/mm/yyyy)		**Weather:**	Sun / Clouds / Fog / Rain (circle)	**Air Temp:**	°F
Time Start: (24hr EST)		**Humidity:**	____ %	**Wind Direction:**	
Time End: 24hr (EST)		**Pressure:**	_____ mb rising / falling (circle)	**Wind Speed:**	mph

2. DOG TEAM

Team Number:		**Handler Name:**	
Canine Name:		**Tracking Collar #:**	
Start Point:	Waypoint #:	Coordinates:	

3. TARGET LAYOUT

Layout Design: (A, B, C...)

Sketch:

4. TARGET DESCRIPTION

Target #	GPS Waypoint #	Coordinates	Oil Type/ Material	Oiling Depth (cm-cm)	Oil Volume	Substrate/ water cover
1						
2						
3						
4						
5						
6						

5. COMMENTS

6. TEST RESULTS

Target #	Oiled Target? (Y/N)	Result - Select only one				
		BLANK *correct* ignored	BLANK False alert	OILED *correct* identified	OILED not identified	CORRECT (✓/ X)
1						
2						
3						
4						
5						
6						

Photographs? Yes / No Numbers: (-) **Video?** Yes/ No Video Time: (-)

Completed by:

Figure 3.11—Wide Area Search Survey Form

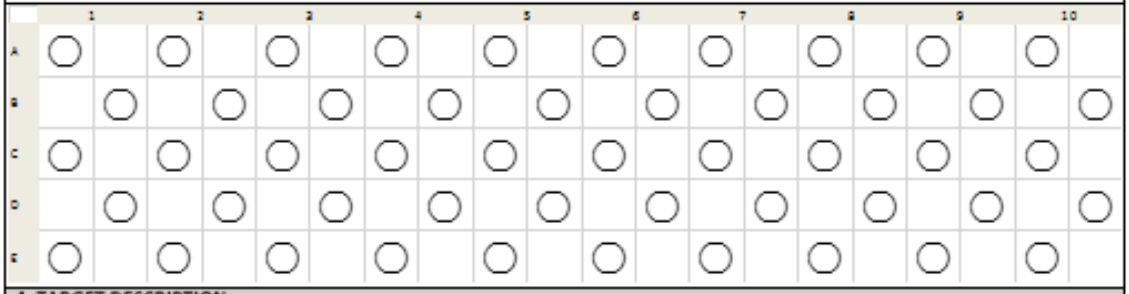
CANINE OIL DETECTION FIELD TRIAL SURVEY FORM: DELINEATION

1.GENERAL INFORMATION					
Date: (dd/mm/yyyy)		**Weather:**	Sun / Clouds / Fog / Rain (circle)	**Air Temp:**	°F
Time Start: (24hr EST)		**Humidity:**	____ %	**Wind Direction:**	
Time End: (24hr(EST)		**Pressure:**	____ mb rising / falling (circle)	**Wind Speed:**	mph

2. DOG TEAM			
Team Number:		**Handler Name:**	
Canine Name:		**Tracking Collar #:**	

3. TARGET LAYOUT

Layout Design: (A, B, C…)



4. TARGET DESCRIPTION

Target #	Oil Type/ Material	Oiling Depth (cm-cm)	Oil Volume	Substrate/ water cover	Target #	Oil Type/ Material	Oiling Depth (cm-cm)	Oil volume	Substrate/ water cover
A1					C6				
A2					C7				
A3					C8				
A4					C9				
A5					C10				
A6					D1				
A7					D2				
A8					D3				
A9					D4				
A10					D5				
B1					D6				
B2					D7				
B3					D8				
B4					D9				
B5					D10				
B6					E1				
B7					E2				
B8					E3				
B9					E4				
B10					E5				
C1					E6				
C2					E7				
3					E8				
C4					E9				
C5					E10				

5. COMMENTS

Photographs? Yes / No Numbers: (-)	**Video?** Yes/ No Video Time: (-)
Completed by:	

Figure 3.12—Delineation Survey Form

4 Field Trials

4.1 Planning and Protocols

4.1.1 Design and Planning

- **Basic Premises.**
    - Canines can detect a wide range of materials for which they are imprinted.
    - The concept of subsurface oil detection by canines is based on the release, or venting, of molecules that move through a medium (sediment or water) to the surface.
    - There are two types of environmentally affected scent molecules: ground scent and air scent. Dogs will use either/both to detect a target odor. Subsurface odor is detected at the point the molecules reach the surface of the substrate (ground scent). The odor carried on the air (air scent) can easily reach, and be detected, at 15–20 m under favorable conditions.
    - Molecules contained within the surface soil structure (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.
    - Once in the air above the ground surface, the resulting oil odor plume can be detected by a trained detection canine that has been imprinted for that odor. The canine can detect the variance in the concentration of odor carried in the air, enabling the canine to follow the increasing odor concentration towards the source.
    - The distance from the odor plume at which a canine can detect the odor is a function of many parameters and environmental variables. A typical minimum range for subsurface oil would be on the order of 15 to 20 m under ideal conditions, and 10 m or less in more challenging conditions. This range of 15 to 20 m was selected for planning purposes for this set of tests. During the Norwegian trials on ice, the air scent of a large surface snow-covered patch of oil (400 L) was detected 5 km downwind, and 400 mL of oil buried in ice at 30 cm was detected at distances on the order of 50 m (Brandvik and Buvik, 2009).
- **Canine Team (K2)—SCAT Liaison (OCC) Knowledge Exchange.** The assumption was made that spill response personnel and search canine teams would work together during a spill response, and would benefit from an exchange of objectives, data needs, and procedures used by each team. Planning meetings and discussions (by telephone and e-mail) and on-site presentations allowed the sharing of understanding and expectations.
- **Field Trials Canines and Handler.** Two K2 Labrador retrievers were selected for testing. Both canines had successfully completed prior detection training. A single certified canine handler worked with both canines during the familiarization and oil imprinting process (Section 2.1 in Annex F).
- **Oil Imprinting.** Two oils (West Texas Intermediate (WTI) Crude Oil and North Dakota Crude Oil) were obtained from www.onta.com and selected for testing and imprinting for both canines. WTI is a relatively low density and low sulfur (sweet) crude oil with fairly consistent properties and is used as a benchmark in oil pricing. Samples of this oil are also available commercially on-line, making it a suitable selection as a "standard" for Canine Oil Detection Team testing. Both canines were successfully imprinted.

- **Search Types.** Two types of detection and delineation search procedures were selected by K2 for the field trials.

  - **Wide Area Search (WAS):** A WAS is used for rapid evaluation of large areas for target materials. In a WAS, the canine searches independently (off leash: photographs F and I in Annex E) by air scenting, ground scenting if air scent is not readily available, or a combination of both. The canine has sufficient appropriate direction from the handler to ensure adequate coverage of the search area through use of visual (hand signals) and/or auditory direction (voice, canine collar sounds or other audible signals). The canine is trained typically to follow a sweeping pattern known as quartering or orbiting (see, for example, the off-leash GPS track line for survey #4 in Annex C). WAS teams are trained to thoroughly and rapidly cover extensive areas to locate plumes or targets which subsequently can be defined in greater detail using delineation search procedures. A WAS pattern also can rapidly clear areas that have no detectable odors or targets.

  - **Delineation Searches:** Delineation searches are used to survey small areas in detail, where the canine focuses on the ground odor of the footprint. For this procedure, the canine is used on-leash (photographs M, N, and O in Annex E) with directional control provided by the handler using leash, verbal and hand signals. An example of this type of search involves a wagon-wheel survey pattern with a shifting center point. This directional control enables the handler to ensure that all sections within the designated area are searched.

- **Double Blind Testing.** All Wide Area Search and Delineation tests were conducted “double blind,” that, is neither the canine nor the handler knew the locations of the target(s).

- **Blank Targets.** For the Delineation tests, blank targets (inner target PVC tubes without any oil) were used to ensure that the presence of an inner target tube did not give a visual clue to the canine or handler that oil may be present.

- **Field Trial Health and Safety Briefing.** Health and Safety briefings covering environmental hazards and hazards unique to the K2 facility were held for all field personnel on arrival. An additional briefing was provided for the participants in the Visitor Program.

- **Environmental Conditions.** The trials were conducted in less than ideal conditions. The air was relatively humid for much of the time and winds ranged from low to gusty and were variable in direction. Wind speed, air temperature, barometric pressure, and humidity all combine to affect the movement and size of an odor plume and therefore the ability of the canine to detect and/or delineate the odor. General weather conditions recorded during the field trials are provided in Table 4.1.

Table 4.1—Field Trial Weather Conditions

	June 2	June 3	June 4
Air Temperature (°F)	83–85	74–82	76–87
Humidity (%)	53–55	53–54	53–56
Barometric Pressure (mb)	999–1001	1001	1001–1003
Wind Speed (mph)	Variable 0–6	Variable 0–12	Variable 2–6
Wind Direction	Predominantly N	Predominantly NE	Predominantly N
General	Cloudy	Cloudy	Cloudy

4.2 Wide Area Search Procedure

4.2.1 Field Trials Site Description

Field trials were held at the 125-acre K2 Training Facility at Jackson Springs, North Carolina. Two sites each exceeding 0.5 ha (1 acre) were used for the WAS procedure and a third field was used for the delineation test area (DTA) (Figure 3.2). These sites consisted of relatively level sandy soil covered with scattered low vegetation. No prior use or spillage of crude oil on the sites was observed or reported. The WAS tests are illustrated in photographs D through I and photograph U, and the Delineation area and tests in photographs J through R in Annex E.

4.2.2 WAS Field Trial Procedure ("Blank": No Oil Sample Used)

- Note: Negative findings from a WAS can be used to "clear" areas having no detectable oil.
- Blank WAS tests were conducted in each of the two fields prior to the target tests to prevent confusion due to residual odor from the oiled targets.
- Canines were tested individually and out of sight of each other.
- GPS tracking equipment was attached to each canine.
- Off-leash procedures were used in which the canines were released from a downwind location at the edge of the field to search into the wind.
- Voice and/or hand signal control by the handler ensured that the entire test area was searched.
- The field trial was terminated when the handler indicated that the area had been thoroughly searched (with negative findings).
- Tests were videotaped and photographed and visual observations were recorded on Canine Oil Detection Field Trial Survey Form (WAS).

4.2.3 WAS Field Trial Procedure ("Target": With Buried Oil Sample)

- The canines were housed in a mobile kennel (photograph B in Annex E), and the handler was offsite during placement of the target in the test area.
- The oil sample tube was carried (using clean nitrile gloves) to a random location on the site, the cap removed and the tube buried vertically until the top was flush with the land surface. The open end of the tube was camouflaged with vegetative litter. Personnel planting the tube returned to the start point by a different route to prevent the canine from picking up on the human scent. The tube was allowed to sit for a few minutes prior to conducting the trial.
- For test #17 on 4 June, the target was placed in the WAS-2 field (Figure 3.2) by a member of the Visitor's Program (photograph U in Annex E).
- Canines were tested individually and out of sight of each other.
- GPS tracking equipment was attached to each canine.
- Off-leash procedures were used in which the canines were released from a downwind location at the edge of the field to search into the wind.

- Voice and/or hand signal control by the handler ensured that the entire test area was searched until the target was located.

- The field trial was terminated when the canine located the target.

- Tests were videotaped and photographed and visual observations were recorded on the WAS survey form.

4.3 Delineation Procedure

- The canines were housed in a mobile kennel, and the handler was offsite during placement of oil targets and blank tubes in the test area.

- Oil sample tubes were carried (using clean nitrile gloves and cap in place) to tube holder locations as designated in each field test design. Caps were removed and each tube lowered vertically to the bottom of the tube holder (top of sample tube flush with the land surface). This process was repeated to install loaded blanks and/or empty tubes in remaining the tube holders.

- The location, content and depth of each oil target, blank tube, and empty tube were recorded on the survey form. All but test # 13 included at least one 36 in. deep oiled sediment target.

- The canine and handler arrived at the test area and a GPS tracking collar was attached to the canine.

- On-leash (long-leash) procedures were used to allow the handler to control the search pattern as necessary and ensure that the search area was completely covered (photographs L through R in Annex E).

- The delineation search was initiated from a downwind corner of the test area.

- When a target was located by the canine it was flagged by the handler. Typically, the handler then initiated a sector or “wagon wheel” search pattern to further evaluate the immediate surrounding area, after which the search was resumed in an adjacent area.

- The test ended when the handler indicated that he had completed a thorough search of the entire gridded area.

- Each test was videotaped and photographed and visual observations were recorded on a Canine Oil Detection Field Trial Survey Form (Delineation).

- Following each test, all oil target tubes were removed from the sample holders using nitrile gloves, capped to prevent spillage, and removed from the test site.

- The canine was returned to the kennel and the handler moved off site prior to the next test deployment.

4.4 Test Layout Designs

Six different layout designs were used for the subsurface oiling Delineation tests. These designs represent different spill scenarios as described in Table 4.2 and shown in Figure 4.1. Two additional designs (A and E) had been prepared for use during the trials; however, as these duplicated other designs that were successfully tested they were considered redundant and were not used.

Table 4.2—Test Layout Design Descriptions

Design #	Description
B	Subsurface leak along a pipeline alignment: continuous line with an alignment change
C	One (1) continuous patch of subsurface oil
D	One (1) continuous patch of subsurface oil
F	Four (4) discontinuous patches of oil (multiple targets in each patch)
G	Five (5) individual patches of oil (one target per patch)
H	One (1) continuous patch of subsurface oil with two (2) individual target outliers

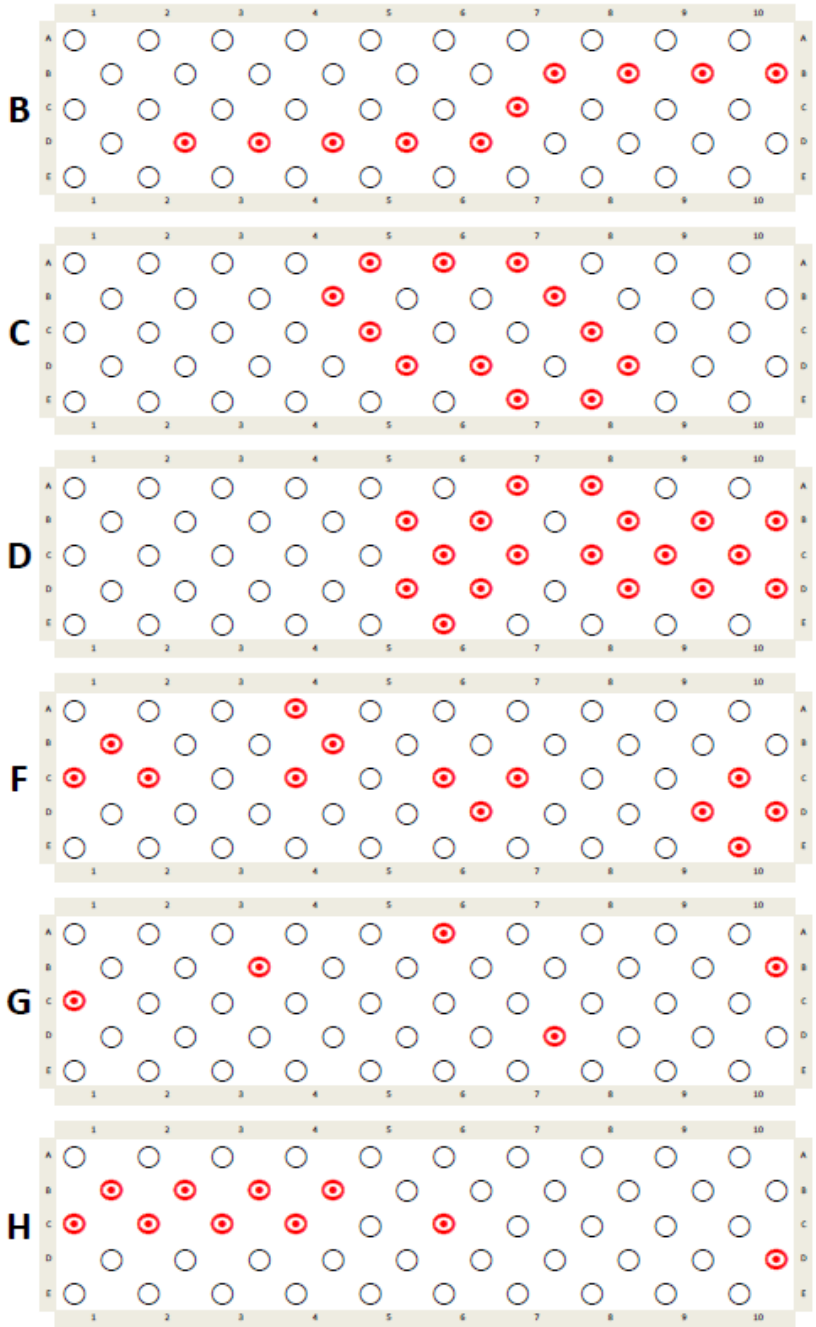


Figure 4.1—Layout Designs for Delineation Tests

4.5 Procedural Issues

The following procedural issues were identified for future reference:

4.5.1 Test Set-up

- In order to prevent spillage and cross-contamination from the oiled target tubes, the tubes were capped during storage, deployment, and recovery. An accidental spillage of potentially oiled water from an oiled target during recovery occurred following one delineation test; however, the contaminated surface sediment was cleaned up immediately and did not affect future tests.

- To prevent cross-contamination, the operator(s) who handed non-oiled target tubes did not handle oiled target tubes, and vice versa.

- Despite best efforts to prevent cross-contamination and spillage, some remnant odor may have remained in/around the outer tubes immediately following recovery of an oiled target tube. When target tubes were changed rapidly between tests, in the opinion of the observers, this may have occasionally led to the canine alerting on an empty of blank tube that had been recently filled with an oiled target.

- Burial of the outer pipes resulted in some ground disturbance that was visible during the tests; however, the canines were trained to ignore visual clues and focus on odor detection. Both canines initially searched the ground in between the tubes during the delineation tests, although by the end of the field trials, one of the canines had learned to use the tubes/areas of soil disturbance to narrow the search field. The canine continued to use the odor to determine the presence of oil; therefore, this did not result in false alerts.

4.5.2 Survey Team

- The handler was left to determine by himself the search pattern and coverage of the test area, and therefore whether the canine had covered the entire area. On discussion, it was agreed that this was not realistic and that in a real-world scenario, the K9-SCAT Liaison would keep note of the canine track line and would be responsible for ensuring complete coverage of the survey area, directing the handler to un-surveyed areas.

4.5.3 Data Recording

- Two different GPS units were used to track the canines during the searches and to mark the location of the oiled targets. This resulted in a systematic offset (up to 10 m) of the tracks compared to the targets. Using the same GPS unit for both tasks would remove this offset.

- Consideration might be given to the use of a GPS unit or RTK (Real Time Kinematic) system with <3 m accuracy for small area delineation.

- A short GPS recording interval (< 5 seconds) may be appropriate in some circumstances to accurately document canine movements, especially when the canine is moving rapidly with frequent turns, e.g. small area delineation.

- Elevated placement of the video-recorder on top of the mobile kennel offered a good view of delineation activities.

- For future tests, a running commentary with video would provide valuable data on the canine behavior, search pattern, and explanation of correct alerts, false alerts and missed targets during searches.

- The use of continuous real-time weather monitoring and recording at canine nose height would help to understand the potential dynamics of an odor plume during surveys.

4.6 Schedule

The trials were conducted over three days (2–4 June 2015). In total, 21 different tests were conducted: 7 Wide Area Searches and 14 Delineation tests (Table 4.3).

Table 4.3—Test Schedule

Day	Survey #	Survey Type	Design	Canine #
2 June 2015	1	Delineation	F—Discontinuous	1
	2	Delineation	B—Pipeline	2
	3	Delineation	H—Continuous	1
	4	Wide Area Search	Blank	2
	5	Wide Area Search	Single Target	1
	6	Wide Area Search	Single Target	2
	7	Delineation	D—Continuous	1
3 June 2015	8	Delineation	G—Discontinuous	2
	9	Delineation	B—Pipeline	1
	10	Delineation	B—Pipeline	2
	11	Delineation	G—Discontinuous	1
	12	Delineation	H—Continuous	2
	13	Delineation	C—Continuous	1
	14	Delineation	F—Discontinuous	2
	15	Wide Area Search	Blank	1
4 June 2015	16	Wide Area Search	Blank	2
	17	Wide Area Search	Single Target	1
	18	Delineation	G—Discontinuous	1
	19	Delineation	B—Pipeline	2
	20	Delineation	H—Continuous	1
	21	Wide Area Search	Single Target	2

4.7 Visitor Program

The trials involved a half-day Visitor's Program for government and industry representatives on 4 June. This program included a project briefing and a field demonstration of a Wide Area Search pattern and three Delineation tests.

The program provided a valuable opportunity for the study team to receive input and answer questions from stakeholders. The organizations represented were:

- US Coast Guard
    - National Strike Team
    - Fifth District
- US Department of Transport
    - PHMSA—Office of Pipeline Safety (CATS Program)
- Clean Gulf Associates, Inc.
- ExxonMobil Ltd.

5 Field Trial Data

The data for each survey is provided in Annex A, and examples of completed field test forms are provided in Annex B. These data are summarized in Section 6 and discussed in Section 7.

Table 5.1 provides a summary of the data in terms of the total number of targets and the successful identification of oiled targets and the "clearance" of non-oiled targets. These data and the results are discussed in Section 7.2. Importantly, information related to the six (6) "False Alerts" and fourteen (14) "Missed Targets" are presented and explained. All but two of the misidentifications are attributed to search pattern or experimental issues (Table A.2 in Annex A).

Survey duration times are provided in Table 5.2.

GPS tracks of the canines were obtained for six of the surveys, and are provided in Annex C. Where GPS tracks are available, the survey distances and speeds have been calculated, and are provided in Table 5.3.

Table 5.1—Data Summary

Targets	704
Targets correctly assessed	684
False Alerts	6
Explained (experimental procedure issue)	5
Unexplained	1
Missed Targets	14
Explained (experimental design issue)	4
Explained (search pattern issue)	9
Unexplained	1
Search pattern (survey) issue	1.3%
Experimental design issue	1.3%
Unexplained	0.3%
Canine success rate	**99.7%**

Table 5.2—Survey Duration Times

Survey Type	Survey #	Design	Canine #	Survey Time (min)
Wide Area Search	4	Blank	2	5
	5	Single Target	1	3
	6	Single Target	2	3
	15	Blank	1	3
	16	Blank	2	4
	17	Single Target	1	3
	21	Single Target	2	3
	AVERAGE			**3.4**
	MAXIMUM			**5**
	MINIMUM			**3**
Delineation	1	F—Discontinuous	1	11
	2	B—Pipeline	2	15
	3	H—Continuous	1	10
	7	D—Continuous	1	15
	8	G—Discontinuous	2	15
	9	B—Pipeline	1	10
	10	B—Pipeline	2	9
	11	G—Discontinuous	1	7
	12	H—Continuous	2	10
	13	C—Continuous	1	10
	14	F—Discontinuous	2	9
	18	G—Discontinuous	1	11
	19	B—Pipeline	2	8
	20	H—Continuous	1	8
	AVERAGE			**10.6**
	MAXIMUM			**15**
	MINIMUM			**7**

Table 5.3—Survey Distances, Times, and Speeds

Survey #	Survey Type	Canine #	Distance Covered (km)	Survey time (min)	Ave. Speed (km/hr)
4	WAS (blank)	2	0.72	5	8.64
5	WAS (oiled)	1	0.56	3	11.2
17	WAS (oiled)	1	0.32	3	6.4
3	Delineation H	1	0.58	10	3.48
7	Delineation D	1	0.56	15	2.24
19	Delineation B	2	0.22	8	1.65

6 Field Trials Results

6.1 Designs and Field Implementation

The Wide Area Search (WAS) pattern was used on four (4) tests with a very simple design that involved a single, shallow (6 in.) buried target that was covered with unoiled sand and camouflaged with vegetation debris. Each canine performed a WAS in two separate fields. Three (3) WAS tests were conducted in which no targets were deployed (Table A.1).

For the Delineation tests, a number of grid designs were developed prior to the trials and six (6) of these designs (Section 4.2) were used in an attempt to replicate four subsurface oiling conditions:

- Subsurface leak from a pipeline in a Right of Way (“B”).
- Continuous oil (“C, D, and H”),
- Discontinuous oil (“F”), and
- Isolated patches of oil (“G”).

Design “B” (pipeline) was used for 4 tests, “F” and “G” (discontinuous/isolated) were used a total of 5 times combined total, and 5 continuous test designs (“C, D, and H”) were conducted (Table A.1).

These designs were selected and canines were chosen to provide a set of different challenges for each canine and the WAS tests were interspersed with the grid design tests.

6.2 Test Results

The field trial involved a total of 704 targets in the seven (7) Wide Area Search tests and the fourteen (14) Delineation grid tests. All results are tabulated in Annex A.

6.2.1 WAS Results

The canine teams detected and located every Wide Area Search target and cleared (No Oil Detected) the remaining areas searched with no false alerts, equating to 100% accuracy.

6.2.2 Delineation Results

One missed target and one false alert during the delineation tests, out of the 704 targets, could not be attributed to experimental procedure/design or to search pattern issues, equating to 99.7 % accuracy (Table 5.1). These results are discussed in Section 7.2.

6.2.3 Survey Performance Results

From an effort/benefit analysis perspective:

- The average time for the Wide Area Search tests in which the areas surveyed were approximately 50 m wide by 100 m long, or 0.5 ha. (~1.2 acres), was 3 minutes for 100% coverage (see Section 7.1.1 for a discussion of "coverage"):
    - This survey rate is equivalent to 2 km/hour or on the order of 15–25 linear km/day for a High Confidence–Low Risk survey with 100% coverage of a 50 m wide shoreline or pipeline alignment.
- The average time for completion of the fourteen 1,250 m^2 Delineation tests was eleven (11) minutes for 100% ground coverage:
    - Typically, a SCAT team is able to complete 1 or 2 pits over that size area during this period.
- Canines were capable of detecting oil at all test depths (up to 3 ft).

6.3 Key Learning Points

1. Trained canine teams have demonstrated the potential for accurate and rapid detection and horizontal delineation of subsurface oil.
2. The survey speed for subsurface oil detection or area clearance is many orders of magnitude faster than can be achieved by walking or mobile SCAT teams.
3. A Team Approach is essential and involves:
    - Trained and imprinted canine(s),
    - Certified handler(s), and
    - A K9-SCAT Liaison (who has trained with canine detection teams).
4. Search patterns will vary on site depending on the search objectives (area delineation, area clearance, pipeline leak, smart pig support, or tank farm leak detection, etc.). These patterns are agreed between the handler and the K9-SCAT Liaison and the K9-SCAT Liaison has responsibility to ensure that the search area is fully covered.

6.4 Visitor Program

The Visitor's Program for government and industry representatives was a valuable opportunity for government and industry representatives to observe the field activities and appreciate the speed at which the canines could search large (off leash) and small (on leash) areas. The program also provided an opportunity for the study team to receive input and to answer questions from the observers.

7 Discussion and Recommendations

The experimental designs worked well with respect to the creation, placement and layout of the subsurface targets.

7.1 Experimental Designs

7.1.1 Wide Area Searches

The canines were trained to follow an odour to source rather than to alert or signal when a plume was detected, so that it is not evident from the GPS track lines or the observations exactly when the canines first detected the odour plumes in the WAS tests. Review of the videotapes and of the track lines (Annex C) for surveys #5 and #17 indicates that the behaviour of the canine changed, in terms of a directional change with nose down, a more focused energy change and a slower quartering behaviour at distances approximately 30 and 45 m downwind of the targets, respectively.

This information is valuable as it points to the fact that the track lines in the WAS test with no target (Survey #4, Annex C) show that the off-leash search pattern effectively covered the entire field as distances between the track line were less than 30 m.

The only recommendations are that future Wide Area Search off-leash designs could involve:

- deeper burial (e.g. 36 in. and/or 48 in.) with a vegetation debris camouflage, and/or
- multiple targets: for example, 2 or more targets per hectare, and
- a commentary on the video that describes the search patterns and behavior during the search: this type of commentary was not possible at the time of these trials as the observers were learning to interpret the canine's actions and behavior.

7.1.2 Grid Tests

The grid design was adequate for the discontinuous and isolated patterns but has an inherent artificiality in that gridded, or "peg board," target patterns do not provide a full subsurface oiling "footprint," and therefore do not truly represent continuous subsurface accumulations or mats of oil or oiled sediments. Consideration could be given to the development of a more realistic design to better represent continuous subsurface oiling. However, there may be a counter argument that the current demonstrated ability with the grid design to locate and delineate on a 5-m separation scale is adequate for: (a) concept evaluation purposes; (b) the development of possible canine detection team standards; and (c) providing targets for SCAT field teams to investigate.

7.1.3 "Pipeline" Design Tests

The detection team was able to locate and define each of the linear patterns intended to represent a pipeline scenario. After the first test, the handler then was requested to initially perform perimeter searches along the sides and ends of the "Right of Way" (ROW) and then apply a series of perpendicular search tracks from the edges towards the center of the ROW.

7.1.4 Survey Performance

The rate of coverage during these short search tests can be extrapolated to some degree for larger surveys. Planning the logistics and expected coverage for real-word searches would consider a range of factors,

including terrain type, weather (temperature, humidity, pressure, and wind), etc. as these affect both the oil behavior and the canine performance and stamina. Planning also would consider more than one canine and/or handler depending on the size of the area in question and the required performance or coverage rate.

Notwithstanding these considerations, in those situations where a canine team would be appropriate to support a SCAT program, the time to survey an area and the per cent coverage that can be achieved far exceed those typically associated with SCAT teams.

7.2 Field Implementation

7.2.1 Survey Coverage

For the WAS tests, the handler was informed if a target had been deployed in the search area and the requirement was to survey the area until the single target was located. If no target was deployed, the requirement was to survey and clear the entire area with no False Alerts.

For the grid tests, the handler was required to operate “blind,” in the sense that he did not know the type of the design being tested or the number and locations of the targets in a layout. The exceptions were that he was informed when a “pipeline” layout was deployed as this involved a different search pattern technique (see Section 7.1.3).

During the delineation tests the handler operated initially without support to avoid the introduction of any bias. A recommended improvement, and a prerequisite for all real world field surveys, would be to have a K9-SCAT Liaison assist the handler to ensure that coverage is complete. Nine (9) of the fourteen (14) missed targets were attributed to this “Search Pattern” issue of incomplete coverage of the entire gridded area (Table 5.1).

7.2.2 Experimental and Implementation Issues

All of the WAS tests were performed successfully.

The grid pattern design resulted in a total of four (4) Missed Targets which the canine overran during three detection tests when a set of targets was deployed in a straight line. The canine identified the start and the end of the lines on tests # 2 (pipeline design), 12, and 13 (both continuous designs) but did not stop at all of the intervening targets. These 4 misses were not attributed to the canine nor the handler but rather to “Experimental Design.” The misses did not affect the delineation of the target patterns. In a real-world situation with continuous subsurface oil distribution, delineation is easier because the search pattern would involve a progressive movement along the edge of the odor (see, for example, the illustration on page 40 in Paterni, 2014). This type of movement was not possible in this gridded target test design. As described by K2, this gridded design forced a search pattern similar to that applied in the peg board game “Battleships.”

The support team worked carefully and slowly to ensure there would not be any cross-contamination of the gridded area while targets were deployed and retrieved multiple times during the 14 delineation tests. However, one small spillage was cleaned up and it is likely that, with the relatively rapid turn-around times, as short as 15 minutes between tests in some cases, some remnant odors may not have been fully dispersed due to light wind conditions. The observers noted that these procedural issues resulted in a total of five (5) False Alerts in tests # 3, 8, and 11 and these were not attributed to the canine nor the handler but rather to “Experimental Procedure.”

One Missed Target (test # 2) and one False Alert (test # 8) cannot be explained in terms of experimental design, experimental procedure, or field observations of the canine’s behavior.

7.3 Other Recommendations

Tests with variations in key parameters would significantly improve the understanding of a canine team's real world abilities and limitations. Examples of the types of field or indoor tests or studies that could be considered in the future include:

- evaluations from a boat of the ability to detect oil that has been stranded, for example, on a wooded river bank or a tall-grass/reed marsh, where aerial or ground visual observations may be constrained,
- development of alternate or specific search patterns for scenarios such as land spills or boat surveys,
- tests on detection levels and concentration discrimination,
- evaluations of the effects of sediment type, oil type, and environmental controls (temperature, humidity, barometric pressure, wind),
- evaluations of detection capability in shallow water (rivers, streams, ponds and near shore),
- deployments of deeper targets in a range of sediment types, snow and ice, and
- tests to discriminate multiple oil types (e.g. background versus spilled oil).

8 Conclusions

8.1 Proof of Concept

The study has demonstrated that a canine oil survey team is a realistic and practical option to support SCAT assessment surveys and other applications identified below.

The short time period of five (5) weeks between project start-up and deployment of a field-ready team demonstrates that, in particular, even early in a response considerable effort and time could be saved by a High Confidence–Low Risk survey to clear areas so that SCAT teams could focus only on oiled areas from the beginning.

Canine teams can be deployed with confidence for the rapid detection and delineation of subsurface oil and, although not universally applicable, offer a non-labor intensive alternative to traditional survey options in a range of oil spill conditions.

8.2 Designs and Field Implementation

The field trial involved a total of 704 targets in seven (7) Wide Area Search tests and fourteen (14) Delineation tests.

The canine teams detected and located every Wide Area Search target and cleared (No Oil Detected) the remaining areas searched with no false alerts, equating to 100% accuracy.

One missed target and one false alert during the delineation tests, out of the 704 targets, could not be attributed to experiment procedure/design or search pattern issues, equating to 99.7 % accuracy.

From a performance and effort/benefit analysis perspective:

- The average time for the Wide Area Search tests which surveyed areas approximately 50 m wide by 100 m long, or 0.5 ha (1.2 acres), was 3 minutes:
    - This search rate would be equivalent to approximately 2 km/hour or on the order of 15–25 linear km/day for a High Confidence–Low Risk survey with 100% coverage of a 50 m wide shoreline or pipeline alignment.
- The average time for the fourteen 1,250 m^2 Delineation tests was eleven (11) minutes for 100% ground coverage.
    - A typical SCAT team would be able to complete 1 or 2 pits over that size area during this period.

8.3 Applications

Based on the results of the trials, there is a range of potential applications for a K9-SCAT team to detect and delineate oil, gas, and other spilled fluids or slurries.

Pipelines	Leak detection and delineation surveys
	Surveys for suspect leaks, for example, following anomalies during inline inspection tool survey (including Smart PIGs), and other pipeline monitoring anomalies
	Regular “no leak” confirmation surveys
Shorelines, River and Inland	Wide Area Search surveys to detect oil and/or to clear segments with No Detectable Oil: particularly where aerial or ground visual inspection is constrained (such as oil under snow and ice or in wetland and river bank vegetation)
	Delineation surveys for subsurface continuous, discontinuous and isolated oil for: • SCAT support during ground surveys, • reconfirmation before or during Operations implementation of an STR, and/or • confirmation of completion after treatment.
	Clearance (No Detectable Oil—NDO) as part of Shoreline Inspection Report (SIR) surveys.

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Annex A—Test Data

Table A.1—Field Trial Data Summary

					TARGETS					RESULTS					EXPLANATION					
	Test #	Design #	Design Type	Canine #	# Targets	# Oiled Targets	# Oiled 36 in.	# Blank Targets	# Empty Targets	Correct Located/ Ignored	Oiled Targets Located	Oiled Targets Not Located	False Alerts	36 in. Oiled Targets Not Located	Search Pattern Issue	Expt. Design Issue	Expt. Procedure Issue	Undete-rmined Issue	% Expt. Design or Survey Issue	% Undete-rmined
WIDE AREA SURVEYS	4	WAS	WAS	2	0	0	N/A	0	0	0	0	0	0	N/A	0	0	0	0	0%	0%
	5	WAS	WAS	1	1	1	N/A	0	0	1	1	0	0	N/A	0	0	0	0	0%	0%
	6	WAS	WAS	2	1	1	N/A	0	0	1	1	0	0	N/A	0	0	0	0	0%	0%
	15	WAS	WAS	1	0	0	N/A	0	0	0	0	0	0	N/A	0	0	0	0	0%	0%
	16	WAS	WAS	2	0	0	N/A	0	0	0	0	0	0	N/A	0	0	0	0	0%	0%
	17	WAS	WAS	1	1	1	N/A	0	0	1	0	0	0	N/A	0	0	0	0	0%	0%
	21	WAS	WAS	2	1	1	N/A	0	0	1	0	0	0	N/A	0	0	0	0	0%	0%
DELINEATION TESTS	1	F	Disc.	1	50	13	2	19	18	49	12	1	0	0	1	0	0	0	2%	0%
	2	B	Pipeline	2	50	12	2	21	17	45	7	5	0	1	2	2	0	1	8%	2%
	3	H	Cont.	1	50	10	2	19	21	48	9	1	1	0	1	0	1	0	4%	0%
	7	D	Cont.	1	50	18	2	20	12	50	18	0	0	0	0	0	0	0	0%	0%
	8	G	Disc.	2	50	5	2	22	23	47	5	0	3	0	0	0	2	1	4%	2%
	9	B	Pipeline	1	50	10	1	19	21	50	10	0	0	0	0	0	0	0	0%	0%
	10	B	Pipeline	2	50	10	1	20	20	50	10	0	0	0	0	0	0	0	0%	0%
	11	G	Disc.	1	50	5	2	21	24	48	5	0	2	0	0	0	2	0	4%	0%
	12	H	Cont.	2	50	10	2	21	19	48	8	2	0	0	1	1	0	0	4%	0%
	13	C	Cont.	1	50	12	0	18	20	47	9	3	0	0	2	1	0	0	6%	0%
	14	F	Disc.	2	50	11	2	21	18	50	13	0	0	0	0	0	0	0	0%	0%
	18	G	Disc.	1	50	5	2	18	27	50	5	0	0	0	0	0	0	0	0%	0%
	19	B	Pipeline	2	50	10	1	19	21	48	8	2	0	1	2	0	0	0	4%	0%
	20	H	Disc.	1	50	10	2	19	21	50	10	0	0	0	0	0	0	0	0%	0%
					704	**145**	**23**	**277**	**282**	**684**	**131**	**14**	**6**	**2**	**9**	**4**	**5**	**2**	**2.6%**	**0.3%**

Disc.: Discontinuous Oiling; Cont.: Continuous Oiling.

Table A.2—Misidentified Targets

	Test #	Design #	Design Type	Canine #	EXPLANATION: Search Pattern Issue	EXPLANATION: Expt. Design Issue	EXPLANATION: Expt. Procedure Issue	EXPLANATION: Undeter-mined Issue	COMMENTS
DELINEATION TESTS	1	F	Disc.	1	1	0	0	0	DETECTION ACCURATE. All patches found: One target initially was not located as the area was not searched; target was located when this survey gap was identified to handler (search pattern issue).
	2	B	Pipeline	2	2	2	0	1	DELINEATION ACCURATE. Pipeline pattern detected and delineated. Two targets not located as not covered by the search pattern (search pattern issue). Canine overran two oiled targets as moved toward the farthest source (experimental design issue). One unexplained missed target. The "miss" did not affect accurate delineation.
	3	H	Cont.	1	1	0	1	0	DETECTION-DELINEATION ACCURATE. All targets located. One target initially was not located as the area was not searched; target was located when this survey gap was identified to handler (search pattern issue). Canine located a "blank": this false alert occurred due to the presence of oil at a target used in the prior test (experimental procedure issue).
	7	D	Cont.	1	0	0	0	0	DELINEATION ACCURATE.
	8	G	Disc.	2	0	0	2	1	DETECTION ACCURATE. Two false alerts occurred at previously oiled targets (experimental procedure issue). The third false alert is unexplained.
	9	B	Pipeline	1	0	0	0	0	DELINEATION ACCURATE. Pipeline pattern detected and delineated.
	10	B	Pipeline	2	0	0	0	0	DELINEATION ACCURATE. Pipeline pattern detected and delineated.
	11	G	Disc.	1	0	0	2	0	DETECTION ACCURATE. Two false alerts occurred at previously oiled targets (experimental procedure issue).
	12	H	Cont.	2	1	1	0	0	DETECTION-DELINEATION ACCURATE. Canine overran to the next target on a set of straight line targets (experimental design issue). One target not located as not covered by the search pattern (search pattern issue). This did not affect accurate delineation.
	13	C	Cont.	1	2	1	0	0	DELINEATION ACCURATE. Canine overran to the next target on a set of straight line targets (experimental design issue). Two targets not located as not covered by the search pattern (search pattern issue).
	14	F	Disc.	2	0	0	0	0	DETECTION ACCURATE.
	18	G	Disc.	1	0	0	0	0	DETECTION ACCURATE.
	19	B	Pipeline	2	2	0	0	0	DETECTION-DELINEATION ACCURATE. Pipeline pattern detected and delineated. Two targets not located as not covered by the search pattern (search pattern issue).The "misses" did not affect accurate delineation.
	20	H	Disc.	1	0	0	0	0	DETECTION ACCURATE.
					9	**4**	**5**	**2**	

Annex B—Examples of Completed Survey Forms

The following example survey forms are provided below:

Test Number	Search Type
17	Wide Area Search
18	Delineation (Design G)
19	Delineation (Design B)
20	Delineation (Design H)

17

CANINE OIL DETECTION FIELD TRIAL SURVEY FORM: WIDE AREA SEARCH

1.GENERAL INFORMATION

Date: (dd/mm/yyyy)	04/06/15	**Weather:**	Sun / (Clouds) / Fog / Rain (circle)	**Air Temp:**	77 °F
Time Start: (24hr EST)	11:16	**Humidity:**	55 %	**Wind Direction:**	N
Time End: 24hr (EST)	11:19	**Pressure:**	1001 mb rising / falling (circle)	**Wind Speed:**	3-4 mph

2. DOG TEAM

Team Number:	1	**Handler Name:**	Neil
Canine Name:	Sam	**Tracking Collar #:**	Sam
Start Point:	Waypoint #: 105	Coordinates:	

3. TARGET LAYOUT

Layout Design: (A, B, C...)

Sketch:

SINGLE TARGET

4. TARGET DESCRIPTION

Target #	GPS Waypoint #	Coordinates	Oil Type/ Material	Oiling Depth (cm-cm)	Oil Volume	Substrate/ water cover
1	106		TX	5-6"	9%	sand
2						
3						
4						
5						
6						

5. COMMENTS

No False Alerts, Target Found

6. TEST RESULTS

Target #	Oiled Target? (Y/N)	Result – Select only one: BLANK correct ignored	BLANK False alert	OILED correct identified	OILED not identified	CORRECT (✓/X)
1	Y			✓		✓
2						
3						
4						
5						
6						

Photographs? (Yes) / No Numbers: (119 - 120) **Video?** (Yes) / No Video Time: (# 22-)

Completed by: H. Dubach

18

CANINE OIL DETECTION FIELD TRIAL SURVEY FORM: DELINEATION

1.GENERAL INFORMATION

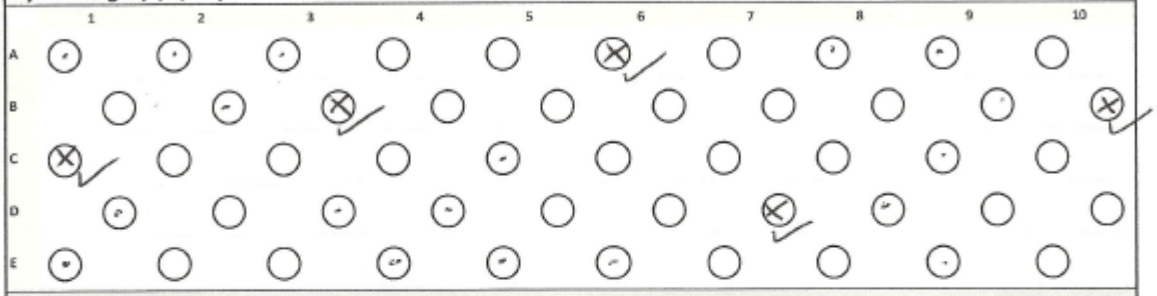
Date: (dd/mm/yyyy)	04/06/15	**Weather:**	Sun / (Clouds) / Fog / Rain (circle)	**Air Temp:**	80 °F
Time Start: (24hr EST)	11:55	**Humidity:**	55 %	**Wind Direction:**	N
Time End: (24hr(EST)	12:06	**Pressure:**	1063 mb rising / falling (circle)	**Wind Speed:**	3-6 mph

2. DOG TEAM

Team Number:	1	**Handler Name:**	Neil
Canine Name:	Sam	**Tracking Collar #:**	Sam

3. TARGET LAYOUT

Layout Design: (A, B, C...)



4. TARGET DESCRIPTION

Target #	Oil Type/ Material	Oiling Depth (~~cm~~ cm) "	Oil Volume	Substrate/ water cover	Target #	Oil Type/ Material	Oiling Depth (~~cm~~ cm) "	Oil volume	Substrate/ water cover
A1	BI				C6				
A2	BI				C7				
A3	BI				C8				
A4					C9	BI			
A5					C10				
A6	TX	18	9%	sand	D1	BI			
A7					D2				
A8	BI				D3	BI			
A9	BI				D4	BI			
A10					D5				
B1					D6				
B2	BI				D7	TX	18	9%	S
B3	TX	12	9%	S	D8				
B4					D9				
B5					D10				
B6					E1	BI			
B7					E2				
B8					E3				
B9	BI				E4	BI			
B10	TX	36	9%	S	E5	BI			
C1	TX	36	9%	S	E6	BI			
C2					E7				
3					E8				
C4					E9	BI			
C5	BI				E10				

5. COMMENTS

All targets found, No false Alerts

Photographs? (Yes) / No Numbers: (121 - 122) **Video?** (Yes) / No Video Time: (#23 -)

Completed by: H Dubach

19

CANINE OIL DETECTION FIELD TRIAL SURVEY FORM: DELINEATION

1.GENERAL INFORMATION

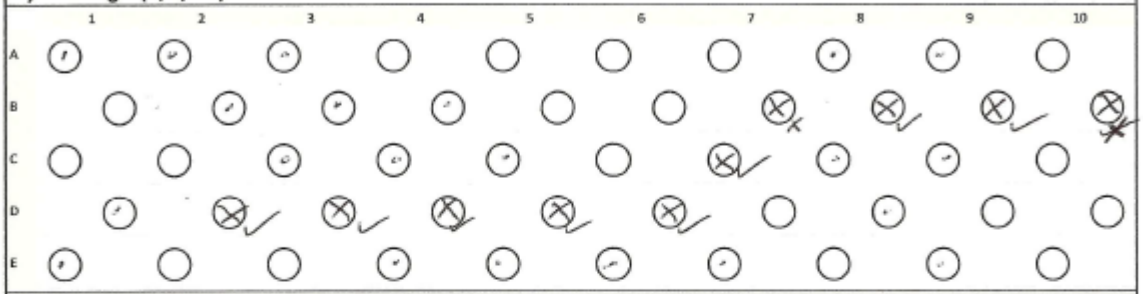
Date: (dd/mm/yyyy)	04/06/15	**Weather:**	Sun / (Clouds) / Fog / Rain (circle)	**Air Temp:**	87 °F
Time Start: (24hr EST)	12:19	**Humidity:**	100%	**Wind Direction:**	N
Time End: (24hr(EST)	12:27	**Pressure:**	55 mb rising / falling (circle)	**Wind Speed:**	3-6 mph

2. DOG TEAM

Team Number:	2	**Handler Name:**	Neil
Canine Name:	Patton	**Tracking Collar #:**	Patton

3. TARGET LAYOUT

Layout Design: (A, B, C...)



4. TARGET DESCRIPTION

Target #	Oil Type/ Material	Oiling Depth ~~(cm-cm)~~ "	Oil Volume	Substrate/ water cover	Target #	Oil Type/ Material	Oiling Depth ~~(cm-cm)~~ "	Oil volume	Substrate/ water cover
A1	B1				C6				
A2	B1				C7	TX	12	9%	S
A3	B1				C8	B1			
A4					C9	B1			
A5					C10				
A6					D1	B1			
A7					D2	TX	12	9%	S
A8	B1				D3	TX	18	9%	S
A9	B1				D4	TX	18	9%	S
A10					D5	TX	18	9%	S
B1					D6	TX	18	9%	S
B2	B1				D7				
B3					D8	B1			
B4	B1				D9				
B5					D10				
B6					E1	B1			
B7	TX	18	9%	Sand	E2				
B8	TX	12	9%	S	E3				
B9	TX	12	9%	S	E4	B1			
B10	TX	36	9%	S	E5	B1			
C1					E6	B1			
C2					E7	B1			
3	B1				E8				
C4	B1				E9	B1			
C5	B1				E10				

5. COMMENTS

B7 & B10 not covered by search pattern

Pipeline fully delineated.

No False Alerts

Photographs? (Yes) / No Numbers: (123 - 124) **Video?** (Yes) / No Video Time: (#28 -)

Completed by: M. Dubach

20

CANINE OIL DETECTION FIELD TRIAL SURVEY FORM: DELINEATION

1.GENERAL INFORMATION

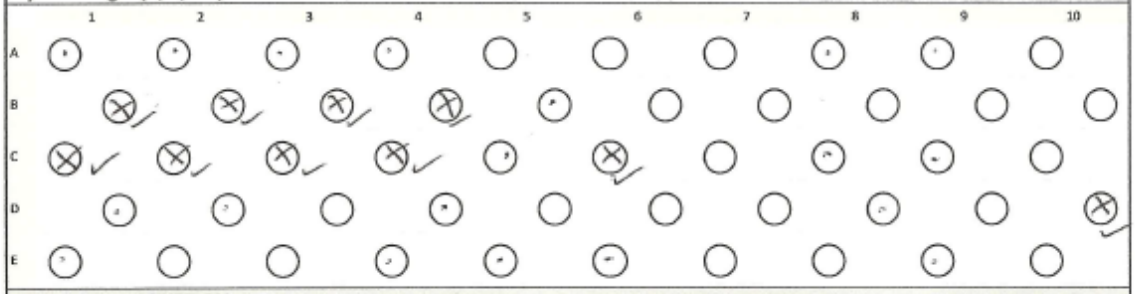
Date: (dd/mm/yyyy)	04/06/15	**Weather:**	Sun / Clouds / Fog / Rain (circle)	**Air Temp:**	85 °F
Time Start: (24hr EST)	12:42	**Humidity:**	56 %	**Wind Direction:**	N
Time End: (24hr(EST)	12:50	**Pressure:**	1003 mb rising / falling (circle)	**Wind Speed:**	3-5 mph

2. DOG TEAM

Team Number:	1	**Handler Name:**	Neil
Canine Name:	Sam	**Tracking Collar #:**	Sam

3. TARGET LAYOUT

Layout Design: (A, B, C...)



4. TARGET DESCRIPTION

Target #	Oil Type/ Material	Oiling Depth (~~cm-cm~~) *	Oil Volume	Substrate/ water cover	Target #	Oil Type/ Material	Oiling Depth (~~cm-cm~~) *	Oil volume	Substrate/ water cover
A1	BI				C6	TX	18	9%	S
A2	BI				C7				
A3	BI				C8	BI			
A4	BI				C9	BI			
A5					C10				
A6					D1	BI			
A7					D2	BI			
A8	BI				D3				
A9	BI				D4	BI			
A10					D5				
B1	TX	18	9%	Sand	D6				
B2	TX	18	9%	S	D7				
B3	TX	18	9%	S	D8	BI			
B4	TX	24	9%	S	D9				
B5	BI				D10	TX	36	9%	S
B6					E1	BI			
B7					E2				
B8					E3				
B9					E4	BI			
B10					E5	BI			
C1	TX	36	9%	S	E6	BI			
C2	TX	24	9%	S	E7				
3	TX	12	9%	S	E8				
C4	TX	24	9%	S	E9	BI			
C5	BI				E10				

5. COMMENTS

All targets found, no false Alerts.

Photographs? (Yes) / No Numbers: (125 -)

Video? (Yes) / No Video Time: (1427 -)

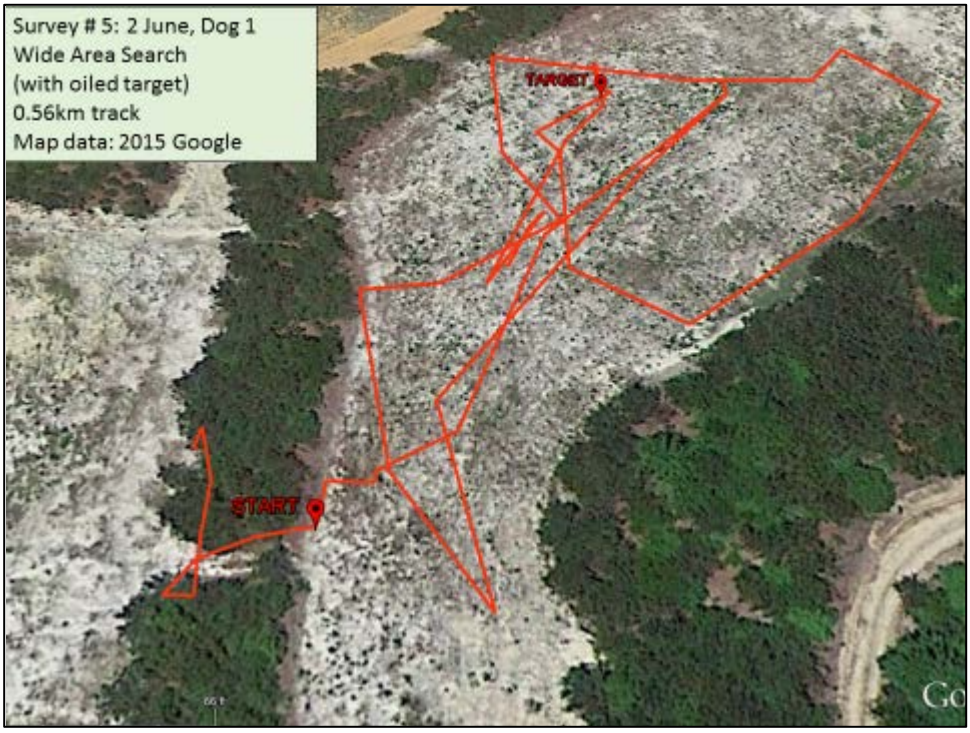
Completed by: M. Dubach

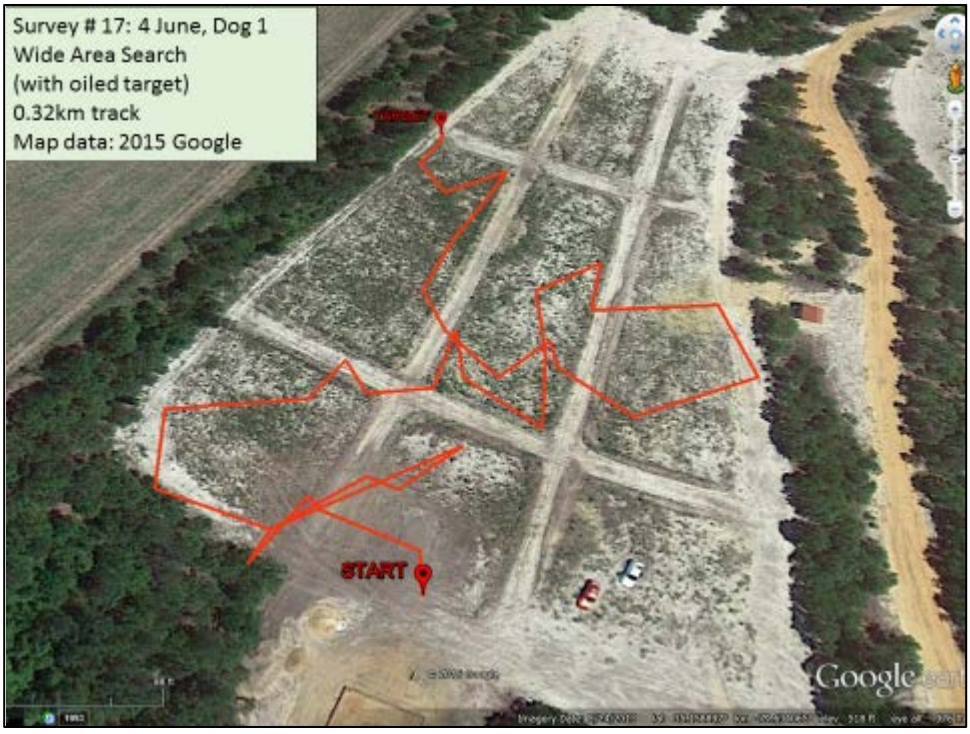
Annex C—Example GPS Track Maps

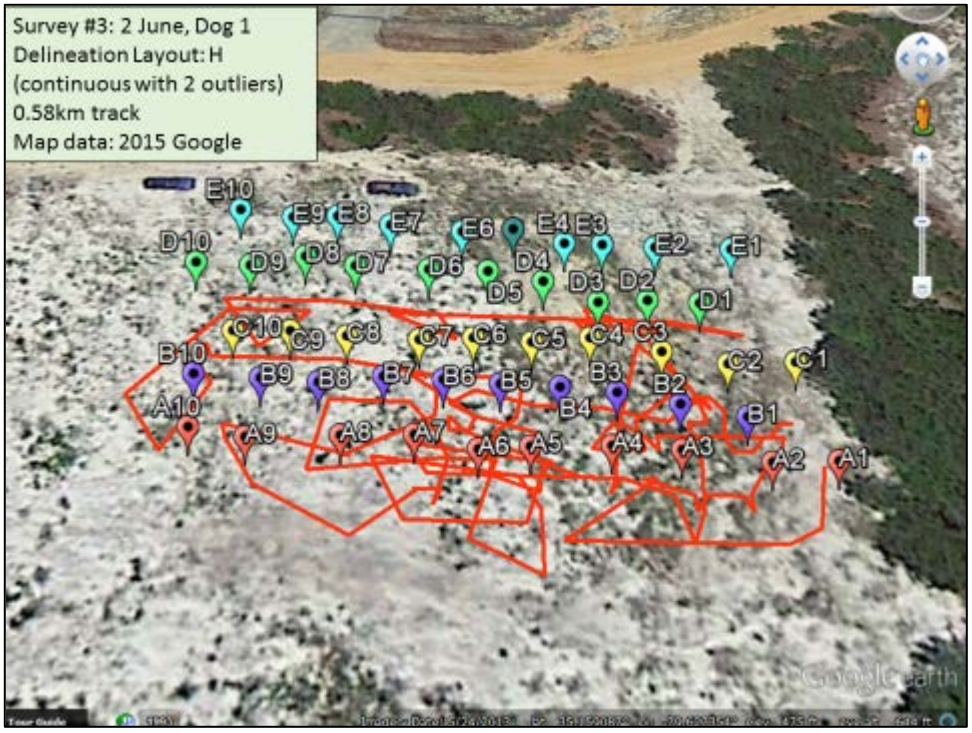
The following example GPS tracks are provided below:

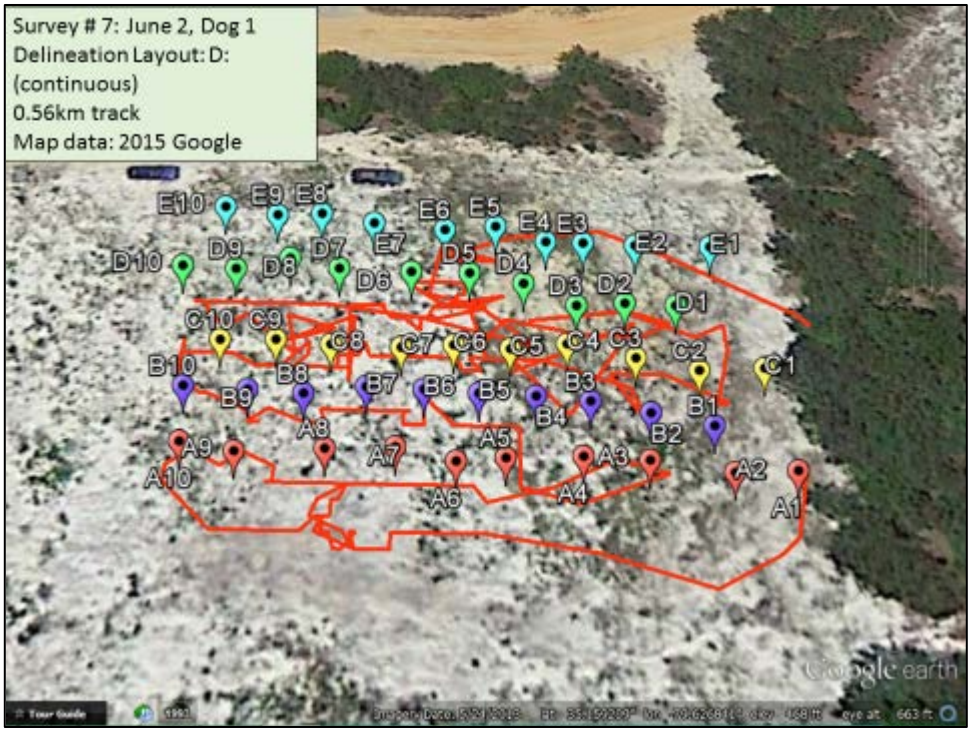
Test Number	Survey Type	Description
4	Wide Area Search (no oiled target)	The canine systematically covered the search area by quartering
5	Wide Area Search (with oiled target)	The canine initially went upwind of the target, but then located the odor plume and ran to the target
17	Wide Area Search (with oiled target)	The canine began quartering, then quickly identified the odor plume and ran to the target
3	Delineation (H—Continuous)	The canine fully covered the delineation test area, using the “wagon wheel” search pattern *
7	Delineation (D—Continuous)	The canine fully covered the delineation test area *
19	Delineation (B—Pipeline)	The canine began a perimeter search of the “pipeline RoW,” then located the first target and proceeded with a series of perpendicular searches under the direction of the handler *

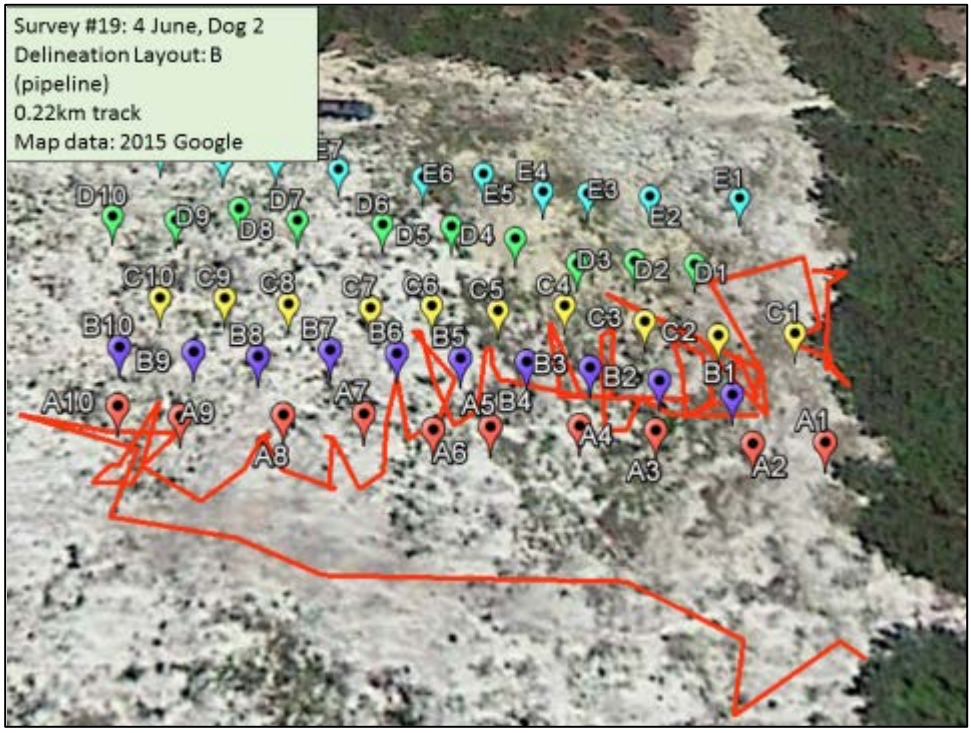
* Note that the use of two different GPS units caused a systematic offset of the track line to the marked targets of up to 10 m (see Section 4.5.3), and therefore the canine tracks do not correspond exactly with the target waypoints. Both GPS units used operate to a ±3 m accuracy.


Survey # 5: 2 June, Dog 1
Wide Area Search
(with oiled target)
0.56km track
Map data: 2015 Google
TARGET
START


Survey # 17: 4 June, Dog 1
Wide Area Search
(with oiled target)
0.32km track
Map data: 2015 Google
START
Google


Survey #3: 2 June, Dog 1
Delineation Layout: H
(continuous with 2 outliers)
0.58km track
Map data: 2015 Google
E10 E9 E8 E7 E6 E4 E3 E2 E1
D10 D9 D8 D7 D6 D5 D4 D3 D2 D1
C10 C9 C8 C7 C6 C5 C4 C3 C2 C1
B10 B9 B8 B7 B6 B5 B4 B3 B2 B1
A10 A9 A8 A7 A6 A5 A4 A3 A2 A1


Survey # 7: June 2, Dog 1
Delineation Layout: D:
(continuous)
0.56km track
Map data: 2015 Google
E10 E9 E8 E6 E5 E4 E3 E2 E1
D10 D9 D8 D7 D6 D5 D4 D3 D2 D1
C10 C9 C8 C7 C6 C5 C4 C3 C2 C1
B10 B9 B8 B7 B6 B5 B4 B3 B2 B1
A10 A9 A8 A7 A6 A5 A4 A3 A2 A1


Survey #19: 4 June, Dog 2
Delineation Layout: B
(pipeline)
0.22km track
Map data: 2015 Google
D10
D9
D8
D7
D6
D5
D4
D3
D2
D1
E6
E5
E4
E3
E2
E1
C10
C9
C8
C7
C6
C5
C4
C3
C2
C1
B10
B9
B8
B7
B6
B5
B4
B3
B2
B1
A10
A9
A8
A7
A6
A5
A4
A3
A2
A1

Annex D—Proposed Canine Oil Detection Team Guidelines

D.1 Purpose

The intent of developing test guidelines or standards is to ensure that detection teams can conduct a survey which generates a high level of confidence in the results. A possible option is to propose these to the ASTM F20 Committee on Hazardous Substances and Oil Spill Response (http://www.astm.org/COMMIT/SUBCOMMIT/F20.htm), within which the F20.17 Subcommittee deals with Shoreline Countermeasures and which has in place a series of SCAT guidelines and standards (e.g. F1686).

The following proposed guidelines or standards are based on lessons learned from the field trials describe in this report.

D.2 Proposed Guidelines/Standards

A. GENERAL REQUIREMENTS

- All tests “double blind”
    - handler and evaluator do not know target locations
    - for a pipeline pattern, test handler can be informed so can apply a “pipeline search” pattern
- All tests use West Texas crude (or equivalent) for standard consistency
- Maximum 10 mL of test oil mixed with 100 mL of test sediment
- Three test components:
    - Detection: Wide Area Search survey
    - Pipeline Delineation, and
    - Shoreline Delineation.
- An evaluation form for each test to be completed by an independent observer
- Each test is videotaped
- Each detection canine is fitted with a GPS to generate track line plots
- Test protocols

B. DETECTION: WIDE AREA SEARCH FIELD TEST

- minimum 1 acre area
- off leash
- target camouflaged
- one no-target test: no false alerts allowed
- two single target tests (preferably) in different fields: 100% required

C. PIPELINE DELINEATION FIELD TEST

- minimum 45 m long axis test area
- no greater than 5-m spacing between targets
- three (3) test designs
- each target design has at least one directional change in alignment
- all oiled sediments depths >12 in.
- at least one 36 in. depth target per test
- perimeter clearance required
- 95% score (three tests) required including all 36 in. targets
- 95% score on combined three tests

D. SHORELINE DELINEATION FIELD TEST

- minimum 45-m × 20-m test area
- no greater than 5-m spacing between targets
- all oiled sediments depths >12 in.
- at least one 36 in. depth target in each test design
- two (2) tests of each of three (3) designs :
    - continuous test designs: minimum 8 contiguous targets with two single target outliers, one of which is at least 15 m from the continuous target set
    - discontinuous test designs: minimum 5 isolated targets no closer than 10-m spacing
    - isolated test designs: minimum 3 targets, maximum 5 targets
- perimeter clearance required
- 95% score required for the combined three designs (6 tests), including all 36 in. targets
- evaluator is permitted to indicate any areas not searched within the overall test area

E. EVALUATION

The evaluator must determine if a misidentified target or a missed target is the result of:

- a search pattern issue,
- an experimental design issue, or
- an experimental procedure issue.

These issues may affect the performance of the canine detection team. One objective of the evaluation is to ensure that a misidentified or missed target in not attributable to the canine in the score. The term “Undetermined Issue” is used to identify those misidentified or missed target which are not attributable to search pattern (handler issue) or experimental (deign or field operations issues) effects.

D.3 Potential Further Steps

Confidence in a survey is critical to acceptance of the results, particularly for a Wide Are Search that “clears” an area. A potential future option is to require a canine detection team handler to have achieved a professional standard, such as the American Working Dog Association (AWDA; http://www.americanworkingdog.com/-certification-standards.html), the International Police Working Dog Association (IPWDA), or the regional state PWDAs in the USA, which provide certifications for different types of targets (accelerants, fire arms, Search and Rescue, etc.).

Annex E—Photography and Videography Log: Example Photographs

Date	Photo				Video	
	HD	RC	EO	TOTAL	# of videos	minutes
1 June	47	28	16	91	1	1
2 June	31	33	63	127	7	76
3 June	10	0	7	17	9	97
4 June	20	9	3	32	7	52
	108	**70**	**89**	**267**	**24**	**226**

Sample photographs are provided in the following pages.

A: K2's mobile kennel for three canines on a pick-up truck

B: Setting up the video camera on K2's mobile kennel trailer

C: GPS tracking collar with handheld unit

D: Digging a hole for the 6 in. oiled target for a Wide Area Search

E: Placing the 6 in. oiled target for a Wide Area Search

F: Off-leash Wide Area Search (Canine 2)

G: Off-leash Wide Area Search (Canine 2)

H: Starting an off-leash Wide Area Search (Canine 1)

I: Off-leash Wide Area Search (Canine 1)

J: Labeled 24 in. “target” tube, containing 9% Texas Crude at a 12 in. depth

K: Setting up a delineation design

L: Starting a delineation test with K2 evaluator (Canine 1)

M: On-leash delineation (Canine 1)

N: On-leash delineation (Canine 2)

O: On-leash delineation (Canine 2)

P: Positive alert (Canine 1)

Q: Positive alert close-up (Canine 1)

R: Positive alert (Canine 2)

S: Visitor Program: classroom brief

T: Visitor Program: field brief

U: Visitor Program: setting of the 6 in. target for a Wide Area Search

V: Visitor Program: Field trial observation

W: Oiled sediment emptied from a 24 in. target tube

X: K2 and OCC team

Annex F—K2 Solutions Report

Canine Oil Detection Project/Trials
Final Report

For
Owens Coastal Consultants

Submitted by:
K2 Solutions, Inc.

29 June 2015

Project Information			
Project Title	Canine Oil Detection Project/Trials		
Start Date	20 April 2015	**End Date**	15 June 2015
Lead Institution	Owens Coastal Consultants (OCC)		
Project Director	Dr. Ed Owens – OCC		
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1 ABSTRACT

This research project sought to evaluate the role of a canine detection team in a Shoreline Cleanup and Assessment Technique (SCAT) program to locate and delineate subsurface oil. The aim of the project was to develop a subsurface oil detection canine capability which can be utilized in both the Wide Area Search and spill delineation techniques. This development was based on the search for buried landmines and utilized secondary research gleaned from previous projects. Based on previous work in route clearance for landmines and IEDs, a system was developed to provide a fast, effective and accurate method of canine team deployment. This first-phase study was designed to better define the expectations and role of a canine survey team within a SCAT survey program. As a concept trial, we demonstrated the capability of canine teams to accurately detect subsurface target oils in a systematic pattern. Upon conclusion of this project, trained canines were capable of correctly detecting subsurface oil buried from 12 to 36 inches at a rate of 99.7% with one false alert, which exceeded the target goal of 95%.

2 METHODOLOGY

K2 Solutions, Inc. (K2) developed a training plan based on the statement of work provided by Owens Coastal Consultants (OCC). The period of performance for the project was from April 2015 to June 2015. The project included training canines in systems of search and imprinting to target oils. Training began six weeks prior to the demonstration date, which was 04 June, 2015. All elements of this Proof of Concept were conducted at the K2 Canine Training Center, a 125-acre facility located in Jackson Springs, North Carolina. One training field was dedicated to this project throughout the period of performance.

2.1 Training Phase

Two canines were selected from the K2 canine inventory. These canines had previously received training at K2 in detection and were part of the cadre of canines utilized for projects of this nature.

Name	K2 #	Breed	Color	Sex	DOB	Chip#
Sam	M055	Lab	Chocolate	M	09/10/2010	981020005018827
Patton	M156	Lab	Yellow	M	05/22/2011	956000003210372

Oil Detection Dog Sam and Trainer

Oil Detection Dog Patton

The training methodology was based on positive reinforcement of required behaviors through the utilization of rewards. Positive Reinforcement is a system of training that utilizes the theories and practices of the psychological concept of behaviorism.

The canines were imprinted on two types of oil utilizing the K2 imprinting protocols as detailed in the Imprint Standard Operating Procedure (SOP). The imprinting was conducted inside K2's purpose-built Imprint Building, which supports the function of this phase of training in a controlled environment. The canines were required to demonstrate a passive response. Initially, the canines were trained on crude oil samples of 5ml, but the samples were reduced to sub 1ml amounts within a week. Once canines reliably indicated on the presence of the target odor, it was mixed with sand taken from the identified training field.

The two types of oil used were Texas Raw Crude and North Dakota Crude. Both samples were procured from http://www.onta.com.

The canines were required to demonstrate a capability standard of 95% detection rate prior to moving to an outside environment for field training.

In the initial field training exercise, the canines were introduced to the on-leash delineation technique. This progressed in complexity until the canines could demonstrate a delineation technique of systematic search and a detection rate of at least 95%. The canines were then advanced to the grid training area for complex delineation training.

The grid was constructed within a 50m x 25m area. Fifty (50) plastic tubes were dug into sandy terrain – forty-four (44) measured 2" x 24" and six (6) measured 2" x 36". The opening to the tubes were set flush to the surface of the sand and were therefore only visible when observed directly at the location.

Training target tubes were constructed from 1.5" plastic pipes which were sealed at one end. Sixty (60) 24" and six (6) 36" pipes were filled with sand taken from the holes dug to contain the 2" pipes. The pipes were divided into two groups: target and blank. Blank pipes only contained sand taken from the training field; target pipes contain sand and 10ml target mix.

A mixture of 1:10 Texas crude and sand (taken from the holes for the 2" pipes) was allowed to rest for 24 hours before being added to the training target pipes at various depths:

Number of Pipes	Target Depth
17	12-18"
7	18-24"
3	35-36"
19	Blank

The pipes were stored outside to mimic realistic environmental weather changes, including temperature ranges. This also ensured that all pipes were at the same ambient air temperature as the training field. All pipes were handled using disposable gloves; those used for target pipes were never used on pipes containing only sand. By constructing the training area and setting the pipes in this way, the only variance was the oil mix.

Target pipes were placed inside the 2" pipes in the field in specific patterns to represent spills. The canines were worked along the grid in a systematic pattern and rewarded for correct

responses to the target pipes. A variable reward schedule ensured canines were able to complete multiple finds within the same search exercise and allow for delineation of the spill pattern.

The canines were taught a passive response; this required the canines to sit and stare at the location of target odor. A response was classified as "correct" when the canine adopted a sit position, looking at the source of the odor and within 12" of the target location. Flags were placed at the locations of response by the handler. This provided an indication of spill mapping upon completion of a training search.

2.2 Search Design

The planned exercises involved off-leash deployment in a Wide Area Search pattern to detect the target location, followed by an on-leash delineation search to detect the subsurface oil targets. All tests were "double blind," meaning neither the handler nor the canine knew the subsurface oil locations. Only the assessors were aware of the target odor locations during testing.

Canine teams were required to search for and detect oiled sediment as detailed in the test plan to represent three distribution patterns:

- Continuous subsurface oils,
- Discontinuous subsurface oils, and
- Scattered subsurface deposits (tar balls).

The distribution of oil tubes represented subsurface oil bands and were generally linear in shape. As a general indication, each target, or group of tubes, was placed in the range of 1 to 20 meters wide and 5 to 40 meters in length.

A range of tests were conducted using the three distribution patterns with:

- Shallow (12") and deeper (24" to 36") subsurface oils
- An approved grade oil (lower priority test)
- Low versus higher oil amounts (concentration) (lower priority test)

Multiple iterations were conducted to ensure sufficient data collection. This included running teams more than once through the test.

The final evaluation was conducted by a K2 Team Leader and OCC representatives. Based on the evaluation criteria developed by OCC, both canines were placed through a series of assessments in the Wide Area Search and delineation roles. This culminated in a visitors' day where visitors were allowed to place target odors and observe the canines' working capability.

Sam detecting a target odor 24in below the surface

Sam gives a passive response on the target odor

The Handler was not present when the targets were placed within the training grid. This ensured both the canine and handler were "blind" to target locations and simulated spill patterns.

Patton completing delineation search of the training grid

Once the canine teams were capable of searching the grid area in a systematic pattern and demonstrated a 95% or higher detection capability, they were trained in the Wide Area Search pattern. Canines were handled off-leash in a systematic pattern within an area 100m x 50m with the purpose of detecting one single source of target odor. The target used was a 5ml 1:10 mix of Texas Crude and sand contained within a 6” pipe sealed at one end. The pipe was buried vertically so the mouth of the pipe was level with the surface. Pipes were allowed to rest for 30 minutes. The canine was then handled in a “quartering” pattern through the area to locate the single source of odor.

Sam utilized in an off-leash Wide Area Search

3 RESULTS/FINDINGS

The capability of trained canines to detect buried target odor exceeded anticipated results. The two canines encountered no issues while imprinting and detecting the two types of oil utilized in the project. Both canines progressed at a comparable rate throughout the training process. Once imprinted on the target odor, the canines were transitioned to outside searches and were consistently achieving over a 99% detection rate, with less than a 1% false alert rate. As training progressed, and when the handler used an effective search pattern, the canine's detection rate was consistently 99.7%. Results showed the both canines were capable of detecting the target odor, but the handler is critical to directing the canines through the correct search pattern.

A review of current SCAT techniques was completed by OCC and K2 and systematic search patterns were developed to support both sub-surface oil spill and pipeline leak detection. The resultant combination of SCAT assessment and canine techniques (K9-SCAT) resulted in a consistent detection rate of over 99%.

It may be possible for a canine to be trained in a small number of baseline odors, which will provide sufficient target odor information for the detection of a wide range of oils. For instance, if oil contains the same molecules across the spectrum of types, then the canine may be able to detect a large range just by imprinting on a base odor.

The usual method of employing detection canines is to reward the dog with a primary reward once a target is detected; repeating this no more than three times within a training session. Due to the requirement to delineate a spill, we developed a system of varied rewards, both in schedule

and type, and this allowed the canine to detect over 20 targets in a row with no detriment to drive or focus.

Canines must be taught using the buried target odors rather than airborne scent. The airborne scent is too easy to locate and therefore results in a degradation of the system of search. By teaching buried odor, it was found the canines would concentrate on the ground odor footprint and work the area in more detail due to the nature of the target.

During training sessions, the handler never knows the start of the target grid for delineation; however, in actual deployments the handler would know the start of the target grid. The only time a handler would utilize the canine in a delineation scenario is when the dog indicates the location of target odor on a Wide Area Search or if the handler is shown a start location based on K9-SCAT assessment. In both cases, the team has a known start point for delineation. Throughout the training and assessments, the handler was never given the start point and was required to locate the target and then delineate the pattern. This was effective in ensuring the canine and handler practice and work the pattern without having any ability to determine layout.

When the canine team was deployed to a simulated pipeline search, they were informed of the type of scenario. This is because in a true search situation, the handler would know if it is a pipeline or non-pipeline search. A specific systematic search pattern was developed just for pipeline leak detection and, therefore, this information dictated how the team would search the training grid.

4 DISCUSSION

The concept trial demonstrated the capability of trained canines to detect buried odor in both a Wide Area Search and delineation pattern.

The results of the trial demonstrate that a trained canine team, utilized correctly, can significantly reduce the requirements in manpower to manually conduct a spill or leak assessment. This reduction in both manpower and time results in significant cost savings and also allows for reduced environmental impact of an incident.

OCC's independent assessment of the capability and the trials observed by the visitor program provided confirmation of a trained team's capability within a SCAT assessment capability.

The development of an Oil Detection Dog capability would greatly impact the oil spill response and pipeline leak management communities. Within the oil spill response community, deploying canine teams to support SCAT assessments will provide accurate information in a reduced timeline than currently available.

Within pipeline leak detection, it is anticipated the canine teams will be capable of deploying in a prevention detection role; searching high risk or suspect leak locations in the Wide Area Search role to confirm or discount potential leak sources. They could also be used to delineate any located leaks to accurately identify the extent of any oil leaks.

In conclusion, it is proven that trained Oil Detection Dog Teams are capable of locating target odor accurately, even when buried to 36” and aged several weeks. By deploying canines using systematic search patterns, the teams are able to cover large areas effectively, efficiently and accurately.

4.1 Recommendations

There are opportunities to further develop the canine capability through detailed research. Oil Detection Dog teams should be field tested on “live” spills or leaks to ensure the demonstrated capability can be transferred to a real situation.

The integration of this proven capability into a SCAT response and pipeline leak detection capability will provide an accurate time and manpower saving capability. This will reduce both the cost and, more importantly, time during a spill and leak response scenario. The overall benefit is a reduction in the environmental impact both in the short-and long-term. It also provides the community a tool which is easy to deploy in a quality assurance role after clean-up as confirmation that the end of clean-up operations were met, or as a survey tool for monitoring further impact of a spill months/years later.

Further research into the capability may include:

- deployments to arctic regions
- reduction in imprinting time
- detection of target oils at deeper depths
- discrimination between “old” spills/nature seeps and target odor

In the longer term, Oil Detection Dog teams could be sustained by K2 Solutions, Inc. through the subscription of teams in a pipeline leak detection role. This will maintain a spill response capability while also providing companies a routine inspection tool. K2 is interested in developing this capability and providing a service to pipeline companies for leak detection/routine inspection as well as government agencies in spill response.

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