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REGIONAL GEOCHEMICAL ASSESSMENT OF METHANE, BTEX, CO2 and H2S GAS OCCURRENCES

PLAYA VISTA DEVELOPMENT
First and Second Phases
Los Angeles, California

Prepared for:

CITY OF LOS ANGELES
DEPARTMENT OF BUILDING AND SAFETY

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EXECUTIVE SUMMARY

Near surface soil gas surveys conducted at Playa Vista have revealed anomalous concentrations of hydrocarbon gases, at a depth of 4 ft, within significant portions of Tracts 49104-01 and 49104-02. The largest magnitude anomalies (> 12,500 ppmv) make up a very small part, only 1.5%, of the 1087 acres in the Playa Vista project. Nearly two thousand samples of soil gas from these tracts have been collected and analyzed. Methane occurs in concentrations as high as 100%, and all of the larger magnitude seeps

also contain associated ethane, propane, and butanes, definitive indicators of a thermogenic source.

Dramatic evidence of the magnitude of the gas flows has been evidenced by intense bubble activity in a large flooded area of Tract 01 following the heavy rains in January 2001. Bubbles were observed erupting from the water surface directly over the region where the soil gas survey contained the highest methane concentrations. At one location, the flow was intense enough to raise the surface of the water a few inches above its surroundings in the form of a low frothy fountain. An observation well (FW-09) installed at this location was found to have a natural flow rate of 9 liters/minute, and in spite of construction related changes, remained active until destroyed in late June of 2001.

The result of this investigation indicates that natural gas steadily migrates upward through the sediments to the surface at Playa Vista. This is the result of an advective pressure, upwards of 20 psig in the gravel aquifer, driving the methane gas to the surface. Another independent indication of the steady migration was obtained from investigations of bubbling seeps in the streams at the confluence of the Centinela and Ballona Creeks and in the riparian wetlands corridor that trends westerly along the base of the bluffs. Samples of gas bubbles collected more than seven years earlier from Centinela Creek were found to have essentially the same composition as that of the methane gases collected in these surveys. Thus, bubbling seeps in streams are present on both the north and south sides of the Playa Vista soil gas anomalies. The results from Centinela and Ballona Creeks confirm that this has been going on for many years and are an indication that effective paths of migration have been established in the subsurface.

An extensive program of drilling and testing of vent wells and monitor wells was carried out within the upper 50 feet of sedimentary cover underlying these gas-charged areas in an effort to characterize the nature and source of these thermogenic gases. One of the most important layers investigated is the Ballona Gravel Aquifer, located at a depth of about 50 ft. This gravel bed contains accumulations of the same thermogenic gases, under essentially the same area as defined by the soil gas survey. In an attempt to measure flow rates and deplete these shallow gas accumulations, over 120 vent wells were installed (mostly in Tract 01) on the largest soil gas anomaly. This effort was essentially a failure because of the weakness and fluidity of these former Los Angeles River sediments, which were too easily disturbed by the drilling operations and the flow of gas, water and sediments towards the well screens, plugging the well screens and preventing the installation of effective vent wells, even when free gas was encountered. The gas pockets were also found to be too erratic to be predictable (for example, three vent wells were drilled within 10 ft of the actively venting macroseep at FW-09, with none of them able to produce gas). Other examples are cited in the text.

The origin of this natural gas is very likely from the Pico sands, that have been found to have gas shows in the interval from 500 ft to 3,000 ft in each of five exploratory wells drilled on Playa Vista property in the 1930's. One of these wells, the Universal City Syndicate Inc. LTD #1, had a blowout in 1930 while drilling at 1831 ft in the Pico Formation, and produced gas at an estimated rate of 5,000 MCF per day. This well was subsequently drilled to 5,960 ft and plugged as a dry hole in 1931. During re-abandonment operations, completed in June 2001, four gas samples were collected at depths ranging from 668 ft to 760 ft near the base of the fresh water zone. The composition of this gas was found to be very similar to that of the methane gas collected by the soil gas survey and from the monitor and vent wells. No significant gas shows were found below the base of the fresh water in this well during the final plugging and abandonment of this well, indicating that the Syndicate well is not the source of the gas.

It is significant that natural gas was discovered at depths of 1,500 ft to 4,700 ft, in the Pico and Repetto sands of the El Segundo field, which is on a similar structural trend only 4.5 miles southwest of Playa Vista. The analyses of two Pico gas samples from this field show that they are very similar to the thermogenic gases at Playa Vista. This field has produced about 23 billion cubic feet of gas, giving an indication of the possible magnitude of the gas accumulations that could, or may have existed beneath

Playa Vista.

An independent assessment has been made of the geological and geophysical characteristics of the formations at Playa Vista in an effort to understand the nature of the structure and stratigraphy of the subsurface gas sources and the gas migration pathways. A high-resolution 2D seismic line, located along Jefferson Boulevard provides an image of the shallow subsurface down to a depth of about 2,000 ft. A 3D seismic survey was also carried out to image the deeper section, extending to about 8,000 ft.

A specific problem that required attention was the proposed existence of the Lincoln Boulevard Fault that was postulated to dip in a westerly direction down toward the gas storage reservoir (operated by Southern California Gas Company). A very careful review of the information from the 2D and 3D seismic surveys does not show any evidence that such a west-dipping fault exists. Corroborative evidence has also been obtained from an investigation of the composition of the gas in the storage reservoir, which proves that the Playa Vista gases are unrelated to the gases from the storage field. Thus it can be concluded that there is no postulated fault migration pathway for storage gases to migration from the storage reservoir located at a depth of about 6,200 ft and the Playa Vista site. Thus two independent methods provide collaborative evidence that the Lincoln Blvd. Fault, as postulated does not exist.

Unfortunately, the seismic data were not acquired in a manner and over a sufficient area to allow a definite conclusion to be drawn as to the exact nature of the subsurface structures beneath Playa Vista. As a result, there are essentially two interpretations of the subsurface geologic structure and the nature of the paths of gas migration, as outlined in Assessment of Geological and Geophysical Characteristics of the Playa Vista Development Site and Integration with the Geochemical Observations by Anderson, Becker and Witherspoon, 2001. One involves a slump model in which 800 to 1,000 feet of strata have been disrupted during slumping of the valley wall that defines the southern boundary of the Ballona Creek floodplain. The surface along which slumping occurred cuts into the uppermost Pico sands. As a result of this truncation, the seal in the sand/shale sequences of this shallow section was breached, and a path for gas to migrate to the surface was provided. An alternative model involves interpreting the seismic data as reflecting a structure with a near-surface system of faulting/jointing that provides a mechanism for migration of gas from the middle and upper Pico sands. Drainage of gas from these sands would explain the very significant migration of gas at the surface of Playa Vista. Lineations observed in the surface gas anomalies may indicate fractures bounding major slump blocks that formed during gravity driven collapse of the valley wall into the deep valley. The main question to be answered is the depth, extent and origin of the fractures, however, neither model leads to a deep-seated "earthquake fault" that would cause structural damage.

Anomalous methane concentrations in the shallow sediments at Playa Vista, and the difficulties experienced in attempting to characterize the magnitude and nature of these gas accumulations present a significant and challenging problem. The presence of gas seeps requires building methane mitigation systems for any building constructed directly over the areas where anomalous concentrations of soil gas have been measured. In the interest of safety, no variances in these methane mitigation requirements should be allowed. Not only do these mitigation systems require extensive field-testing to determine their effectiveness in handling the gases venting naturally at Playa Vista before initial occupancy, in view of future seismic activity in the Los Angeles Basin, this effectiveness must be periodically revaluated. The installation of real-time monitoring systems installed in the vent risers in the Playa Vista buildings could provide significant protection, provided that they are properly calibrated and demonstrated to be responding to the actual gas levels, which accumulate under the buildings foundations. This testing has not been done, and must be completed as part of the due diligence before occupancy.

Utility conduits, utility vaults and sewers contained within the streets and public right-of-ways are also subject to explosive gas concentrations. The building mitigation systems offer no protection, nor mitigation for this area of concern. The design of these features should be such that risk of explosion is minimized. ETI has never received any information from Playa Vista regarding the handling of methane problems associated with the utilities and suggest that this area be given due consideration.

1.0 INTRODUCTION

1.1 Location

The proposed Playa Vista Development (Site) encompasses about 1,087 acres approximately 15 miles west of downtown Los Angeles (McLaren Environmental Engineering, May 8, 1987, ENSR, October 1997). The site is four miles south of the City of Santa Monica, 0.5 miles west of the City of Culver City, and approximately 1.5 miles north of Los Angeles International Airport. As shown by Figure 1, the Playa Vista Development is bounded by Marina del Rey on the north, Culver City on the east, Playa del Rey and Westchester Bluffs on the south, and Vista del Mar and Playa del Rey on the west. Playa Vista will be developed as an integrated, mixed-use, master-planned community composed of residential, commercial, recreational, and civic structures. Lincoln and Jefferson Boulevards are the major north-south and east-west traffic arteries, respectively, in the area.

The site has been subdivided into four planning areas, A, B, C, and D based upon the quadrants formed by the intersection of Ballona Channel and Lincoln Boulevard. These planning areas are shown in Figure 2. The proposed development of Playa Vista includes two major phases, as shown in Figure 2. Initially, only the western portion (Tracts 01, 02, 03, 05, and 06) of the Phase 1 area was surveyed. Lot and product numbers used to refer to specific building construction areas for these Phase 1 tracts are shown in Figure 3 for reference. The eastern portion of Phase 1 (Tract 04) was only recently surveyed along with the Phase 2 areas as part of this regional soil gas survey.

1.2 Previous Work

Exploration Technologies, Inc. (ETI) of Houston, Texas was originally retained in May 1999 by the Los Angeles Department of Building and Safety (LADBS) and Playa Capital to serve as "Peer Reviewer" regarding subsurface methane gas issues in the proposed Playa Vista Development in Los Angeles, California. The initial scope of work was to review and comment on previous studies/reports concerning methane at the Playa Vista Development (PVD). Following a review of the available data, and a meeting with the Playa Vista consulting experts on September 15, 1999, it was readily apparent that previous studies were not adequate, nor thorough enough to fully assess the occurrence of methane gas at the PVD due to limited sampling and analyses. Methane gas concentrations in groundwater from three zones had been measured in five monitor wells that had been installed in Tract 03 by Sepich and Associates (Sepich Associates Inc., April 2, 1999). The data from this assessment was included in the report by Integrated Environmental Services, Inc. (IES, May 28, 1999). These wells confirmed the presence of large methane concentrations in the 50-foot gravel aquifer. However, the results did not provide definitive methane content, nor adequate information about the source of methane in the aquifer.

Based on ETI recommendations, a preliminary subsurface methane assessment (ETI letter report, November 29, 1999) was conducted during October and November, 1999 over Tract 03 in the proposed Playa Vista Development. The location of this first soil gas data set collected by ETI is shown in blue on Plate 1 for reference to the other ETI soil gas data sets. Measurable concentrations of ethane, propane, and butanes were confirmed for the first time from Playa Vista soil gas and ground water samples following protocols set by ETI. Concentrations for all of these light gas components were noted to increase in a southwest direction towards the University City Syndicate Inc. LTD #1 well, which at that time was considered as a possible source of thermogenic gas.

Geochemical results from the soil gas and monitor wells (dissolved gas in ground water, and free gas bubbles liberated from the ground water) indicated that the methane and other associated light hydrocarbon gases likely had a common, deep petrogenic source. Ethane, propane, iso-butane and normal-butane are never found associated with 100% biogenic methane gas (Coleman et al., 1977, Coleman, 1979, Coleman et al., 1981, 1988, Jones and Drozd, 1983, Jones et al., 2000, Jones and Agostino, 1998, Thompson, 1966). Thus, the presence of these four independent light gases indicated a definite thermogenic gas contribution, which clearly shifted toward the thermogenic end member to the southwest near the University City Syndicate Inc. LTD #1 well. Methane stable carbon isotopes analyses performed on free gas samples collected from each of the five monitor wells in Tract 03 also showed an increased thermogenic contribution of methane gas towards the southwest.

In contrast to earlier results reported by Playa Vista contractors, the light gas compositions of the free and dissolved gases obtained from the water wells were found to be nearly identical to those measured at four feet in the soil gas samples. Two previous soil gas data sets collected by CDM on September 21 and again on October 7, 1999 failed to report any ethane or propane, yet did report small quantities of butanes and pentanes (ETI letter report, November 29, 1999, CDM October 12, 1999 fax report). This compositional disagreement with the free gas in the 50-foot aquifer was the reason that ETI changed the soil gas protocol and collected an independent soil gas data set for evaluation of the 49104-03 area.

This initial ETI methane assessment conducted within Tract 03, involved sample collection of soil gas from the shallow subsurface and the collection of groundwater and free gas samples from a group of newly installed monitor wells screened in the 50-foot gravel aquifer. Following a review of this initial survey data, it was readily apparent that previous studies were inadequate for assessing the methane gas issue at the Playa Vista site due to limited and poorly done sampling and analyses.

Based on the results of this first survey within Tract 03, ETI designed and recommended a more regional assessment of the Phase 1 development area. This second, more through assessment was conducted between October 1999 to April 2000, and included the collection of 812 four-foot deep soil gas samples placed on a 100-foot grid spacing and 41 monitor wells, installed and sampled in the 50-foot deep Ballona gravel aquifer. Delays by Playa Vista and wet weather caused the monitor well portion of this second investigation to extend into early April of 2000. This second, more thorough assessment, directed and supervised by ETI, was successful in determining the nature, magnitude and distribution of methane gas in near surface soils, as well as in the 50-foot gravel aquifer located beneath the site in the Phase 1 area. This second ETI soil gas data set is highlighted in green on Plate 1.

ETI's second assessment report (Subsurface Geochemical Assessment of Methane Gas Occurrences, Playa Vista Development, First Phase Project, Los Angeles, California) for the City of Los Angeles, Department of Building and Safety (LADBS) was issued on April 17, 2000, immediately following the collection and analysis of the monitor well data. Soil gas samples for both of these two surveys were collected by Scientific Geochemical Services in Casper, Wyoming and the analytical laboratory work was done by Microseeps Laboratory in Pittsburgh, Pennsylvania. Sampling and analytical protocols are given in the appendices to these first two reports. All stable carbon isotopes analyses were done by Isotech Laboratories in Champaign, Illinois.

Geochemical results from the April 17, 2000 assessment show two main areas of high methane concentrations (above 70% methane) in the west half of Tract 01 and the south half of Tract 02. Anomalous levels of ethane, propane, and butanes are also coincident with these main two methane seepage areas, indicating the methane is related to deeper thermogenic sources. Areas of anomalous methane concentrations dissolved in groundwater and methane from free gas in the groundwater from the 50-foot gravel aquifer are nearly coincident with the anomalous areas where ethane, propane and butanes was found in the soil gases. The coincidence of anomalous soil gas and ground water data further confirms that the methane is from a thermogenic source, which must lie beneath the gravel aquifer.

Evaluation of available Pico gas well data reported in the April 17, 2000 report, indicated that the source of the anomalous thermogenic methane was most likely from shallow natural gas within the Upper Pliocene Pico Formation. The presence of gas in these shallow natural gas sands was established from available driller's logs, and by the fact that the University City Syndicate Inc. LTD #1 well blew out and produced 5 million cubic feet of gas per day while drilling at approximately 1830 feet. In addition, the El Segundo field, which lies on the same geologic trend as Playa del Rey, produced over 23 billion cubic feet of dry gas from the Pico sands (Cordova, 1963; Wright, 1991). The chemical and isotopic composition of the El Segundo dry gases lie very close to those observed in the Playa Vista gravel monitor wells (Dennis Coleman, 2000, private communication). Coleman's isotope data from these El Segundo samples are listed in Table 5 for comparison with the soil gas and monitor well data.

The Playa del Rey Oil Field, and now Southern California Gas Storage Field lies immediately to the west of Lincoln Blvd. (Barton, 1931, Hodges, 1944 and Riegle, 1953). In order to determine whether or not this gas storage field had contributed as a source, ETI had suggested that additional studies needed to be conducted (ETI 1st and 2nd Progress Reports, 1999). The most important study required was to sample and analyze several of the gas storage wells from the field for comparison with the Playa Vista seepage anomalies, and the second most important study was to conduct a soil gas survey over the storage field. Nine of the gas storage and observation wells were sampled on September 5, 2000 by CDM (observed and assisted by ETI) and analyzed by Isotech Laboratory. A comparison of this chemical and isotopic data with the surface macroseeps and with the gas data from the Ballona gravel monitor wells has demonstrated that the gas storage wells are isotopically and chemically different, and cannot be the source of the gases found in the surface macroseeps and in the Ballona gravel monitor wells.

1.3 Scope of Work

A regional soil gas survey was recommended in the first progress report issued on June 18, 1999, and was repeated in every subsequent report, including the April 17, 2000 report. This important objective was finally completed in January 2001. Including all of the data from the first two soil gas surveys completed in 1999-2000, a total of 1621 sites were used to construct a set of regional soil gas maps over the entire Phase 1 and Phase 2 areas of the planned 1087 acre Playa Vista Development. Soil gas samples for the regional data set were again collected at four-foot depths by Scientific Geochemical Services from Casper, Wyoming and analyzed by Microseeps Laboratory in Pittsburgh, Pennsylvania. Soil gas collection and laboratory analysis procedures are contained in Appendix A (see also ETI April, 17, 2000) for reference. Hydrogen sulfide (H2S) was again measured in the field on soil gas samples using a Jerome 631-X instrument, manufactured by Arizona Instruments. Laboratory analyses of the light hydrocarbons, permanent gases, BTEX and H2S are included in Tables 1, 2, 3 and 4 and individual component contour maps are shown in Plates 2 through 10. Concentrations of methane, ethane, propane, and butanes with detection limits of approximately 10 ppbv and BTEX at 70 ppbv are reported.

The additional regional soil gas sites collected by ETI are plotted in black on Plate 1, along with the soil gas data from the first two surveys. All soil gas sample sites for all three data sets were surveyed by Psomas & Associates. Although a 100-foot grid spacing was recommended by ETI, only the Phase 1 areas were sampled on this spacing, except in areas of recent surcharge or existing buildings. At the insistence of Playa Vista, the Phase 2 areas were sampled on a 300-foot grid spacing within Areas A, B, C, and D that had been sited for construction, and on a 500-foot grid spacing in the wetland portion of

Area B. These variations in sample spacing are clearly shown on Plate 1. A high water table in the western part of the marshy area precluded sampling a large portion of this area. Additional detail on a 100-foot grid was later added between November 2000 and January 2001 around the sites in the Phase 2 areas where methane concentrations exceeded 1000 ppmv, and around some of the storage/observation wells of the Playa del Rey Gas Storage Field.

In addition to soil gases, free gas samples were collected from bubbling seeps located along Centinela Creek near the confluence with Ballona Channel and from the riparian wetlands corridor that lies just north of the south bluffs. These bubbling macroseeps are also plotted on Plate 1 with the soil gas data. Three individual seep samples, denoted as A, B and C, were collected from Centinela Creek by Walt Merschat (SGS) and Paul Witherspoon (LADBS Consultant) using an inverted funnel on October 20, 2000.

Another area of strong seepage where gas bubbles through water lies within the riparian wetlands corridor that runs east-west along Teal Street just north of the bluffs. A macroseep gas sample (denoted as seep 1, see Plate 1) was collected on March 16, 2001 just south of soil gas site 817 from this riparian wetlands corridor. Within the wetland corridor several additional macroseeps were observed. This wetland area was not sampled during the earlier Phase 1 soil gas surveys because the area was off-limits for surface access. Additional survey data should be gathered throughout this wetland corridor in order to properly complete this regional assessment.

Data from these bubbling macroseeps was analyzed by Isotech Labs and has been compared with the previous isotope data collected and analyzed in 1993 by Global Geochemistry Labs. Seeps analyzed by Global Geochemistry were reported to have been collected near the confluence of the Centinela and Ballona channels, although no site location map exists for these samples collected by Global. Comparison of these two independent data sets shows that they are nearly identical in composition and suggests that the A, B, C seeps are probably the same seeps previously collected by Global.

Several additional bubbling seeps that have not been sampled were also noted along Centinela Creek during the October 20, 2000 reconnaissance. The locations of all of the seeps observed are shown on Plate 1. Because of accessibility, these other seeps were not sampled during this reconnaissance survey. Chemical and isotopic data should be collected from these additional seeps.

Advective gas flows were observed by means of visual observations made after flooding rains in the vicinity of most of the large magnitude soil gas anomalies. A series of shallow trenches and very shallow (5 to 10 foot deep) 24-inch diameter monitor wells were constructed in these areas for observation of the gas flux from these observation stations. More than 120 geoprobe Cone Penetrameter Tests (CPT boreholes) were installed in the vicinity of these active gas seeps by CDM working with LADBS consultant Dr. Gary Robbins in an attempt to vent the gas pockets contained within the upper 50 feet of sediments, and in particular near the top of the Ballona gravels. Summary data from these boreholes are listed in Table 7. The methodology developed for this testing is given in Appendix C.

In an attempt to improve the placement of these vent and monitor wells, additional infill soil gas samples were collected within the main seepage area located in area 49104-01. The data was collected using the exact same soil gas collection methods using ETI's four foot soil gas probe, however, in order to expedite turnaround and decision making the data was run in the field using a MTI field-portable gas chromatograph. This instrument has the ability to detect only methane, ethane and carbon dioxide, with detection limits of 10 ppmv for methane and ethane and 0.01% for CO_2. This data was used only for defining the variation of gas seepage anomalies within the 01 area where the largest macroseeps exist. All data within the calibration range of this instrument (i.e. 10 PPMV to 100%) are essentially of the same quality as the laboratory data. However, below the detection limit of 10 PPMV the field-screening data is bottom truncated. A few of these samples were analyzed in a laboratory GC with lower-level detection limits to verify the quality of this data. None of the infill samples were field screened for H2S because no H2S was found to be associated with the deeper methane sources. H2S is clearly derived from surficial sources, and although it is a nuisance, it is not a deep source gas. A total of 303 infill soil gas samples were collected. This data is listed in Table 8 and site locations are plotted in Plate 12. Contour maps for methane, ethane and carbon dioxide are plotted on Plates 13, 14 and 15.

2.0 RESULTS AND INTERPRETATIONS

2.1 Soil Gas Methane

The concentration of methane in soil gas (Table 1, Plate 2) is highly variable over the survey area. Values fall within the interval from background (<2 ppmv) to over 900,000 ppmv. The highest contour values shown on the methane map (Plate 2) are the upper explosive limit 150,000 ppmv (15%) and 25% of the lower explosive limit 12, 500 ppmv (1.25%). These contour values distinguish areas where the concentration is above these two thresholds. These two thresholds are commonly used to define areas of greater concern, and were selected for this reason. However, it should be noted that these values are significantly below the highest values that lie between 25 to 98%. The lower values for contours on Plate 2 delineate the edges of the largest magnitude seeps. Such large contour cuts for methane emphasizes the large contrast with background areas, where no macroseeps even close to these thresholds have been found.

Large areas of seeps with anomalous methane concentrations (greater than 12,500 ppmv) are clustered in two main areas (Plate 2). One of these extends about 900 feet in the western part of Tract 49104-01. The second methane anomaly, which is more than 1000 feet long, is in the southern part of Tract 49104-02. The total area of anomalous methane concentrations (greater than 12,500 ppmv) covers only about 1.5% of the entire 1087 acre Playa Vista site. Smaller methane anomalies occur in the vicinity of, and north of these two large methane anomaly areas. Contoured anomalies appear to be controlled by some sort of subsurface geological influence that defines three principal directions, with azimuths of N 65 E, N 7 W, and N 62 W, suggesting some sort of subsurface geological control.

As shown by Plate 2, much lower methane concentrations were found in the Phase 2 (A, B and C) areas. Soil gas values within these three areas are more typical of normal soil gas concentrations, (Jones et al. 2000). Slightly lower threshold contour values on the second methane contour map (see Plate 2a) outline the much lower level soil gas anomalies observed within these three areas. On Plate 2a the areas of highest methane concentrations are truncated to only 10,000 ppmv (1%), which only slightly enlarges the most anomalous areas, again emphasizing the contrast between the background areas and these very large magnitudes associated with the areas containing the macroseeps. In order to show contrast within the background areas typical of areas A, B and C the contour values used were reduced to values ranging from 10 to only 2 ppmv. The lower contours used were 10, 8, 6, 4 and 2 ppmv. Both Plates 2 and 2a show the enormous contrast in magnitudes of normal soil gas concentrations measured in the background areas with those of the two main macroseep areas.

Soil gas concentrations within the 25% to 90% range at a depth of only four feet generally cannot be sustained without advective gas flow from depth. Methane is too volatile to be sustained at these levels without a source. Advective gas flow has been confirmed within the vicinity of most of the large magnitude seeps by means of visual observations made after flooding rains, or in areas which are permanently water covered, or in water saturated areas that overlap the largest soil gas seeps.

Attention on the Product 700 area (see Figure 4) was initially focused by the observation of many bubbling macroseeps noted after heavy rains (Mike Reader personal communication, January, 2000). In order to evaluate this area of potential macroseeps under dry conditions, which prevailed when this work started, a series of shallow trenches (Figure 5) and very shallow (5 to 10 foot deep) 24-inch diameter monitor wells (Figure 6, 7) were constructed. Figure 4 shows the location of this construction area, along with the trench, flux and deep venting wells. The symbol T was used to denote a shallow trench and FW (flux well) was used to denote a 24-inch monitor well. Coarse gravel was placed within the 24-inch FW wells and a 24-inch PVC casing was used to cap these locations, which were installed in order to observe gas flux from some of the most anomalous soil gas areas. The trenches were dug only 36 inches deep using a backhoe and were then filled with water for gas bubble observations, since they did not penetrate the ground water table which was about 5 to 7 feet below surface in this area. The 24-inch FW wells did penetrate the ground water table adequately to allow observation for gas bubbles. Initial observations made before they were cased showed that the gases entered these flux wells more from the sides than from their bottoms, indicating that they did not intersect natural, vertical migration pathways, and would, in all likelihood stop venting when the shallow sands were depleted. They did, however, amply illustrate the tremendous gas charging of the shallow subsurface within the areas containing the larger methane concentrations.

Data from the analyses of gas samples collected by volume displacement on November 30, 2000 from the first two trench wells, T-1 and T-2 are listed in Table 5. As shown, methane ranges from 62.90% to 76.16%. These concentrations are in the same general range as the soil gases collected from four foot soil gas probes from this area. These trench samples were collected by volume displacement, with the venting gases displacing the water in the inverted bottles within seconds. Thus the bottles must contain 100% gas from the shallow sands, and could not have picked up any significant volume of air from the atmosphere during the sample collection. The presence of 23 to 36% air in these samples requires that the air had to be contained in the soil gas with the methane discharging from the shallow sands. The presence of air within such shallow gas filled sands would provide ideal conditions for oxidation of the hydrocarbon gases in-situ. The methane isotopes for these two samples are nearly identical at -59.30 and -59.28 parts per mil with respect to the PDB standard, and fit right in with the isotope values noted within the 50-foot Ballona gravel monitor wells. Thus, the methane contained in the gravel aquifer does not appear to have been further oxidized within this very shallow sand.

The ethane isotopes, on the other hand, are the heaviest values found on the site, out of over 80 individual analyses. The ethane from these two trenches have the very heaviest ethane isotope values found to date, of -17.94 to -13.62 parts per mil with respect to the PDB standard, suggesting very degraded (oxidized) ethane. In contrast, the ethane in the 50-foot deep Ballona gravel monitor wells is much lighter, although it is still fairly heavy when compared to typical reservoir values, which normally range from about -29 to -32 parts per mil. The monitor well gas has ethane isotopes ranging from about -18 to -21 parts per mil, and is also unusual. Such heavy ethane isotope values in the trench samples would suggest severe degradation, either very near the surface, or somewhere along the migration pathway taken by these gas seeps. Because of the large free gas discharge rates (liters per minute) from these two shallow trenches it would be impossible for the air to be a sampling artifact. This air must have naturally diffused into the shallow sediments where it mixed with the methane gas from depth, and was then discharged with the seepage gases when the surface cover was removed by digging and installing the trenches.

In October/November of 1999 very large magnitude soil gas anomalies were initially found at sites S77 and S78 within area 49104-03. The methane and ethane concentrations and stable carbon isotopes of these gases were as follows:

Site	Methane %	Ethane ppmv	Methane Delta C12/13 parts per mil	Ethane Delta C 12/13 parts per mil
S77	70.66	2400	-58.74	-20.57

S78	56.32	2900	-52.46	-19.92

These concentrations and isotope values are fairly close to those observed in the gravel monitor well MMW77 that underlies these soil gas anomalies (see Plate 11 from the ETI April 17, 2000 report). The reported values in this well were:

Site	Methane %	Ethane ppmv	Methane Delta C12/13 parts per mil	Ethane Delta C 12/13 parts per mil
MMW77	89.02	3400	-59.95	-20.49

Both compositional and isotopically the larger soil gas sample (S77) is very similar to the dissolved gases in the gravel aquifer 50 feet below the surface. The CO2 soil gas values for these two samples are 5.56 and 16.65%, indicating an increased level of degradation for S78 over S77. This degradation appears in both the methane and ethane isotopes, but is clearly greater for S78.

In August 2000 a second survey was conducted over this same area following the installation of the concrete pilings for construction of the foundation of the Fountain Park Apartments (Concentration Of C1-C4 Gaseous Hydrocarbons, BTEX Aromatic Hydrocarbons, Carbon Dioxide And Hydrogen Sulfide In Soil Gas At Tract-03 Beneath Fountain Park Apartments Following Installation Of Concrete Pilings, March 14, 2001). The anomaly defined by these two sites (S77 and S78) was used as a test control area, during the August 2000 survey because it is located outside of the apartments, and therefore outside of the influence of the concrete piles. On resurvey, the 75% magnitudes had changed, values that had been as high as 75% now ranged only to 25%. Two of the largest magnitude sites found within this anomaly on the second survey were 5011 and 5018. The measured concentrations for these sites on resurvey were:

Site	Methane %	Ethane ppmv	Methane Delta C12/13 parts per mil	Ethane Delta C 12/13 parts per mil
5011	25.33	1100	-51.63	-16.83
5018	10.16	400	-45.09	-14.37

Because of somewhat drier conditions, this reduction in magnitude was suggested to be related to the reduction in moisture content increasing permeability of the near-surface vadose zone. In spite of this reduction in relative magnitude, the presence of advective flow at this location was later confirmed using the EPA flux chamber technology on March 16, 2001. Measured gas flux ranging as high as 9313 mg/cubic meter was reported (Sepich Associates, Soil Gas Investigation for 5457 S. Brisa St., March 29, 2001).

As with the trench samples, it is apparent that the gases at depth in the gravel aquifer are being altered by oxidation effects that occur whenever these gases migrate to the near-surface. These examples demonstrate that both the methane and ethane isotopes can be altered by biological degradation. It is possible that changes in these isotopes, which are related to exposure to oxygen sources, might be useful for separating gases that migrate directly from the gravel aquifer from those that have an appreciable residence time in the very near-surface where the degradation changes mainly occur. This would require very discrete and controlled samples collection from various depths.

In January of 2001 a very large rain occurred which flooded the surface, allowing the visual observation of numerous additional macroseeps, which could be located from their bubble trains. Over 140 stakes were placed in the southern portion of the Product 700 pit in an attempt to mark all of the individual bubble trains before the staking crew ran out of stakes. The largest magnitude natural macroseep (Figure 8, 9 and 10) found by this method within the Product 700 pit was gauged to vent about 9 liters/minute of free gas. Observation well FW-09 was installed at this location by digging a 24-inch 10-foot deep hole, which was cased with 24-inch PVC pipe and used as an additional flux observation station. Two free gas samples were collected from this well on January 24, 2000 and sent to Isotech Labs for chemical and isotopic analysis (see Table 5). In sharp contrast to the two trench samples, these free gas samples were found to contain nearly 100% methane, 97.68% and 97.66%. The carbon dioxide levels are 0.72% and o.67%, respectively, providing nearly 99% of the total gas when added to the methane. Ethane and propane are 0.34% and approximately 0.0046% (3400 and 46 ppmv). Ethane isotopes are -20.08 and -20.01 parts per mil with respect to the PDB standard. Comparison with the 50-foot Ballona gravel monitor wells shows that these gases are nearly identical to the gases contained within the aquifer at depth. Clearly these samples must represent direct vertical discharge from the Ballona gravel aquifer without any additional degradation related to residence within the upper 50 feet of sediments. This certainly suggests that the trench gas samples are likely degraded very near the surface.

Numerous geoprobe Cone Penetrameter Tests (CPT boreholes) were installed by CDM working with LADBS consultant Dr. Gary Robbins in an attempt to install vent wells in the 50-foot Ballona gravel aquifer. Figures 11, 12, 13, 14 and 15 illustrate the process which is described in detail in Appendix C. The first test performed was very successful. A CPT borehole was pushed to 66 feet below surface at TV-1 near soil gas site 207. When the probe rods were pulled up to 60 feet subsurface, the well discharged about one gallon of water and then flowed free gas at the rate of 10 liter/minute for 69 hours, until destroyed in an unsuccessful attempt to replace the CPT probe rods with a monitor well. Most of these attempts to install gas vent wells failed because the shallow silts at the top of the 50-foot gravels were too unconsolidated to remain open. The wells were clogged by unconsolidated clastic sediment and were invaded by water, which shut off the gas flow. Many unsuccessful attempts were made by CDM to solve the mechanical production problems, with 10 monitor wells installed and 122 CPT borehole attempts. Gas production was too sporadic and unpredictable to be effective. Free gas is generally present somewhere in the upper 50 feet of sediments within the areas having the largest methane soil gases. However, this free gas is not easily found, nor vented from these unconsolidated sediments. Gas could not even be successfully vented from the vicinity of some of the largest macroseep areas. For example, three of these potential vent wells were drilled within 10 feet of FW-09, on three sides, none of which were capable of venting gas from the gravel aquifer.

A backhoe accident during February knocked over the casing of flux well FW-09 and filled the hole with gravel. An attempt was made to dig out the gravel, which resulted in reducing the gas flow to about 2 liters/minute (Figure 16). As of May 16, 2000 this FW-09 observation well has continued to flow gas, unabated by the attempts to vent the gases from the 50-foot Ballona gravel aquifer (see Figure 17). This observation well, and many other tests (over 120 attempts were made to install vent wells in the gravel aquifer) have yielded similar results. These tests suggest that the gas contained within the 50-foot Ballona gravel aquifer provides a vertical pathway for the gas, but is not an intermediate source for the macroseep vents, at least not for the largest soil gas anomalies. The gravel serves as a transmission zone, but unfortunately does not appear to provide a significant intermediate reservoir that serves as a source for the four-foot deep near-surface soil gases. These observations suggest that the main gas source must lie below the Ballona gravels.

Numerous surface flux tests (Figures 18, 19, 20 and 21) were also conducted using an EPA flux chamber over portions of the methane anomaly in Tract 49104-01 by CDM (assisted by Dr. C. E. Schmidt) during the first quarter of 2001 (March 6, 2001 CDM letter report to David Nelson entitled "Methane Surface Flux Emissions for Product 700 Area, Lots 58 and 59 in Tract 49104-01"). Methane gas flux rates as high as 23,000 CFG/D were conservatively estimated to be present over a 44,000 square foot area within the Product 700 area, where the very largest magnitude seeps have been found. These observations, together with the observed elevated methane soil gas concentrations shown by Plates 2 and 2a clearly classify the largest, and most anomalous methane contours as surface methane gas macroseeps.

2.2 Soil Gas Ethane, Propane, and Butanes

The presence of detectable concentrations of methane homologs (ethane, propane, iso-butane, and normal-butane) illustrated on Plates 3, 4, 5, and 6, respectively, have similar distributions as methane, proving that a major portion of the methane is from a thermogenic origin. Distinctive compositional ratios for ethane/propane and iso-butane/normal-butane confirm that the four foot deep soil gases are directly related to deeper gases measured in the 50-foot Ballona gravel aquifer monitor wells. An iso/normal butane ratio greater than one generally indicates an immature source (such as the Pico sands), however this ratio has also been shown to increase during oxidation of these hydrocarbons (Coleman et al. 1981, James, 1983, 1984 and 1990). Additional deeper gas source information from the abandoned wells are required to determine the controls on these ratios.

As with methane, contour intervals were chosen in order to emphasize the larger macroseeps in Plates 3 to 6. Lower values were selected for ethane and propane so that the much lower concentrations within these background areas are defined. This is required to properly illustrate the gas concentrations typical of areas A, B and C. (Plates, 3a and 4a, are contoured in ppbv). Soil gas data measured at four feet provides a very cost-effective method for finding macroseeps over such a large regional area, however, soil gas cannot be used exclusively for evaluation. As shown (ETI April 17, 2000 report), the four foot soil gas data does aid significantly in defining appropriate locations for the deeper monitor wells, however, monitor wells are also essential for proper due diligence in order to evaluate the Ballona gravels for their gas content. If no significant gas is found in either the soil gas or the monitor wells, then the area can be declared as completely safe from charging by deeper gas sources. The requirement for monitor wells is particularly important in this case because of the wide regional soil gas spacing used to survey these three areas. With this spacing anomalies can be missed, and will at best be poorly defined. When monitor wells are used with soil gas, then these two independent data sets can provide a reasonably good compromise for properly defining subsurface gas anomalies, and even for suggesting their potential migration pathways.

Anomalies from these lower contour intervals shown on Plates 2a, 3a and 4a were used to pick locations for the 50-foot deep Ballona gravel monitor wells that are recommended for due diligence in completing this regional assessment. At a minimum, five monitor well locations have been selected for area A, B and C at soil gas sites 6002, 6041, 7058, 8008 and 8022. These five sites were selected because they have low grade soil gas anomalies in methane, ethane and propane. A very important distinction is to note that the methane, ethane, and propane magnitudes, and the methane/ethane and ethane/propane ratios for these selected sites all exhibit oil-type rather than gas-type signatures, in sharp contrast with the much larger methane anomalies located east of Lincoln. These are (in ppbv):

Site	Methane	Ethane	Propane	C1/C2	C2/C3
6002	4000	570	230	7.02	2.48
6041	4100	520	230	7.89	2.26
7058	7000	2140	1700	3.27	1.26
8008	5300	400	170	13.25	2.35
8022	5400	590	270	9.15	2.19

Methane/ethane and ethane/propane ratios for the macroseeps in area 49104-01 are significantly gassier, typically ranging upwards of 250 for C1/C2 and 65 for C2/C3. Two of the largest magnitude seeps from sites 207 and 211 (both of which had blowouts during the installation of the monitor wells) are listed below in (ppmv):Methane/ethane and ethane/propane ratios for the macroseeps in area 49104-01 are significantly gassier, typically ranging upwards of 250 for C1/C2 and 65 for C2/C3. Two of the largest magnitude seeps from sites 207 and 211 (both of which had blowouts during the installation of the monitor wells) are listed below in (ppmv):

Site	Methane	Ethane	Propane	C1/C2	C2/C3
207	798800	3234	49	247	66
211	891543	3188	43	280	74

Although magnitudes can change rapidly, the compositions of soil gas and monitor well data are much more stable, allowing the definition of groups of data having common compositions that can then be related to a specific source.

Empirical compositional classifications derived from previous soil gas surveys conducted over producing fields have been established (Jones & Drozd, 1983). Typical ratios for soil gas or produced gases for different types of hydrocarbon deposits are:

Methane/Ethane Ratio	Ethane/Propane Ratio	Composition
> 100	> 5.0	Dry Gas
20 - 100	3.5 - 5.0	Gas
10 - 20	2.5 - 3.5	Oil and Gas/Intermediate
5 - 10	2.0 - 2.5	Oil
< 5	< 2.0	Heavy Oil/Degraded

Comparison of the above low-grade soil gas anomalies with these general empirical classifications clearly shows that the low level microseeps typical of these three areas are related to oilier sources, as might be expected for soil gas data collected directly over an oil field.

If the proposed monitor wells agree with the soil gas samples and show that there is no appreciable gas contained in the gravel aquifer in the A, B and C Phase 2 areas, then there would be no need for methane mitigation for buildings constructed within these areas. However, regardless of the lack of subsurface gas sources within these areas, no building should be constructed over any of the active or abandoned gas storage wells or the gas storage field. DOGGR regulations should be followed in these areas.

2.3 Soil Gas Hydrogen Sulfide

Hydrogen sulfide in detectable concentrations (Table 3, Plate 7) in the near-surface soils are very localized in areal extent with respect to the entire Playa Vista Development. Concentrations ranged from non-detect to 41 ppmv. Anomalous areas of hydrogen sulfide, with the greatest areal extent, are generally coincident with the western methane anomaly in Tract 49104-01 described above. Only 12 samples exceed 1 ppmv in concentration, and all but one of these samples lie within area 49104-01 where the largest macroseeps occur. The second largest anomaly of 27 ppmv does occur in association with a methane level of 5.33 % at site 9349 in area 49104-04. Ethane and propane anomalies are also present in the vicinity of this site, but are not coincident with the methane and hydrogen sulfide at this location. A tighter grid spacing of soil gas should be applied in order to better define this hydrogen sulfide anomaly, followed by installing at least one monitor well for sampling of the Ballona aquifer. Two existing monitor wells, C-23 and C-28 should also be sampled from this general area for background control.

Although hydrogen sulfide has often been observed within archeological trenches, an evaluation of the many boring logs drilled and sampled on this site have shown that hydrogen sulfide does not occur systematically in the boreholes, and almost always within natural or shallow fill, such as La Brea sediments. The main source of the hydrogen sulfide appears to be from shallow recent swamp deposits and perhaps from the fill brought to the site from the La Brea area during the Hughes operations. It is very significant to note that the observations of H2S in the soil gas collected near the surface always occurs with significant methane anomalies. The H2S that was observed during the blowouts from installing boreholes or monitor wells was from isolated subsurface pockets of gas that was effectively trapped in the shallow subsurface. When the borehole or monitor well opened this isolated pocket the gases discharged quickly. Long term venting from the same monitor wells that recorded blowouts did not continue to discharge additional H2S. Apparently the H2S was then diluted by additional gas from deeper depths, which did continue to flow.

During the installation and monitoring of the methane vent wells, CDM and ETI/LADBS consultants inspected every vent well for H2S odors. In no cases were H2S odors detected in any long term vent wells, in spite of the fact that significant levels of methane gas was being vented from these same wells. The most important observation made with respect to hydrogen sulfide, is that it has not been detected in near-surface soils, except in the areas of advective methane seeps. Thus, outside of high-volume methane discharge areas, no hydrogen sulfide anomalies have been found in the near-surface soil gas.

Within the current density of sampling, it appears that all of the major methane and H2S discharge areas have been reasonably well defined. Closer-detailed sampling within the main methane anomaly areas has demonstrated that there are some very localized gas vents that can range from inches to 10's of feet in dimension, however, such vents are not usually isolated, with no other vents nearby. To improve due diligence ETI has requested that 50-foot centers be used to resurvey underneath planned building footprints before the foundation is laid. This is very important within areas having numerous advective vents, because this higher density soil gas data can aid in defining the areas requiring additional vent risers. However, in background areas this is probably not necessary. A combination of soil gas and monitor well data can determine the likelyihood of finding any advective vents. If neither is anomalous, then it is reasonably safe to conclude that the assessment surveys are adequate.

Another safeguard for insuring that the current soil gas grids have effectively found most of the dangerous vents is to measure all of the biogenic gases that are generated by subsurface contamination. As described, below, carbon dioxide provides another potential safety factor for helping to define areas containing significant subsurface contamination.

2.4 Soil Gas Carbon Dioxide

Although carbon dioxide is generated by the biodegradation of all types of organic materials and must be used with caution in soil gas investigations, the presence of a concentrated petroleum source such as gasoline, diesel, kerosene, or even methane can cause a concentrated buildup of carbon dioxide in the subsurface. The average concentration of carbon dioxide in ambient air is only 0.03 percent. Biodegradation of typical soil organic matter generally yields carbon dioxide concentrations between 0.2 to 3-5 percent. Higher concentrations of carbon dioxide measured in various soil vapor samples collected in the vicinity of subsurface petroleum contamination often yields values as high as 5 to 30 percent, an indication that biodegradation is significantly enhanced. Such an enhancement of CO2 is almost always found within an area containing a significant contaminant plume.

Bacteria consume hydrocarbons and generate carbon dioxide under aerobic conditions and methane under anaerobic conditions. Carbon dioxide and methane generated by this process are commonly the largest magnitude components in the soil gas mixture. In general, the longer the hydrocarbon source is present in the subsurface environment, the larger are the concentrations of these biogenically produced gases. Carbon dioxide also has the advantage that it is generated near the edges of the contamination because that is where the proper mixture of oxygen and organic contamination can be found. Within the heart of the contamination, the generation of carbon dioxide can be significantly reduced because of a lack of available oxygen. Thus an area containing high methane and low CO2 is likely at the heart of a macroseep and an area containing moderate methane with large CO2 is probably near the edge of a contaminate plume. In contrast, areas containing neither methane nor CO2 is a true background area. Given this relationship, it can be very useful to measure these two biogenic gases (methane and carbon dioxide) and to use their contrasting behavior to help define the location of the more significant contaminant plumes.

Carbon dioxide (CO_2) concentrations at PVD (Table 4, Plate 8) range from background levels of less than 3% to greater than 30%. These results indicate that significant aerobic degradation is occurring at specific locations on this site. The generation of CO_2 by this process is very rapid and can occur only where there is sufficient oxygen to support the consumption of the hydrocarbon contaminant source. Generally, as noted above, the areas of anomalous CO_2 occur as halos around the areas of advective methane seeps (methane anomalies) where oxidation consumes the available oxygen. Within an advective seep the hydrocarbon source may use up the available oxygen, causing the generation of CO_2 to cease. Thus areas of low CO_2 concentrations that are coincident with anomalous methane concentrations can define the seepage areas containing the most rapid rates of advection, and conversely areas where the methane and CO_2 are both anomalous may indicate more moderate vertical migration rates where the methane flux is in balance with the diffusion influx of oxygen from the air. Areas where both methane and CO_2 are near background would confirm areas where there is no hydrocarbon seepage (i.e., true background).

The map of CO_2 values shown by Plate 8 was generated in order to use these relationships for due diligence in interpreting this regional soil gas data. In order to avoid mapping background variations the CO_2 contour values were set at 5, 7.5 and 10%. With these contour values, areas A, B and C have almost no CO_2 anomalies. Most high values, greater than 15 to 20%, particularly those that occupy more than one adjacent site, occur mainly within the main methane seepage areas in Tract 49104-01. The highest value of 32.43% occurs at site 9774 and is confirmed by low magnitude, more oily light hydrocarbons. At this site the C2/C3 ratio is less than one (0.95) and the C1/C2 ratio is nearly 10,000 (9286), suggestive of some minor oily contamination. The majority of the largest magnitude CO_2 sites (those greater than 15 to 25%) appear to occur near the edges of the main advective seeps. For example, sites 275, 267, 253, 242 and 233 coincide with the southwestern edge of the highest methane anomaly centered on Product 700. Sites 203, 267, 253, 242 and 233 define the western extent of this big methane anomaly. Sites 188 and 193 contain an anomaly that sits right in a low area (hole) on the eastern edge of the methane anomaly.

Sites 207 and 211, which lie right in the heart of the Tract 49104-01 methane anomaly are typical of the largest soil gas seeps. A comparison with the monitor well data from these same two sites shows that the concentrations at four feet are comparable to those measured at 50 feet below surface, suggesting the presence of advective flow from the sources in the Ballona gravel aquifer at depth to the surface. Bubbling seeps, as discussed above in Section 2.1 under Soil Gas Methane provide visible evidence of this active migration. Methane values near 100% (80 and 89%) and CO_2 values ranging from 0.5 to 1% (0.82 and 0.66%) for gas at these two sites support the interpretation of gas moving through the upper 50 feet of sediments without dilution or alteration.

In contrast to the very largest flux sites, there are many places where a moderate methane anomaly exists that is coincident with a CO_2 anomaly. These sites, such as, (734, 735) and (802, 803, 804, 805) and (811, 812, 813, 814), just to point out three specific cases, show locations where it is likely that the CO_2 is generated directly from the center of the methane seep (which is the food source). This would indicate that the flux of methane in these areas is slow enough to allow oxygen from the air to diffuse into the upper meter of soil and be used to generate these coincident methane/CO_2 anomalies. Examination of Plates 2 and 8 show that there are many such coincident anomalies.

No close detail sampling has been done on the eastern methane anomaly that occurs in Tract 49104-02 (Plate 2) of Phase 1. This large anomaly has a definite east-west orientation, and extends from the Phase 1, Tract 49104-02 area into area D of Phase 2. This Phase 2 area must be evaluated simultaneously with the western portion of the anomaly that lies within the Phase 1 area. Both the soil gas and the monitor wells from this anomaly exhibit a slightly oilier signature than the main 01 anomaly. This change in composition as compared to the monitor wells in area 49104-01 is very minor, much like the changes shown by the Centinela Creek macroseep bubbles. In both cases these changes are probably reflecting separate Pico reservoirs at depth. Low CO2 with high methane on the western portion of this anomaly suggests some advective flow, whereas the eastern portion (in area D) has large CO2, accompanied by moderately large methane, suggesting a lower methane flux rate, with considerably more oxidation occurring near the surface.

Where both methane (and it's homologs, ethane, propane and butanes) are absent and there is no CO2, one may be fairly confident that there is no organic contamination in the soil at that location. CO2 is always generated by shallow diagenesis because the bacterial filter is everywhere and oxygen is always present in shallow vadose zone soils and ground water near the edges of any subsurface contaminant plume. Large CO2 magnitudes always signify the presence of shallow oxidation of an organic contaminant. The tendency for CO2 to occur in larger concentrations near the edge of the oxidizing organic matter provides an advantage when coupled with direct detection of the organic contaminant, such as methane in this case. Adding CO2 analyses increases the likelyhood of finding the subsurface contaminant plume. Thus the CO2 is very valuable, particularly when the soil gas grid has been undersampled as much as it has by using 300 foot centers within areas A, C and portions of area D of Phase 2. Area B is so under sampled that no assurances regarding the detection of gas anomalies can be made. However, a nearly complete lack of large CO2 or methane anomalies within areas A and C suggests that no major contaminated areas have been missed in those portions that have been surveyed, in spite of the wide spacing used for the soil gas survey.

2.5 Soil Gas BTEX (benzene, toluene, ethylbenzene and xylenes)

Concentrations of benzene, toluene and total xylenes (Table 2) are illustrated in Plates 9 and 10, respectively. There is, effectively, no benzene present in the vadose zone soil gases. Toluene concentrations range from non-detect to 6.4 ppmv while total xylenes concentrations range from non-detect to 6.7 ppmv. Toluene and total xylenes in detectable concentrations in the near-surface soils are very localized in areal extent with respect to the entire Playa Vista Development. As with hydrogen sulfide, anomalous areas of toluene and total xylenes, with the greatest areal extent, are generally coincident with methane anomalies in Tract 01 and Tract 02 described above. Toluene and total xylenes are generally not detected in near-surface soils except in the areas of advective methane seeps. The probable source of the toluene and total xylenes is from volatilization of the fill brought to the site from the La Brea area during the Hughes operations. The anomalous areas of toluene and total xylenes coincide with areas in which zones of the La Brea fill were described in borings. Water samples from the 50-foot gravel aquifer (MW 1 through MW 5) were collected by CDM from the monitor wells in Tract 03 and analyzed for BTEX. As shown by Table 6, the BTEX levels were below detection limits. Toluene and total xylenes are not detected at the surface, however, except in areas of advective methane flow.

It is interesting to note that the largest toluene and xylene anomalies appear to be associated with the eastern methane anomaly (sites 921 to 914) and with the more central methane anomalies (sites centered near 735, 813 and 803). These groups of methane anomalies are the oiliest (they have the largest ethanes, propanes and butanes). Additional sampling and testing of the existing monitor wells needs to be done, plus the installation of several additional new monitor wells. Proposed locations for the new wells are at soil gas sites 970, 9006, 9726, 9845, 9848, 9830, 9787, 9050 and 9739.

Formal requests for the installation, sampling and analysis of these additional monitor wells was made to Playa Vista through LADBS on January 24, 2000 when these regional maps were formally presented during a joint technical meeting of the Playa Vista and ETI/LADBS consultants. Final interpretation of this soil gas data and this new monitor well data needs to be completed and this report rewritten whenever data from these new, additional monitor wells is available. Due diligence on this regional assessment report will not be done until this final task is completed.

2.6 Centinela Creek Bubbling Seep Isotope Results

Gas seeps containing ethane collected and analyzed in 1993 from the general area of the confluence of the Ballona and Centinela Creeks (Global Geochemistry, 1994, ETI, June 18, 1999 1st Progress Report). This data established the presence of advective flow macroseeps, which contained some ethane. These seeps have methane isotopic values that are very similar to those found and reported in the surface soil gases, and 50-foot Ballona gravel monitor wells by ETI in the April 17, 2000 report. A second reconnaissance along Centinela Creek, conducted on October 20, 2000 by Paul Witherspoon and Walt Merschat from SGS identified several bubbling seeps. These were noted and are mapped on Plate 1.

Three, free gas macroseeps were sampled from Centinela Creek at the area where the Global seeps were reported to have been collected. These three samples, denoted as A, B and C are plotted on Plate 12 along with the original Global macroseep samples and with the Ballona gravel monitor well data. Nine samples from the Southern California gas storage field (CDM, Sept. 5, 2000) and two gas samples from the El Segundo nonassociated, dry gas field are also plotted on Plate 12 for comparison with the Centinela Creek and Ballona gravel well samples. The two sets of Centinela Creek samples are similar. This Centinela Creek data establishes the compositional stability of this set of macroseeps and also confirms the presence of a significant pressure drive and volume required to keep these seeps active over at least seven years. The slightly different isotopic compositions of these samples from the Ballona gravel monitor wells supports the interpretation of deep "Pico" sources, which would be similar to one another, but would differ slightly from sand to sand because of source and migration dependent variations within the various Pico reservoirs.

The presence of these seeps also extends the area of known thermogenic seepage north, from the regional area surveyed to at least the confluence between Centinela and Ballona Creeks.

2.7 Riparian Wetlands Corridor Bubbling Seep Isotope Results

Another specific area of intense seepage has been found within the Riparian wetlands corridor just south of soil gas site 817 near Teal Street (Figure 22, 23). A free gas sample was collected by volume displacement directly from one of these bubbling macroseeps on March 16, 2001 and sent to Isotech Labs for analysis. This data is listed in Table 5 and plotted on Plate 11. The methane concentration was 94.93%, the CO_2 was 1.90%, typical of the CO_2 values measured in the Ballona gravel aquifer in monitor wells 803 and 813, which were 1.97 and 1.54%. The ethane and propane were 3800 and 130 ppmv. The methane isotope of -56.91 parts per thousand fits right in with the main group of monitor wells from this area. Monitor well 803 and 813 are more than 200 feet away from the important group of seeps. Interpretation of the gravel aquifer gases suggests that the gap between the eastern and western methane anomalies in this area was caused by under-sampling related to the fact that access to this area was restricted. A new monitor well should be installed at this location to check for ventable gas and to allow proper interpretation of both the soil gas and the associated Ballona gravel aquifer anomaly.

Visual observations made on March 16, 2000 along this wetland corridor also reveal several macroseep areas that have never been sampled. In fact, as noted above, this wetland area was not sampled during the earlier Phase 1 soil gas surveys because the area was off-limits for surface access. Additional survey data must be gathered throughout this wetland corridor in order to properly complete this regional assessment. There is no question that this under-sampled wetland corridor does contain significant subsurface methane potential, which has not been properly assessed.

Gases from these bubbling macroseeps have nearly the same composition as the soil gases and the gases from the Ballona gravel monitor wells. This strong similarity suggests a common origin for these thermogenic gases. The presence of bubbling macroseeps associated with the largest soil gas and monitor well anomalies also confirms the presence of advective, pressure driven gas seepage over both land and water covered areas. The chemical and isotopic compositions of these gases collected from soil, bubbling macroseeps, and gas-charged aquifers clearly belong to a family of dry nonassociated gases, which are not connected to the deep Playa del Rey oil field, or to the Southern California Gas Storage Field. Direct comparison with the nonassociated dry gas produced from the Pico Formation on strike to the south from the El Segundo Oil field strongly suggests that these gases have probably been derived from similar deep sources, such as the Pico sands at depth. The seepage gases would have migrated from these Pico reservoirs that lie beneath the Playa Vista site. Gas shows from the driller's logs from the abandoned exploration wells suggests that these gases likely originate from between 500 to 3000 feet below surface.

2.8 Infill Detail Soil Gas in Tract 49104-01

As noted above in section 2.1 under Soil Gas Methane, the attempts to find and vent gas pockets within the top of the Ballona gravels was not successful. The observations regarding the numerous advective gas seeps demonstrated the very high spatial variability of the gas vents. In order to improve the placement of vent and monitor wells additional infill soil gas samples were collected within the main seepage area located in area 49104-01. Data collection used ETI's four foot soil gas probe, and followed the same procedure as the regional data. However, in order to expedite turnaround and decision making most of the data was analyzed in the field using a MTI field-portable gas chromatograph. This instrument has the ability to detect only methane, ethane and carbon dioxide, with detection limits of 10 ppmv for methane and ethane and 0.01% for CO2. This data was used for better defining the local variation of gas seepage anomalies within the 01 area, where the largest macroseeps exist. All data within the calibration range of this instrument (i.e. 10 PPMV to 100%) are of the same quality as the laboratory data. However, below the detection limit of 10 PPMV the field-screening data is bottom truncated. A few of these samples were analyzed in a laboratory GC with lower-level detection limits to verify the quality of this data. None of these samples were field screened for H2S.

Contour maps for these three components are very similar to the regional maps, with two very important distinctions, one is that higher density sampling always reduces the areal size of the contoured anomalies because soil gas macro-vents are usually very limited in size. The second major distinction is the fact that this smaller estimate in the size of soil gas anomalies is usually accompanied by the presence of more individual (smaller sized) anomalies, resulting in increasing spatial variance. This is a very important concept because soil gas anomalies don't have to occupy a large aerial extent in order to provide a significant gas source under a building.

The best method for measuring the actual flux into the atmosphere would be to construct a large flux chamber that would cover the entire area of interest. This, or course is not practical, although the foundations of the buildings will become large flux chambers. The best alternative is to recognize that the earth also serves as a large flux chamber. When advective flow exists (driven by pressure), gas migrates toward the surface, enters the vadose zone and fills the permeable pathways with gas. A breakthrough into the atmosphere provides a pressure relief that acts to reduce lateral flow. Finding these breakthrough points is nearly impossible using EPA flux chambers because of the very small size of both the seeps and the chambers. The soil gas, on the other hand, offers a practical approach for finding these natural flux sites. This is because a natural equilibrium will be formed in which the gas flux from depth and the gas flux into the atmosphere must eventually balance. During this process a soil gas anomaly will form, taking it's shape from the permeability of the adjacent sediments. Thus the sediments act as a choke, allowing leakage whenever the pressure is large enough, but also providing a near-surface reservoir in the soil pore space that will always retain some of the migrating gas. When in balance with the atmosphere, the soil gas will have a concentration that must be the same as the gas that leaked into the atmosphere at the exit point of the seep. If the pressure is reduced below atmospheric then the soil gas can, and will become diluted with air if the earth gases are not recharged from depth. Thus sites having large atmospheric flux have to be associated with soil gas sites which also have large, essentially equivalent concentrations at the exit point of the seep into the atmosphere. Lateral migration, both by advection and diffusion, will always occur within the near vicinity of the vertical pathway, building a soil gas anomaly. This lateral gas migration creates a soil gas anomaly with a stable "flux footprint" and concentration which can be contoured in order to vector the direction from background toward the largest soil gas concentrations where the "flux pipes" must be located. By definition, then, these large magnitude soil gas sites must be the sources that control any advective seepage.

The application of a limited number of EPA flux chamber measurements without any guidance from the soil gas is a serious concern. Data from such a survey would have no value for predicting dangerous building sites, but could be misconstrued if used inadequately and incorrectly. The regional survey was conducted using 100 foot centers, which works very well for defining the main areas of concern. This spacing is, however, inadequate for placement of flux chambers. The reduction to 50 foot centers, with occasional infill, appears to provide a much better estimate of the actual size and shape of the individual soil gas anomalies, or "flux footprints". The success of this approach for locating "flux pipes" is demonstrated by the following two examples where an infill grid of 50 feet, coupled with a few additional offsets directed by the soil gas results has established the presence of two new active flux areas.

One significant new "flux pipe" was found in the Product 600 area. An expanded detail, contour map for methane is shown in Figure 24, where methane concentrations greater than 80% were found approximately 10 feet apart. Sites 9943A and 9943B had measured concentrations of 80.8 and 82.4%. In contrast, the largest values surrounding these two big macroseep sites have concentrations, which are generally less than 2000 ppmv (0.2%), and just 10 feet to the east of this large anomaly lies site 153, where only 80.9 ppmv (0.0081%) was measured. During the placement of an infill grid, site 9943 was placed halfway between sites 153 (80.9 ppmv) and 154 (612.5 ppmv). The value of 2040 ppmv measured at site 9943 was larger than either of the two original sites, but clearly did not find the macroseep in this area; however, previous observations by Walter Merschat (ETI's field party chief) had noted free gas bubbling up to the surface in this general area. The extra infill sample (9943A) added halfway between sites 9943 and site 153 found a concentration of 807,870 ppmv, confirming the existence of a large magnitude soil gas anomaly, or "flux footprint" in this area.

A second offset sample at site 9943B provided additional confirmation, and indicated that the soil gas anomaly associated with this macroseep occupies an area at least 10 feet in width. Sites 9943C and 9943D were added to further define the northern and western edges. When placed into the regional map (as shown by Figure 24 and Plate 13) it is evident that additional samples should have been placed to the northeast, toward sites 9952C and 9940. A potential northeast - southwest alignment is suggested by this soil gas data.

The presence of two large magnitude soil gas anomalies located only 10 feet apart, when taken in context with the other anomalous samples shown on Plate 13 indicates a very high potential for significant seepage under this Product 600 construction area. It is important to note that these sites would probably never have been collected close enough for this confirmation without the visual observation of bubbles that had been noted earlier (Walt Merschat, personal communication). Of even more significance, however, is the fact that this "flux footprint" confirms the presence of adequate conditions for vertical migration directly from the underlying gravel aquifer, also confirming the existence of the previously observed "flux pipe". This large macroseep also confirms that the gravel aquifer is a potential source, and must be given serious consideration when evaluating any building sites that are located above the gas-charged portions of the aquifer.

Another excellent example of a very well-defined macroseep was found by adding a grid of samples near MMW-04. This monitor well had blown out for over an hour when it was first drilled and had also contained very anomalous free and dissolved gas concentrations in the water samples initially collected (ETI April 17, 2000 report). As shown by Plate 11 in the ETI April 17, 2000 report, contouring the data from the monitor wells appeared to define a possible area where deep gas might be entering the gravel aquifer from below. It was puzzling then that the initial soil gas contour maps (see Plate 2) did not show a large soil gas anomaly vertically over this very anomalous area of the gravel aquifer, as the data from this well would suggest. Only site 201 had noted the possible presence of an anomaly in this general area. In order to evaluate the potential for this gravel aquifer anomaly to be a gas source, an infill grid was placed between site 201 and monitor well MMW-04. Initially sites 004A through 004I were collected within the boundaries defined by sites 180, 181, 200 and 201, and only sites 004C and 004F showed appreciable values of 75.7% and 98.6%. Based on these initial infill results the remaining grid sites were added, up to 004Z.

In order to properly display this anomaly, an expanded view of this infill grid using a scale of 20 feet to the inch has been included in Figures 25, 26 and 27 for the methane, ethane and carbon dioxide. This infill grid provides one of the most important and well defined anomalies mapped by these soil gas surveys. Sites 004P, 004K and 004Z found very large concentrations of 75.8%, 97.8% and 100%, respectively, the largest soil gas concentrations measured anywhere on the site. The important of these sites cannot be overemphasized. These anomalies showed that there is vertical seepage very close to MMW-04. Previous discussion and interpretations had suggested that the offset to the east of the very largest soil gas anomalies (shown by Plates 2 and 11 from the ETI April 17, 2000 report) might represent lateral migration from the gravel aquifer (near MMW-04), eastward towards sites soil gas 207 and possibly even to site 211. This anomaly shows that vertical migration does occur at this location (site 004Z), and also at site 9943A and B (discussed above). Both of these new macroseep areas defined by close-detail sampling have demonstrated that vertical soil gas anomalies are associated with the free and dissolved gas anomalies in the gravel aquifer, which had been previously defined by the monitor wells (such as, MMW-04 and MMW-153, which directly underlie these two macroseeps).

This 004Z anomaly was also found in an area that was too high in relative elevation to flood, significantly reducing the chances of visually seeing bubbling macroseeps in this area. Once defined by the soil gases, further examination of the area around this site did, however, result in the location of several very small macroseeps located between 004Z and 004Q, near the eastern edge of the anomaly where surface conditions allowed visual observation of the gas bubbles (Figures 28, 29). These small macroseeps were photographed and viewed over several days when conditions were just wet enough to allow favorable detection.

Although, no visible seepage could be observed at site 004F, a small 4 foot by 4 foot plastic tent was placed over this site and sealed on it's edges by burial in the soil (see Figure 30). The soil conditions appeared to be too damp and tight to allow free gas bubbles to appear at the surface at site 004F, however this site did have a soil gas concentration of 98.6% methane at four feet below surface. Ambient air samples were taken under the tent over the next two days in order to establish whether or not there was any positive flux at this site. Within 24 hours the tent had ballooned up, and a concentration of 4.73% methane had developed under the tent (see Figure 31). Thus even though the venting was not visible, these measurements indicated that it was occurring and would have been overlooked if the detection of visible bubbles was the only method of detection used to find the "flux pipes".

This macroseep anomaly has also provided an opportunity to illustrate the range of concentrations within the anomaly and the enormous contrast between the anomaly and the adjacent background samples. The very largest methane magnitudes within the anomaly were contoured using intervals ranging from 90% (red) to 70% (yellow). The transition to background is shown using intervals from 10% (green) to only 1% (blue). General observations made over the site where other macroseeps had been noted had suggested that whenever soil gas concentrations exceeded the 1 to 25% range (10,000 to 250,000 ppmv) that visible macroseeps were likely to be found. Ethane also shows just how rapidly the magnitudes change at the edges of the macroseep area (see Figure 26).

Subsequent testing for ventable gas from the underlying gravel aquifer was unsuccessful at this site. Five TVW CPT vent boreholes were attempted at this location, three found no gas (TVW-35, TVW-75 and TVW-94), and two found only a small amount. TVW-93 was tested all the way from the top of gravel at 54.5 feet bgs (below ground surface) to the surface and found a minor gas pocket at 24.2 feet bgs. TVW-104 never found a point of refusal and was pushed to 82 feet bgs. As shown in Table 9, trace gas was recorded as present from 62 to 82 feet bgs. Clearly there is no gas pocket in the 50-foot deep gravel aquifer at this location, yet gas is venting at the surface. Five test wells, sampled from the gravel to the surface for free gas pockets within this soil gas anomaly provides conclusive evidence that deeper gas is venting straight through the Ballona gravels, and through the upper 50 feet of sedimentary cover at this location.

These two examples demonstrated that, while the presence of free gas bubbles could help in finding macroseeps, there could be no assurance that this method would be sufficient for insuring that all of the macroseep areas had been found and mapped. Tight clayey soils could also be the source of advective gas vents that were essentially invisible to this useful, but crude method of detection. Thus while mapping the presence of bubbles is conclusive evidence of advective flow, a lack of bubbles cannot be used to assume that advective flow is not occurring. Soil gas and monitor well data is essential for mapping the "flux footprints". Due diligence cannot be achieved by any other approach.

As noted earlier, numerous surface flux tests were conducted using an EPA flux chamber over portions of the methane anomaly in Tract 49104-01 by CDM during the first quarter of 2001 (March 6, 2001 CDM letter report to David Nelson entitled "Methane Surface Flux Emissions for Product 700 Area, Lots 58 and 59 in Tract 49104-01"). Plate 16 shows the EPA chamber locations and the calculated flux values posted on top of the infill detailed methane map (Plate 13). A derivation of the flux equation and the flux data is given in Appendix D. The calculated flux values, which range from 0.000182 to 2.367 are in cubic feet of gas per square foot per day. As expected, the higher flux values do correlate regionally with the underlying soil gas data. For example, the larger values of 2 cubic feet/square foot/day occur over macroseeps (see Figure 20) located in the Product 700 area where the largest and most extensive soil gas anomalies also occur, and only background flux values occur over areas where the soil gas is uniformly low. However, because the flux chamber covers such a restricted surface area, it is possible for a single flux chamber measurement to fail at finding an advective seep, where the surface exit point may be very restrictive in size and is not marked by visible bubbles. Soil gas has the capability to approximately locate a gas venting site without actually sampling right in the vent hole. A flux chamber, on the other hand, has to exactly locate the vent hole in order to make an accurate flux measurement associated with an advective seep.

These examples demonstrates the ability of soil gas sampling to approximately locate areas which must be searched for active vents before accurate and real flux measurements can be made. The flux chamber was designed to measure diffusive flux and does not accurately measure, nor easily locate advective flux sites. In order to achieve useable flux results without having a very large number of individual flux stations, it is imperative that the flux chamber measurements be guided by a soil gas survey to vector in the potential location for the flux measurements.

2.9 Ballona Gravel Structural Maps

As noted above, the point of refusal, or so-called depth to the "Top of Gravel" was recorded during the many attempts to find subsurface gas pockets using the CPT method. Detailed testing procedures are given in Appendix C, and information on specific TVW boreholes are listed in Table 9. Over 120 CPT boreholes were pushed to refusal in the Ballona gravels using a Cone truck by CDM and 53 additional attempts were made by ECI. It was hoped that the finer sediments capping the 50-foot gravels would provide a seal, allowing free gas pockets to accumulate just below this interface. Both hand contoured and computer contoured maps were generated from this data in order to determine the potential correlations with the soil gas anomalies and any ventable gas pockets defined by these extensive CPT push-probe projects.

An initial set of field work maps were generated by Walter Merschat during several work sessions that were held at Playa Vista during January/February 2001 between the Playa Vista Consultants and the LADBS/ETI Consultants. These maps have been reproduced as scanned pdf files and have not been digitized (Walter Merschat "Top of Gravel" work products, Feburary 2001). CDM provided a color scheme for their CPT borehole venting attempts, with blue used for TVW wells that would vent gas and green for wells that did not vent any gas. As shown, by Figure 33, most of the TVW wells were not capable of venting gas. Only two main areas were responsible for most of the vented gas. Wells TVW-23 (Figure 32) and TVW-24 are the principal CPT holes that define these two main areas. An examination of the depth to the "top of gravel" shows that the areas where wells could be vented occurred mainly within an intermediate depth, which was not at the top of the gravel. Merschat's maps were generated with some slight geological/ geochemical bias related to the strong east-west lineations expressed by the geochemical soil gas maps.

A second attempt to correlate this data was made by Dr. David Becker, who prepared a set of computer-generated maps for this report. Three maps were generated, one with the ECI data, one with the CDM data and a third using both data sets. The CPT trucks used by these two separate efforts were slightly different in that the ECI data used an instrumented cone capable of creating an electric log of the sediment type as the probe was pushed and the CDM probe did not use the instrumented probe. Without the instrumented cone, the CDM probe could be pushed slightly deeper before refusal, so there is some bias between the two data sets. Plates 17, 18 and 19 are the CDM, ECI and ECI/CDM data sets, respectively. All of these very important data sets have been produced so that the reader of this report can view the available information. In the opinion of the authors, there is no correlation between the "top of gravel" and the locations of ventable gas.

3.0 SUMMARY AND CONCLUSIONS

A regional soil gas survey, consisting of 1621 sites sampled at four-foot depths, was constructed by compiling data from all of the previous three soil gas surveys that were conducted from October 1999 to January 2001. As shown by Plate 1, this includes both the Phase 1 and Phase 2 areas of the planned 1087 acre Playa Vista Development in Los Angeles, California. The purpose of the soil gas survey is to provide baseline data that reveals the areal distribution and concentration of methane gas in the near subsurface directly underlying the areas of planned construction. The survey also reveals the presence of methane homologs (ethane, propane, or butanes) derived from deep thermogenic source(s). Concern about the possible presence of toxic gases prompted additional analyses to determine the concentrations of BTEX and H2S in the soil gases.

Methane concentrations over the survey area are highly variable and range from background (<2 ppmv) to over 900,000 ppmv (90%). Anomalous methane concentrations (greater than 12,500 ppmv) are clustered within two main areas that were identified during a previous survey conducted in 1999 and reported in the ETI April 17, 2000 report. The most significant area of anomalous methane concentrations is more than 900 feet long and occurs in the western part of Tract 49104-01. The second highest methane anomaly, more than 1000 feet long, occurs in the southern part of Tract 49104-02. Based on the regional soil gas data, the total area of anomalous methane concentrations (greater than 12,500 ppmv) underlies only about 1.5% of the 1087 acre Playa Vista site. Other methane anomalies, of smaller areal extent, occur both between and north of the two largest methane anomaly areas. The anomalous methane seeps also appear to define elongate linear anomalies that trend N 65 E, N 7 W, and N 62 W, suggesting subsurface structural or fracture control. Ethane, propane and butanes occur within each of the major methane anomalies, establishing the presence of a thermogenic source.

During rainy periods, or within wet areas, bubbling macroseeps have been observed within most of the areas containing the largest methane soil gas concentrations. Seepage also occurs east of Lincoln within the riparian wetlands corridor that runs east-west just north of the bluffs. Visual observations along this wetland corridor have revealed the presence of several macroseeps that were not sampled by the soil gas survey because of restricted access. One bubbling macroseep collected from this area was found to have nearly the same compositions as the soil gases and the dissolved gases in the 50-foot gravel monitor wells, indicating a common origin for these thermogenic gases. This macroseep fills a gap in the soil gas data, and strongly suggests the need for collecting additional geochemical data within this wetland corridor in order to properly complete the assessment of seepage throughout the planned development site.

Bubbling macroseeps near soil gas and monitor well anomalies indicates advective, pressure driven methane seepage. Chemical and isotopic compositions of soil gas, bubbling macroseeps, and gas-charged aquifers clearly define a family of dry nonassociated gases that are definitely not connected to the deeper Playa del Rey oil field, or to the Southern California Gas Storage Field. Comparison of Playa Vista site gas compositions, with the nonassociated dry gases produced from the Pico Formation in the El Segundo Gas Field, on strike southeast of Playa Vista, shows strong similarity. It is probable that the Playa Vista gas is also derived from the Pico Formation.

Free gas collected from macroseeps in Centinela Creek extends the area of thermogenic gas seepage north from the surveyed area to at least the confluence between Centinela and Ballona Creeks. Samples collected more than seven years earlier from this same area show strong similarity to those collected recently. The fact that these same seeps are still active demonstrates the long-term stability of the advective methane gas flow in this area. It is also significant that these Centinela Creek seeps are very similar, but slightly different from the main seepage area located within 49104-01. Small localized, but systematic changes in the chemical and isotopic compositions of close-spaced, but different Pico reservoirs at depth would be created by the source and/or migration factors that control the trapping and formation of specific gas reservoirs. Biogenic changes would generally be more random and less stable. Such systematic and stable changes, strongly supports the interpretation that the source of the seeps are close, but distinctly different traps formed in the Pico sands at depth.

This soil gas data shows that no large areas of methane leakage have been found within areas A and B, which are located over and adjacent to the Southern California Gas Storage Field. Closer spaced infill detail samples placed within the areas containing the gas storage wells also did not find any large magnitude soil gas anomalies. In addition, the chemical and isotopic compositions of the soil gases in these two areas have an oilier composition than either the soil gases or the deeper gases from the 50-foot gravel aquifer mapped east of Lincoln. These latter gases are similar to the known Pico production gases, and are very different from the original oil field gases, or from the gases currently stored within the gas storage field. A direct comparison of the storage gas samples (nine new samples were provided for this comparison) with those from the soil gases and monitor well gases on the Playa Vista site demonstrate that the gas storage field is not the source of any of the gas seepage reported on the Playa Vista Development site.

Area C was also found to be devoid of large methane anomalies, and contains only background level soil gas concentrations. This area contains two abandoned wells (Del Rey #1 and #2) that must be properly reabandoned. Provided that no significant gas is found in the 50-foot gravel aquifer within any these three areas, and the Del Rey wells are properly reabandoned, then there should be no objection to development of all three of these areas. No construction is recommended directly over the gas storage field, and if the dissolved methane concentrations are low enough in the 50-foot gravel aquifer within these three areas, then it may be worthwhile to consider waiving the installation of methane mitigation and monitoring systems for all the portions of these three areas that are far removed from any existing wells.

The areal distribution of the toxic gases, hydrogen sulfide and BTEX, have been shown to be restricted to areas where advective methane seepage occurs. The sources for these gases appears to be from shallow, organic rich soils, which may have been supplemented by La Brea fill brought in by Howard Hughes operations during early construction activities on the site. The mechanism for these gases to migrate to the surface appears to be aided by the advective methane seepage. Even with methane as a carrier gas, the levels are low, and should be readily diluted to below concentrations of concern by the methane mitigation systems required within the areas of advective gas flow. These toxic gases do not appear to migrate to the surface without a methane gas carrier and do not require consideration outside the areas of high methane seepages.

Some portions of the Playa Vista site should be considered as a high potential methane zone due to the documented areas of high-volume surface macroseeps of methane gas.
These results provide the basis (methane concentrations) for establishing a matrix table (designed by a methane engineer) with three levels of methane mitigation for prevention, detection, and monitoring of methane gas. These methane system requirements are to be implemented in areas of planned construction at Playa Vista. Results from this subsurface geochemical assessment may contribute important guidelines for improving the Los Angeles Methane Gas Code.

The presence of significant gas seepage requires building methane mitigation systems for any building constructed directly over the areas where anomalous concentrations of soil gas have been measured. In the interest of safety, no variances in these methane mitigation requirements should be allowed. These mitigation systems require extensive field-testing to determine their effectiveness in handling the gases venting naturally at Playa Vista before initial occupancy. The effectiveness of these mitigation systems must be periodically revaluated in view of future seismic activity in the Los Angeles Basin. It should be noted that a small earthquake (magnitude 3.3) did occur on September 16, 2001 on the north edge of the site, on-strike with the Charnock Fault (Preliminary Earthquake Report). A larger magnitude earthquake at this location could easily cause the gas flux on the site to increase significantly.

The installation of real-time monitoring systems installed in the vent risers in the Playa Vista buildings could provide significant protection, provided that they are properly calibrated and demonstrated to be responding to the actual gas levels, which accumulate under the buildings foundations. This testing has not been done, and must be completed as part of the due diligence before occupancy

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4.0 RECOMMENDATIONS

1) As with the April 17, 2000 report, this additional regional soil gas data set collected within areas A, B and C in the Phase 2 area should be supplemented and confirmed by collection and analysis of the associated dissolved gases contained in the Ballona gravel aquifer. Using the soil gas anomalies as a guide, a minimum of 18 additional monitor well locations have been selected to supplement the original 42 already installed. Installation of these wells should follow the same procedures used in the ETI April 17, 2000 report, with both free gases and dissolved gases collected and analyzed as described in Appendix B of the ETI April 17, 2000 report. All monitor wells (both the original 41 and the 18 proposed new wells) should be sampled at one time in order to generate a uniform aquifer data base for evaluation of the free and dissolved gas content in the Ballona gravel aquifer.
2) As agreed to by Playa Vista and LADBS, 100 foot grid spacing soil gas surveys shall be conducted over all Phase 1 or Phase 2 sites before construction may proceed.
3) If soil gas concentrations exceed 12,500 ppmv, then an additional soil gas survey shall be conducted over the planned building foundation using no less than 50 foot centers. Flux chamber measurements should not be used without adequate guidance by gridded soil gas surveys.
4) Buildings should not be constructed over the Playa del Rey Gas Storage Facility in Areas A and B. For maximum safety the areas directly over the gas storage field should be reconfigured as open space.
5) The Del Rey 1 and Del Rey 2 abandoned wells in Area C should be reabandoned to current DOGGR standards if this area is to be developed.
6) Based upon the results of the regional soil gas survey under current grid spacing, and favorable results from the additional proposed wells discussed in (1) above, it does not appear that methane concentrations are high enough to warrant methane mitigation and monitoring for planned construction in Areas A, B, and C of Phase 2 provided that the above recommendations are adhered to.
7) The methane mitigation systems proposed for these buildings must be thoroughly tested to insure that their performance meets the specifications. Gas samples must be collected from the sampling ports located both above and below the membrane and analyzed in a laboratory for their methane through butane contents. Simultaneous sample collection must be performed in the vent risers in order to determine how closely the vent monitoring system meets the requirements of monitoring the gas concentrations under the slab and in reducing the methane gas concentrations below the membrane to below 3.75%. If these testing and reporting procedures are not followed, then a hazardous condition could result.

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