



# **Simple techniques for assessing impacts of oil and gas operations on public lands: a field evaluation of a photoionization detector (PID) at a condensate release site, Padre Island National Seashore, Texas**

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**by James K. Otton<sup>1</sup> and Robert A. Zielinski<sup>1</sup>**

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**U.S. DEPARTMENT OF THE INTERIOR  
U.S. GEOLOGICAL SURVEY**

<sup>1</sup> Lakewood, Colorado

U.S. DEPARTMENT OF THE INTERIOR  
GALE A. NORTON, Secretary

U.S. GEOLOGICAL SURVEY  
Charles G. Groat, Director

---

For additional information write to:

Team Chief Scientist  
Energy Resources Team  
U.S. Geological Survey  
MS 939 Box 25046  
Denver Federal Center  
Denver, Colorado 80225-0046

Copies of this report can be  
purchased from:

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## ABSTRACT

Simple, cost-effective techniques are needed for land managers to assess the environmental impacts of oil and gas production activities on public lands, so that sites may be prioritized for remediation or for further, more formal assessment. Field-portable instruments provide real-time data and allow the field investigator to extend an assessment beyond simply locating and mapping obvious disturbances. Field investigators can examine sites for the presence of hydrocarbons in the subsurface using a soil auger and a photoionization detector (PID). The PID measures volatile organic compounds (VOC) in soil gases. This allows detection of hydrocarbons in the shallow subsurface near areas of obvious oil-stained soils, oil in pits, or dead vegetation.

Remnants of a condensate release occur in sandy soils at a production site on the Padre Island National Seashore in south Texas. Dead vegetation had been observed by National Park Service personnel in the release area several years prior to our visit. The site is located several miles south of the Malaquite Beach Campground. In early 2001, we sampled soil gases for VOCs in the area believed to have received the condensate. Our purpose in this investigation was: 1) to establish what sampling techniques might be effective in sandy soils with a shallow water and contrast them with techniques used in an earlier study; and 2) delineate the probable area of condensate release.

Our field results show that sealing the auger hole with a clear, rigid plastic tube capped at the top end and sampling the soil gas through a small hole in the cap increases the soil VOC gas signature, compared to sampling soil gases in the bottom of an open hole. This sealed-tube sampling method increases the contrast between the VOC levels within a contaminated area and adjacent background areas. The tube allows the PID air pump to draw soil gas from the volume of soil surrounding the open hole below the tube in a zone less influenced by atmospheric air. In an open hole, the VOC readings seem to be strongly dependent on the degree of diffusion and advection of soil gas VOCs into the open hole from the surrounding soil, a process that may vary with soil and wind conditions. Making measurements with the sealed hole does take some additional time (4-7 minutes after the hole is augered) compared to the open-hole technique (1-2 minutes).

We used the rigid-plastic tube technique to survey for soil gas VOCs across the entire site, less than  $\frac{1}{2}$  acre.

Condensate has impacted at least 0.28 acres. The impacted area may extend northwest of the surveyed area.

## INTRODUCTION

Land managers have increasing responsibilities to assess the nature and extent of environmental impacts of various activities on public lands and to determine the associated risks to human health and ecosystems. Often, the land manager has a large number of sites to evaluate, limited resources to perform remediation and assessments, and limited guidance on how to evaluate and prioritize sites. Because formal site assessments are lengthy and expensive (see, for example, ASTM, 1999a) and limited resources need to be used on those sites with the greatest problems, accurate prioritization is vital.

The generally remote location of oil and gas production sites on Federal lands has historically limited public concern regarding impacts on human health and ecosystems. More recently, oil and gas production sites on public and private lands have come under increased scrutiny as past production impacts are being noticed, impacts on fish and waterfowl are documented, use of surface and ground water supplies expands, rural areas are encroached upon by residential and commercial development, and recreational uses of producing areas increase.

For oil and gas production sites, the main sources of human health and ecosystem risk are hydrocarbons (especially that fraction that is dissolved in water), saline water co-produced with the hydrocarbons, and radionuclides, principally radium in the produced water or associated scale and sludge. Although a previous study by the authors examined techniques designed to evaluate all three of these contaminants (Otton and Zielinski, 2000), this study looked just at the detection of volatile hydrocarbons in soils and shallow ground water. The purpose of this study was to extend and modify soil gas sampling methods used in the previous study.

The method evaluated here to detect hydrocarbons has the advantage of being simple and cost-effective and extends the reach of the observer into the shallow subsurface. The method provides real-time field data. Using this method and simple site mapping, one or more locations a day may be assessed, depending on the level of detail required.

Knowledge of the site characteristics (geology, slope, drainage, topography, etc.) and site history enhances the ability to search for and recognize likely locations of contamination. Thus, these techniques are best used by, or in collaboration with, knowledgeable personnel.

Hydrocarbon releases can range from single or episodic spill events to prolonged seepage from pits, pipes, stuffing boxes, and tanks. Spills and seepage can be generated by equipment or containment failure, past oilfield practices, vandalism, lightning strikes, flood damage, and other natural phenomena. Released hydrocarbons can flow across the land surface or seep into the subsurface from pits and bermed areas designed to contain spills. Because condensate and most crude oils are less dense than water, they remain on the surface of the water table. The hydrocarbon components present will dissolve to some extent in ground water and volatilize to the soil gas in the unsaturated zone.

The ratio of the partial pressure of a compound in air to its concentration in water at a given temperature is called the Henry's Law constant. Henry's Law constants for pure phase components of crude oil can be used to predict dissolution in water and volatilization to air, a critical step to an assessment of the toxicity (ASTM, 1999b; Yaws, Pan, and Lin, 1993). The water-soluble and volatile fractions often include those components of crude oil that have high toxicity (for example, benzene, toluene, ethylbenzene, and xylene- BTEX). Where a significant vapor-phase fraction is present, a subsurface hydrocarbon plume can be detected by measuring volatile organic compounds (VOCs) in soil gas above the hydrocarbon layer. Microbial degradation of hydrocarbons can contribute to detection of a plume because degradation products tend to be volatile.

Hydrocarbon releases at a production site are typically visible at the surface in the form of dead vegetation, stained soil, oil in depressions or in pits, or an oil sheen on the surface of nearby ponds and streams. These features are readily documented by observation and simple site mapping. What is typically not visible are hydrocarbons that have soaked into the soil and are now moving downslope in the subsurface either dissolved in the groundwater or moving as a separate phase on the surface of the water table. Also not readily discerned are dissolved hydrocarbons that may be present in groundwater seeps or surface waters downgradient from the release site.

Leakage of refined petroleum products from underground storage tanks, seepage of chlorinated hydrocarbons from waste pits, and spills of petroleum products during refining and transport have required the development of detailed site assessment and remediation procedures for hydrocarbon-contaminated sites (ASTM, 1999c). A photoionization detector (PID) (fig. 1, appendix) is often used as a screening instrument at such sites to check for the presence of volatile organic compounds and to protect personnel from exposure to them.

The simple technique for site assessment described here uses a PID to detect volatile organic compounds in soil gas in auger holes at oil and gas production sites, whether spills are apparent or not. This approach has advantages in that readings are instantaneous and the sensitivity and range are excellent (0.1 to 10,000 ppm VOCs). The instrument can detect direct hydrocarbon contamination of soils, VOCs being given off by a non-aqueous-phase hydrocarbon layer on top of the water table, or hydrocarbons dissolved in the water. It thus allows personnel to evaluate contamination beyond the immediate area of obvious contamination. Understanding how far and in which direction hydrocarbons may have migrated beyond the immediate site is critical to assessing and prioritizing the site, especially if potential receptors (i.e. stream, pond, water well) may exist downgradient from the site.

Much work of this type has been done as the preliminary or screening phase of formal site assessments or to guide cleanup of hydrocarbon spills on an emergency basis (Hayden Truscott, Kinder Morgan, Inc., oral commun., 2001). Little of this work has been published, and experience with screening techniques is usually limited to oil and consultant company environmental, health, and safety personnel.



Figure 1- Photoionization detector (RAE Systems, appendix 1) used to determine the concentration of volatile organic compounds in air (either in soil gas in an auger hole or being given off by a soil sample to the headspace of a plastic sample bag).

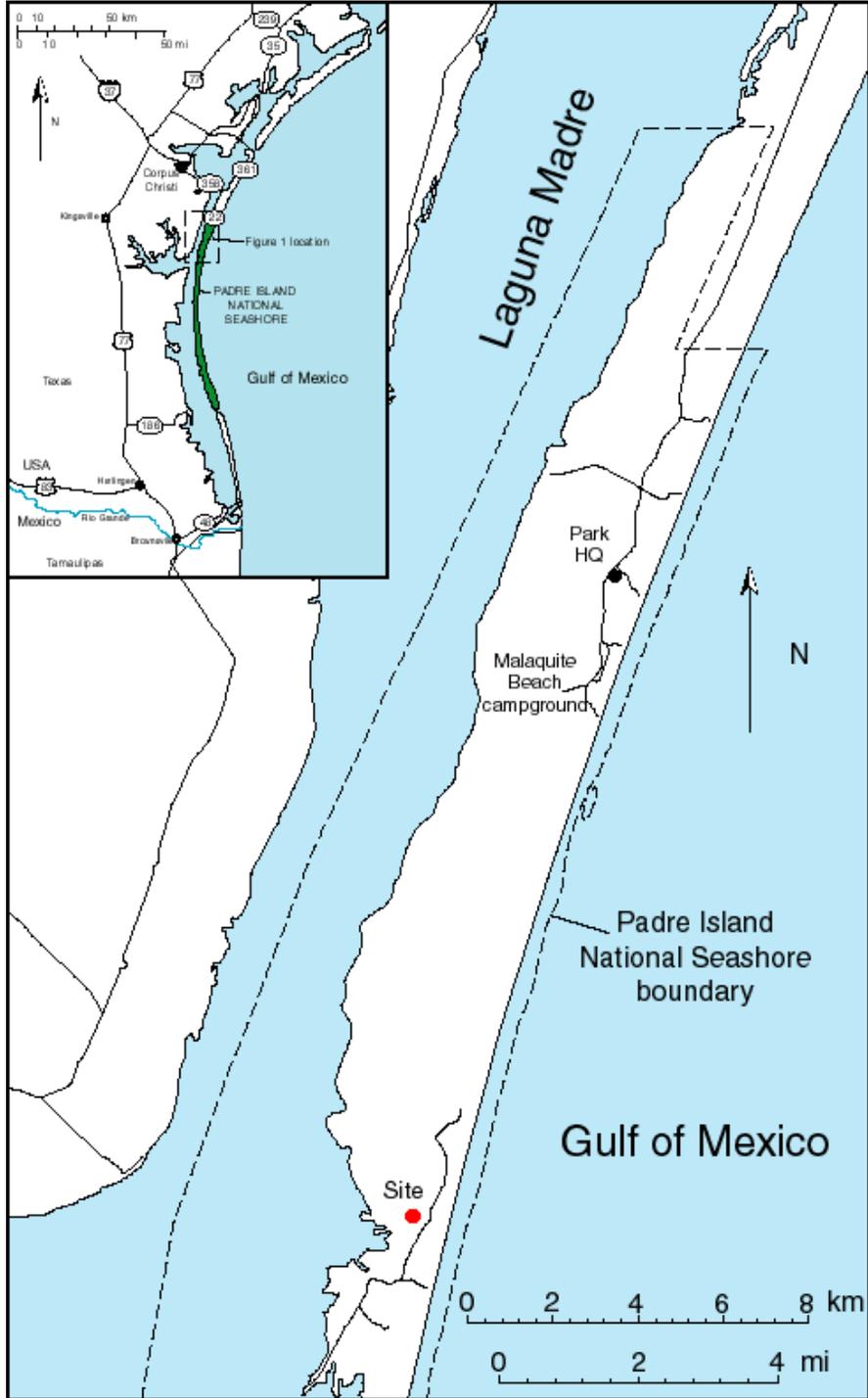


Figure 2- Approximate location of the study site in the Padre Island National Seashore, Texas.

In January 2001, the authors and personnel of the National Park Service visited the A-4 site, Dunn-McCampbell lease, in the Padre Island National Seashore, Texas. The site is located about 9 miles south of the Malaquite Beach Campground (fig. 2).

The main objectives were: 1) to establish what sampling techniques might be effective in the sandy soil and shallow-water-table conditions present in this area; and 2) delineate the probable area of condensate release at a known release site.

#### Site features

The site includes of a gas-and-condensate-processing unit placed on a 6-foot-high bulkhead adjacent to an area of low, vegetation-covered dunes (figs. 3, 4, and 5). The bulkhead is about 25 feet wide and 46 feet long. The long dimension of the bulkhead is oriented N. 50° E. Three pipelines extend from the bulkhead at its northeast end; one carries produced gas and fluids from a nearby well to the unit, and the other two carry natural gas and condensate product away from the bulkhead. A 2-foot by 4-foot sump is located on the northwest side of the bulkhead (fig. 5). Various oily fluids (lubricating oils, etc.) have seeped from the sump into the adjacent soil, leaving it slightly stained.

The site also includes an area where, in 1992 or 1993, a stream of condensate and natural gas was sprayed into the air northwest and west of the bulkhead. It was common practice in the 1980's and early 1990's for personnel working on equipment at such sites to vent pressurized lines to the atmosphere prior to working. Condensate landed on the nearby sandy soils and percolated into the ground. NPS personnel who visited the site after the event reported death of vegetation over an area of about 1/3 to 1/2 acre (Paul Eubank, National Park Service, oral commun., 2001). During subsequent visits, NPS personnel noted revegetation of the dead area. Only one such area of contamination has been documented by earlier observations of NPS personnel and data from this study, although other areas of condensate contamination in soils may be present at this site. The location of our sampling was based on the documented area.

During the three days of the 2001 visit, 29 shallow auger holes at 26 sites (fig. 3) were sampled. Data from these holes provide 1) information regarding the best approach to sampling VOCs in vadose-zone soil gases in sandy soils with a shallow water table, and 2) an

evaluation of the extent of shallow groundwater and vadose-zone hydrocarbon contamination at this particular site. For this study we measured volatile organic compound concentrations in soil gases from: 1) an area of obvious soil staining adjacent to the sump; and 2) an area away from the bulkhead where vegetation kill had been observed in past years. Below these auger holes will be labeled AHX except in figure 3 where just the numbers are used.

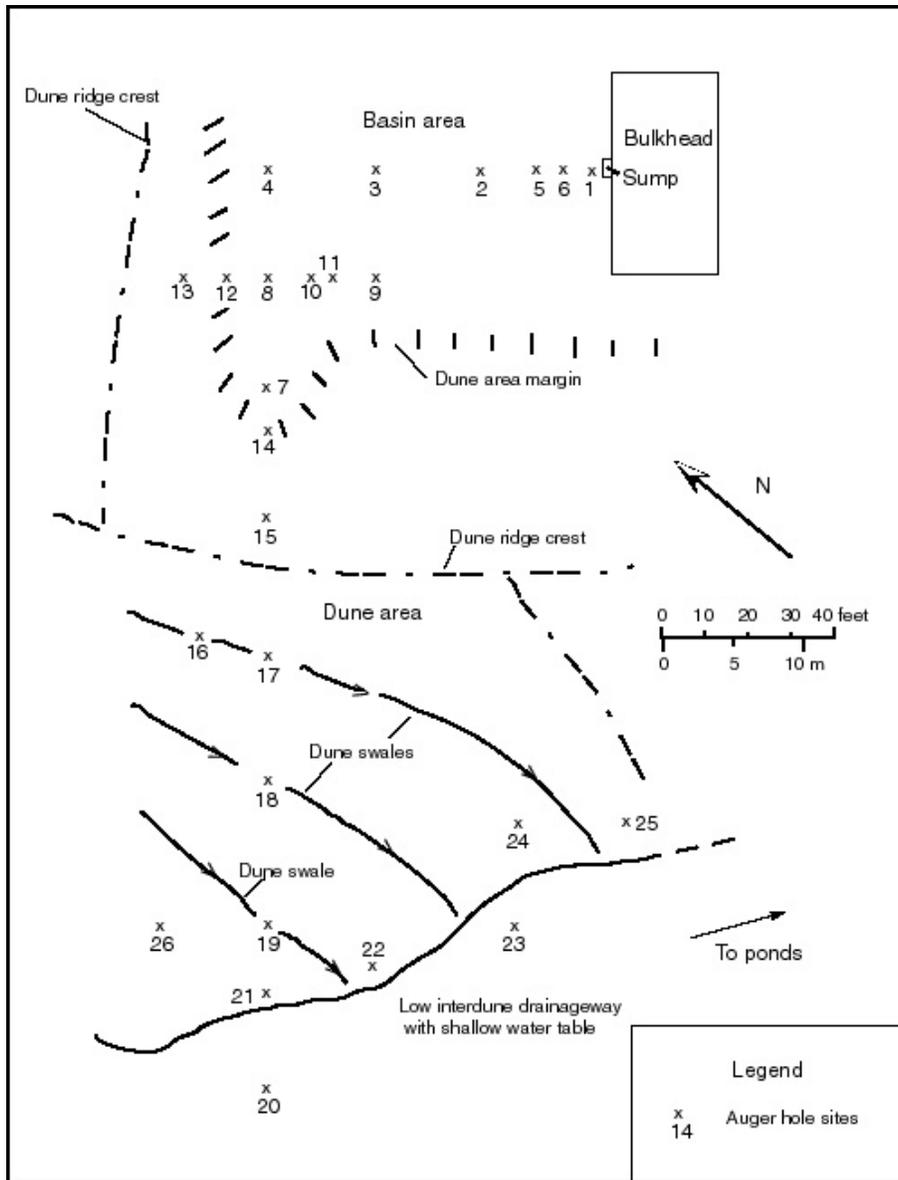


Figure 3- Sketch map of Site A-4, Dunn-McCampbell lease, showing cultural and natural features and soil-gas-sample sites. Sample locations mapped by tape and compass.



Figure 4- Gas-processing unit on bulkhead, A-4 site, Dunn-McCampbell lease. View from the east looking west. Note low dune area beyond the bulkhead.



Figure 5- View of the sump on the northwest side of the bulkhead and the area of oil-stained soil adjacent to the sump. Note low dunes beyond bulkhead.

## Geologic setting

The site is located in an area of deflation basins and low, vegetation-stabilized blowout dunes (fig. 6) between the fore-dune area and the back-island dune area (Weise and White, 1980). The bulkhead lies near the margin of a deflation basin, at the edge of a low blowout dune. Auger holes suggest that the water table ranges from about 0.6 m below the surface in the topographically low areas at the site to about 1.5 m in the dune areas that we sampled. The water table may lie at greater depths in higher parts of the dune not sampled. Although the water table depth was noted at many auger hole locations, we did not survey the elevations of the collars of the auger holes nor did we measure the water table depth consistently enough to establish the local hydrologic gradient. We suspect that the water table topography is a subdued version of the dune topography.

A typical profile of contaminated soil at the site (from the surface downward) consists of 1) dry, powdery, fine- to medium-grained, well-sorted noncohesive sand; 2) damp, cohesive, grayish orange to pale grayish orange, fine- to medium-grained sand (no condensate odor); 3) damp to nearly saturated sand, generally grayer in color with depth and progressively stronger in condensate odor; and 4) water-saturated sand, gray to black in color, variably strong condensate odor. Free condensate may be present at the level of the water table. In areas with a shallow water table, the dry surface layer is often absent. A layer of decayed plant material may occur at the surface. Locally, in areas of documented contamination, we observed reddish iron-oxide staining at the surface and in the shallow subsurface. The gray to black color of the sand at and above the water table likely reflects the presence of an iron-monosulfide coating on the sand grains. That coating may have formed by the reduction of sulfate to sulfide by sulfate-reducing bacteria, and the reaction of the sulfide with iron. The presence of iron monosulfides suggests that sulfate-reducing bacteria are actively consuming hydrocarbon in the soil. Sulfate is likely derived from sea salt carried from the beach by wind.



Figure 6- View, looking east, of the northeast part of the sampled area. The person in the photo is standing near site AH8. He is flanked to the northwest and southwest by the low dune ridges (fig. 3). The bulkhead and the parking area beyond are in a deflation flat.

#### SAMPLING METHODS

In a previous investigation in northeastern Tennessee (Otton and Zielinski, 2000), the authors sampled soil gas by augering 5-cm-diameter holes about 75-100 cm deep and then inserting a flexible Teflon tube into the hole to within a few centimeters of the bottom. The PID was then used to draw the sample from the bottom of the open hole through the tube. The highest reading using this technique was typically the initial value after pumping started, because ambient air is drawn into the hole and up the tube as sampling progresses and dilutes the soil gas in the open hole.

We tested the open auger hole technique at this site and compared it to an alternative technique in which a 5-cm-diameter, clear, hard plastic tube (capped at one end) is inserted into the open auger hole (fig. 7). The soil adjacent to the upper part of the hole (or soil removed during augering) is pushed against the walls of the tube at the top of the hole to form a seal (fig 8). The tip of the PID probe is inserted into a hole in the cap. However, a hole in the thick, rigid plastic cap would be a source of air leakage because it is difficult to get an airtight seal

between the cap and the metal tip of the PID probe; thus the hole is covered with duct tape, which is replaced often. The duct tape is flexible and if a hole slightly smaller than the diameter of the probe tip is punched in the tape, the tip of the PID probe can form a seal with the tape (fig. 8). The pump in the PID then draws air from the space within the tube and from the space in the open hole below the end of the tube.

Initially, this air is a mixture of atmospheric air and soil gas that has diffused from the walls of the auger hole. As sampling progresses, soil gas is drawn from the volume of soil surrounding the open hole below the tube walls. The volume of air in the open space can be calculated from the depth of the hole and its radius. About two volumes of air should be drawn from the hole (the PID pump pulls at 500 cc/minute) to insure that soil gas is being pulled into the open space. This may take up to five minutes. The PID used here provides continuous readings; thus the hydrocarbon values can be monitored to watch for peak values. At the end of the measurement session, peak and average readings are provided by the instrument. We typically see a gradual, then sharp, rise in readings that reach peak values in 1.5 to 3.5 minutes. The readings then gradually decline (see AH26 sampling results below in table 1). The peak value is recorded for the site. The length of hard plastic tube used at this site was usually 61 cm; however we also used a 30.5-cm-long tube at some sites with a shallow water table. At one site we compared values obtained using the longer and the shorter tubes.

In areas of dry, sandy, poorly cohesive soils at the surface, we dig a small pit at the sample site to get below the dry sandy layer, then use a small plastic bucket with the bottom removed to prevent sand from falling into the open auger hole. The depth of the auger-hole collar below the soil surface is estimated, and this value is added to the depth of the auger hole, to determine total depth of the hole. If the soil is damp or oily and cohesive at the surface, the bucket is not necessary.



Figure 7- Individual is inserting the 61 cm clear, rigid plastic tube into the open auger hole. The yellow instrument is the PID. The other instrument is a microRmeter, designed to check for naturally occurring radioactivity.



Figure 8- Site AH 16. Top of inserted tube with blue rigid plastic cap and duct tape. Note hand impressions from pushing soil down around the top of the tube to seal the soil. Also note the weak iron oxyhydroxide staining in soil surface layer.



Figure 9- Individual is pulling the 61 cm tube from the auger hole. The PID is in his right hand. The small, white disk below the black tube on the PID is the water trap, a device designed to prevent water from entering the ionization chamber in the instrument. The probe tip is below the trap. The probe tip is inserted in the hole in the duct tape and the soil gas sample is drawn from the auger hole by the pump in the PID.

#### Sample method test results

##### Teflon tube, open hole versus rigid tube, sealed hole

Soil gas samples were taken at locations AH1 and AH8B (fig. 3, table 1) using both the Teflon tube/open hole and rigid plastic tube/sealed hole methods. At AH1 the soil was oily and cohesive from the surface downward because of the coating of hydrocarbon on the mineral grains. AH1 was initially augered to a depth of 40 cm and the Teflon tube was inserted to within a few cm of the bottom of the hole.

The maximum reading (7.1 ppm) occurred early, and then values declined. After this first sample, background readings were taken on the Teflon tube. They dropped to about 1.3-1.4 ppm after several minutes of drawing ambient air (0.0 ppm) through the tube. The hole was deepened to 83 cm. A maximum value of 19.2 ppm was observed near the bottom of the hole.

We observed several large, brown-colored droplets on the inner walls of the Teflon tube near the bottom after this second sampling. We also observed water condensation on the inner walls of the Teflon tube. The larger water

droplets were probably drawn into the bottom of the tube from standing water or water-saturated sand in the bottom of the hole. Water condensation formed on the inner wall of the Teflon tube because the ground temperature was warmer than the air temperature by several degrees.

After pulling the Teflon tube from the hole, we attempted to get the tube back to ambient air VOC concentrations (0.0 ppm) by pulling air through the tube with the PID. The VOC readings did not decline readily and went above the bottom hole value (>20 ppm) initially. After several minutes the values still had not declined significantly. We believe that the walls of the Teflon tube and the water droplets on the walls had sorbed and were subsequently releasing substantial amounts of VOCs.

We switched to the 61-cm-long, 5-cm-ID rigid plastic tube. We calculated the approximate volume of our hole, which was 83 cm deep and 2.5 cm in radius (about 1600 cc) and determined that 5 minutes was an adequate sampling time. The maximum reading was 419 ppm of VOC during a 5-minute sampling period. This value is a factor of 20 higher than the value obtained with the Teflon tube in the open auger hole. After removing the probe from the hole we noted that the instrument read 4 ppm without any tube attached (presumably VOCs were sorbed to the inline water trap). It took several minutes to get the instrument down to ambient levels (0.0 ppm). We also pulled ambient air through the 61 cm tube to check for contamination. Initial readings were about 15 ppm, but after several minutes the levels dropped to less than 4.0 ppm.

Throughout the study, we noted that background readings should be checked on the tubes after moderately to highly contaminated sites (20-1000 ppm) have been measured. The tube can be cleaned of sorbed VOCs by removing the cap and swinging the tube through the air for a few minutes. Pushing a clean cloth through the length of the tube can also lower VOC readings. If the tube is used without getting the VOC concentrations down to ambient levels (0.0 ppm at this site), then the background reading on the tube should be recorded and subtracted from the results in the next reading. Background readings are used in table 1 to calculate the true VOC reading.

We sampled soil gas at Site AH8 and then returned to that site three days later and augered three additional adjacent holes (AH8B, AH8C, and AH8D, fig. 10). In hole AH8B (90 cm deep, measured 112 ppm with the rigid tube), we inserted the Teflon tube to various depths above the bottom of the hole (10, 20, and 30 cm, table 1). The maximum

values were 22, 24, and 19 ppm, respectively. The values were one-fifth to one-sixth of the values obtained by the rigid tube technique. These maximum values were typically obtained early in the measurement period as observed in the previous study; however, a strong wind was blowing during the sampling, and we noted that the values fluctuated substantially after the initial reading, in some cases reaching or exceeding the initial reading.

#### Comparison of the longer and shorter rigid tubes

At AH15 (159 cm deep) and AH21 (66-75 cm to the WT), we compared values obtained using the 61-cm-long rigid tube to a 30.5-cm-long rigid tube. At AH15 the 61-cm tube yielded a maximum value of 83.9 ppm, whereas the 30.5-cm tube yielded a maximum value of 63.0 ppm. The lower readings with the 30.5 cm tube are expected. It is likely that an upward-decreasing VOC concentration gradient exists in the soil profile, with maximum VOC values at the top of the hydrocarbon layer at the water table. The shallower tube is drawing soil gas from a larger soil volume that includes soil of lower VOC concentrations closer to the surface; thus values are expected to be lower.

At AH 21, the hole was initially augered to 90 cm. When checking the hole depth, we noted that the water level in the hole was at 75 cm. We used the 30.5 cm rigid tube and obtained a maximum VOC concentration of 50.2 ppm between 1 and 2 minutes into the reading. We then inserted the 61 cm tube; however we noted that the water level had risen to 66 cm in the hole. A maximum reading of 40.4 ppm was obtained during a 4-minute reading. We raised the 61 cm tube out of the hole about 9 cm and remeasured. A 36.5 ppm reading was observed at 1 minute and lower readings thereafter. We were expecting the initial reading with the 61 cm tube to be higher than the 30.5 cm reading. However, with long measurement times on a relatively shallow hole, the pump may have pulled low-VOC air in the sample from near the surface or even atmospheric air.

#### Within site variability

We sampled soil gas at Site AH8 and then returned to that site three days later and augered three additional holes (AH8B, AH8C, and AH8D, fig. 10) about 0.5 m from the original hole. The initial reading for hole AH8 was 96.5 ppm (83 cm deep). Readings for AH8B, AH8C, and AH8D were 112 ppm (90 cm deep), 112 ppm (91 cm deep), and 88.1 ppm

(91 cm deep), respectively (table 1). The lower reading for AH8 may reflect the somewhat shallower depth of sampling; however the lower reading for AH8D cannot be explained by that. The readings for AH8B, AH8C, and AH8D reflect variability, but we are uncertain whether the variability is because of site, operator, or instrument.



Figure 10- Site AH8. Initial hole is marked by the orange flag (the flag is visible but not the metal wire inserted into the ground; the hole is beneath the meter stick). Adjacent locations, AH8B, AH8C, and AH8D, are marked by 10-penny nails tied with red flagging. The opening for one of these holes is visible, just to the right of the red flagging on the left side of the photo. The PID (yellow) and an open field notebook are visible.

#### EXTENT OF HYDROCARBON IN SOIL AT A-4

VOC analyses for the 26 sites are tabulated in Table 1 and portrayed in Figure 11. The highest reading (419 ppm at AH1) at the site was from the area of oil-stained soil adjacent to the sump (table 1, fig. 3, fig. 5). Outside of that area, the highest reading was 159 ppm in AH14 (table 1, fig. 3). The area of hydrocarbon soil contamination documented by the sampling (fig. 12) is 0.12 hectares (0.28 acres). The area of contamination is well constrained only at the northeast end and the southwest end where the edge of the area is bracketed by sample locations. The impacted area likely extends northwest of the surveyed area.

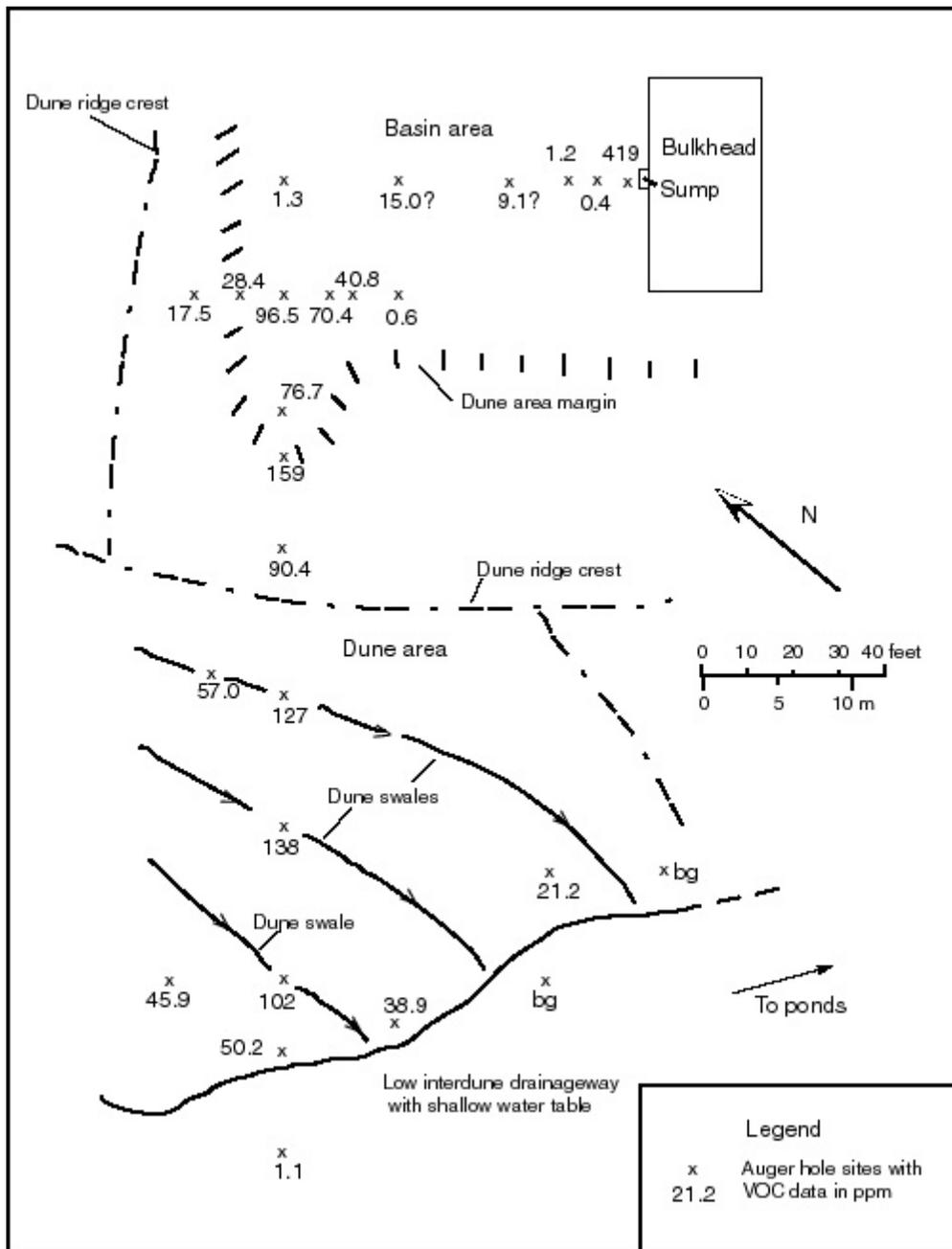


Figure 11- Site map showing VOC values (in ppm, from table 1). VOC readings are the maximum observed at each site. Values are queried where background measurements were not taken prior to sampling. bg- no odor to sand at total depth4; background VOC readings assumed with no measurement made.

Table 1- VOC measurements at auger hole locations at the A-4 site

BG- background hole; RT-rigid tube; except where noted, the tube was 61 cm long; TT (XX)- Teflon tube, number of cm above bottom of hole; NA- not applicable; bg- no odor, no measurement, background value assumed; WT- water table.

Site #	Method	Date	Depth (cm)	Time of measurement (mins:secs)	Raw VOC reading, peak, if just one listed (ppm)	Raw minus background (ppm)
BG	RT	01/09	72	5:00	0.3	0.3
AH1	TT (2.5)	01/09	40	NA	7.1	7.1
	TT (2.5)	01/09	83	NA	19.2	17.9
	RT	01/09	83	5:00	419	419
AH2	RT	01/09	85	5 :00	9.1	Unknown
AH3	RT	01/09	85	11:00	15.0	Unknown
AH4	RT	01/09	88	5:00	1.3	1.3
AH5	RT	01/09	88	4:00	1.2	1.2
AH6	RT	01/09	84	5:00	0.4	0.4
AH7	RT	01/09	66	5:00	76.7	76.7
AH8	RT	01/09	83	5:00	96.5	94.9
AH8B	RT	01/12	90	4:00	112	111
	TT (10)	01/12	90	NA	22	NA
	TT (20)	01/12	90	NA	24	NA
	TT (30)	01/12	90	NA	19	NA
AH8C	RT	01/12	91	4:00	112	111
AH8D	RT	01/12	91	4:00	88.1	85.4
AH9	RT	01/11	87	5:00	0.6	0.6
AH10	RT	01/11	88	5:00	70.4	70.4
AH11	RT	01/11	90	5:00	40.8	40.0
AH12	RT	01/11	88	5:00	12.1	11.0
			114	6:00	28.4	27.3
AH13	RT	01/11	104	5:00	2.7	0.7
			138	5:00	17.5	15.5
AH14	RT	01/11	88	5:00	159	159
AH15	RT	01/11	100	5:00	8.5	6.4
			156	4:00	90.4	89.2
AH15	RT (61cm)	01/12	159	5:00	83.9	83.9
	RT (30.5cm)	01/12	159	5:00	63.3	63.0
AH16	RT	01/12	134	4:00	57.0	56.6
AH17	RT	01/12	141	4:00	127	127
AH18	RT	01/12	160	1:00	131	131
				1:50	138	138
				3:00	127	127
				4:00	117	117
AH19	RT	01/12	121	1:55	102	102
				4:00	86.2	85.8
AH20	RT (30.5cm)	01/12	57 WT at 57	4:00	1.1	1.1

Table 1 (continued)- VOC measurements at auger hole locations at the A-4 site  
 BG- background hole; RT-rigid tube; TT (XX)- Teflon tube, number of cm above bottom of hole;  
 NA- not applicable; bg- no odor, no measurement, background value assumed; WT-water table

Site #	Method	Date	Depth (cm)	Time of measurement (mins:secs)	Raw VOC reading (ppm)	Raw - background (ppm)
AH21	RT (30.5cm)	01/12	90 WT at 75	1:00	49.4	49.4
				Max	50.2	50.2
				2:00	46.5	46.5
				3:00	45.6	
	RT (61 cm)	01/12	90 WT at 66	2:00	32.0	30.9
				4:00	41.5	40.4
	RT (52 cm)	01/12	90 WT at 66	1:00	36.5	35.4
				2:00	34.6	33.5
AH22	RT (30.5cm)	01/12	80 WT at 65	0:30	21	20.9
				1:00	30.8	30.7
				1:30	35.7	35.6
				2:00	38.6	38.5
				2:30	38.9 (max)	38.8
				3:00	37.9	37.8
				3:30	37.1	37.0
				4:00	36.1	36.0
AH23	NA	01/12	69 (WT)	-	bg	NA
AH24	RT	01/12	100 WT at 96	0:30	6.7	6.7
				1:00	16.4	16.4
				1:30	20.0	20.0
				2:00	21.2 (max)	21.2
				2:30	21.1	21.1
				3:00	20.7	20.7
				3:30	20.4	20.4
				4:00	19.8	19.8
AH25	NA	01/12	105	-	bg	NA
AH26	RT	01/12	133 WT at ~110	0:30	3.2	3.2
				1:00	24.7	24.7
				1:30	38.1	38.1
				2:00	44.5	44.5
				2:30	45.7	45.7
				Max	45.9	45.9
				3:00	44.7	44.7



Figure 12- Areas where data suggest hydrocarbons are present at and near the water table. The larger area of hydrocarbons may extend to the northwest and is reasonably well delineated only at the northeast end and southwest end of the mapped area, where sample sites bracket the contact. The area near the sump is mapped based on one reading and the stained soil at the surface.

## CONCLUSIONS

Under the conditions at this study site and elsewhere in sandy soils on Padre Island, the rigid tube/sealed hole technique offers better results than the open hole/Teflon tube technique because:

- 1) the rigid tube technique draws VOCs from the soil gas surrounding the hole; VOC concentrations are higher in the soil gas surrounding an auger hole than in the bottom of the open auger hole. The open auger hole must rely on diffusion and convection of VOC-bearing soil gas from the surrounding soil. This can be affected by several variables, including wind speed across the open hole and the porosity and permeability of the soil surrounding the open auger hole. The higher values derived by the rigid tube technique provide a greater contrast between background and contaminant soils, and a greater sensitivity for identifying slightly contaminated areas; and
- 2) the rigid tube appears to sorb less VOCs from the soil gas than the Teflon tube, making it easier to get the tube back to acceptable background levels prior to the next sample.

The sandy soils found on Padre Island are well suited to the rigid tube technique because the high permeability of the soil allows the PID pump to draw sufficient soil gas to maintain a 500cc/minute flow. The PID-rigid tube technique may have limits in soils where the permeability is lower and the 500cc/minute rate cannot be sustained. The PID has an automatic pump shutoff when the back pressure becomes too high. Note that if very high permeabilities were present (gravelly sand, for example), the PID may draw atmospheric air into the tube in situations in which the sample depth or the water table is shallow, or the sampling time is long.

In the case where the hydrocarbon contamination is at the water table, an upward decreasing concentration gradient seems to be present, as predicted by theory, and as documented here. In those cases, there may be an ideal interval above the water table to sample soil gas, perhaps 20-30 cm. The best procedure may be auger the hole to the water table and then insert a tube to the proper depth to leave a 20-30 cm open hole interval above the water table. This would require having various lengths of tube available. Sampling times needed to reach maximum values may be longer when the tube is longer and the initial volume of low-VOC air in the hole is greater.

VOC data obtained using the rigid tube technique and the PID successfully delineate an area of condensate contamination near the bulkhead. The boundaries are best delineated where they are bracketed by sample locations. The area is open to the northwest, but VOC values in soil gas seem to be decreasing in that direction.

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Appendix- Field equipment used during this study\*

1) RAE-2000 Photoionization Detector

RAE Systems  
1339 Moffett Park Drive  
Sunnyvale, CA 94089

2) Soil auger

2¼" diameter general-purpose soil auger- threaded, stainless steel bit, cross handle, and 3-foot extension rods

AMS Supplies  
105 Harrison  
American Falls, ID 83221

\* Mention of equipment used during this study is for information only and does not imply endorsement by the U.S. Geological Survey. Instruments and equipment sold by other manufacturers may achieve the same results.