# RESEARCH REPORT

# Study Of Houses Affected By Hazardous Lands: Appendixes A, B, C, D, E and F

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# STUDY OF HOUSES AFFECTED BY HAZARDOUS LANDS

## APPENDIXES A, B, C, D, E, AND F

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March 1992

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**Appendix A**

# EASTERN CANADA CASE STUDIES

**CMHC SOIL GAS RESEARCH PROJECT**
**EASTERN CANADA SECTOR**
**CASE STUDY #1**

**BUILDING TYPE AND LOCATION:** Single family dwelling, Valdemur

**GAS TYPE:** Gasoline

**SOURCE:** Gasoline spill from a leaking underground storage tank

**TYPE OF CONTROL USED:** Excavation and venting from excavation

**CASE STUDY PRÉCIS:**

On October 14, 1986, a gasoline leak was reported to the Ministry of the Environment of New Brunswick. A backhoe was ordered to the site for the excavation of some test holes. Upon excavation, significant product was discovered in the test holes. Water samples were collected for analysis. Interceptor trenches were dug for the protection of nearby houses. A vacuum truck was used to remove contaminated water from the trenches.

On October 16, 1986, gas fumes were detected in a basement, two houses away from the gasoline station. The basement of the affected home in places had no foundation which allowed the rapid entry of soil gases. The gas fumes were checked by the local fire chief with the use of a gas sniffer; the readings were not explosive. In an effort to remediate the gas fume problem, a trench was then excavated next to the house for the purpose of soil gas ventilation. During the excavation of the trench, many large boulders were encountered in a sandy soil - good for soil gas migration. The attached figure (Figure A-1) shows the location of the affected house and the various trenches.

Despite the venting trench, by October 24, 1986, gas fumes still persisted in the affected house. By October 27, the owners of the affected house were ordered to vacate. By November 12, gasoline fumes were still noticeable; however, the odours had diminished considerably. The residents had still not moved in.

Some testing was also completed late in the project by the Ministry of Health. Gastech detector tubes were used for the indoor air quality evaluation. Occupational TLV standards were used as health guidelines. Actual readings were not available at the time of writing of this report. Within approximately one month, the residents were allowed to return to their home.

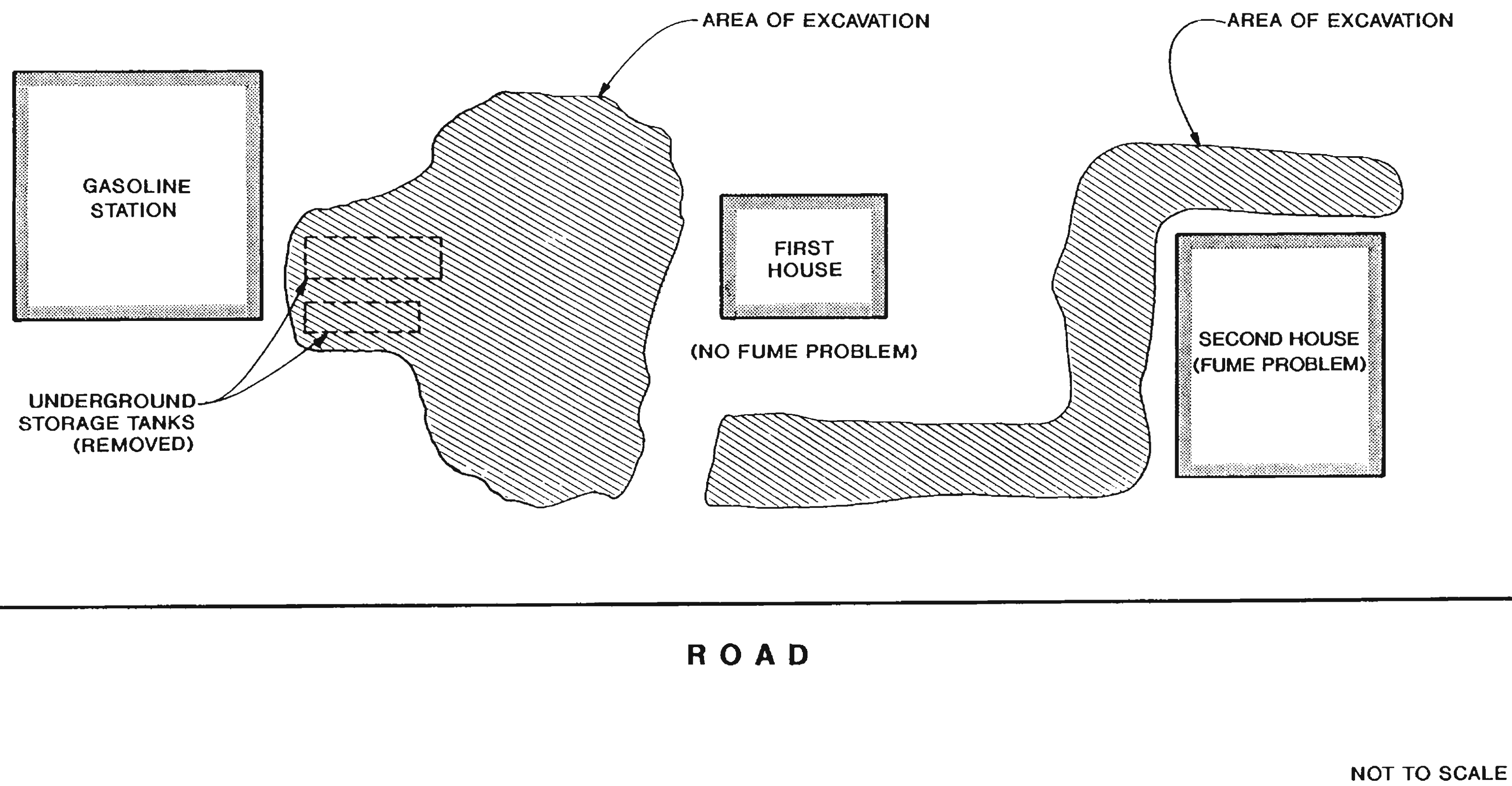


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**FIGURE A–1: LOCATION OF AFFECTED HOME RELATIVE TO LEAKING UNDERGROUND STORAGE TANKS**

**CMHC SOIL GAS RESEARCH PROJECT**
**EASTERN CANADA SECTOR**
**CASE STUDY #2**

| | |
|---|---|
| **BUILDING TYPE AND LOCATION:** | General Store, Yarmouth |
| **GAS TYPE:** | Petroleum Products |
| **SOURCE:** | Spill from a leaking underground storage tank |
| **TYPE OF CONTROL USED:** | Removal of tanks and contaminated soil |

**CASE STUDY PRÉCIS:**

The general store in Yarmouth was situated approximately 100 - 150 metres from the shore of a river. A group of 2 - 3 underground storage tanks were located between the shore and the river. The detection of odours in the store was the first indication of a spill from a leaking underground storage tank. The building was on stilts; however, excessive snow was piled around the building, which likely funnelled the gases up into the crawl space and floor.

Odours within the building noticeably fluctuated. This fluctuation was believed to be the result of tidal fluctuations causing the petroleum to shift back and forth. The fire department was contacted on several occasions but contamination was not detected. Eventually, gas fumes were measured. A combustible gas meter was used for this purpose. The Ministry of Environment ordered removal of the tanks. During excavation, 5 - 7.6 cm of sludge were discovered. The sludge and the tanks were removed. The odour problem was rectified.

The Ministry of Health was also apparently involved in this case. However, no confirmation of their involvement exists.

**CMHC SOIL GAS RESEARCH PROJECT**
**EASTERN CANADA SECTOR**
**CASE STUDY #3**

**BUILDING TYPE AND LOCATION:** Single Family Dwelling, Millford

**GAS TYPE:** Pesticides

**SOURCE:** Pesticide disposal from feed store/hardware store

## CASE STUDY PRÉCIS:

Pesticides were disposed of in the soil in the vicinity of a hardware store in Millford. Infiltration of rainwater caused the contaminants to migrate into weeping tiles of the adjoining structures. The indoor air quality of the home next to the store was believed to have been affected by negative pressure created by the forced air heating system. Detection of the contaminant was based primarily on olfactory evidence as well as burning sensation of the eyes. No details concerning the testing procedures were available.

The problem was solved by excavation of the soils and sealing of the basement cracks to prevent entry of gases.

## CMHC SOIL GAS RESEARCH REPORT
## EASTERN CANADA SECTOR
## CASE STUDY #4

| | |
|---|---|
| **BUILDING TYPE AND LOCATION:** | Restaurant, Apartment |
| **GAS TYPE:** | Perchloroethylene |
| **SOURCE:** | Dry cleaning operation flushing solvent down the drain |

**CASE STUDY PRÉCIS:**

The dry cleaning operation routinely flushed dry cleaning agents down the sewer once the cleaning procedure was complete. The vapours from the operation travelled back up the sewer connections and entered the building next door. The air intake from the cooker fume hood was in the basement which helped to extract the vapours from the drain. Quick spread of vapours was recorded in the process.

Poor P-trap connections were rectified and illegal dumping of the solvent was prohibited.



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**CMHC SOIL GAS RESEARCH PROJECT**
**EASTERN CANADA SECTOR**
**CASE STUDY #5**

**BUILDING TYPE AND LOCATION:** Single Family Dwelling, Cape Breton

**GAS TYPE:** Methane

**SOURCE:** Mining Operation in Cape Breton

**CASE STUDY PRÉCIS:**

A mining operation in the Cape Breton area was once operated by Cape Breton Development Corporation. Owners of a home situated above the mine became involved in a boot-leg mining operation years after the mine had closed. The basement floor of the house was 7.5 m above the existing mine shaft.

The case was discovered by the Department of Energy, Mines and Resources. Upon discovery, the Fire Marshall was called in to investigate. At this time, excessive explosive gases were discovered indoors. Readings in the home on occasion exceeded 100 percent LEL at which time the house was evacuated. A cavity where the illegal mining operation was conducted was found to be as deep as 7.5 m. The Fire Marshall's office noted that on humid days, extremely high methane levels were recorded; mild days had low methane levels. Remediation of the problem was accomplished by pouring concrete into the void. In total, 11 $m^3$ of concrete were required to fill the hole. No methane was recorded after remediation. Documentation was requested; however, it has not yet been cleared by the Fire Marshall's Office.

# CMHC SOIL GAS RESEARCH PROJECT
# EASTERN CANADA SECTOR
# CASE STUDY #6

**BUILDING TYPE AND LOCATION:** Single Family Dwellings, Glace Bay

**GAS TYPE:** Methane

**SOURCE:** Underground mines

**CASE STUDY PRÉCIS:**

A number of home owners in Glace Bay (20 homes involved) were concerned about soil gas entry from a subsurface mining operation. Various residents complained about odours; however, no odours/readings were detected by the Fire Marshal. As a result, sewer gases were suspected. No correlation was made with respect to detectable odours and atmospheric conditions. Data has been requested; however, it has not cleared official channels.

There is recent concern that affected homes may be structurally unstable. This fact may indicate that soil gas influx could exist.

**CMHC SOIL GAS RESEARCH PROJECT**
**EASTERN CANADA SECTOR**
**CASE STUDY #7**

**BUILDING TYPE AND LOCATION:** Office Building, Sydney

**GAS TYPE:** Petroleum Products

**SOURCE:** Fuel Oil Spill

**TYPE OF CONTROL:** Soil vacuum extraction system, groundwater treatments

**CASE STUDY PRÉCIS:**

A driver who was delivering a shipment of fuel oil to an apartment building observed a standpipe at the rear of the building, removed its cap, and released the fuel. Several days later, the building's furnace oil level was low. The standpipe that received the fuel oil was a monitoring well for groundwater.

Several days later, the fumes in the building were intense, and people were forced to evacuate. A soil vacuum extraction unit was installed, and vapours indoors were managed. Groundwater treatment is still occurring. No more details have been released due to confidentiality.

**CMHC SOIL GAS RESEARCH PROJECT**
**EASTERN CANADA SECTOR**
**CASE STUDY #8**

**BUILDING TYPE AND LOCATION:** Single Family Dwellings, Kentville

**GAS TYPE:** Methane

**SOURCE:** Landfill

**TYPE OF CONTROL:** Houses were moved

**CASE STUDY PRÉCIS:**

An investigation was first conducted on a landfill site in Kentville to determine the landfill's effect on groundwater. However, during the study, excessive levels of methane were found in the vicinity of the landfill. Based on the consultant's findings an investigation into the occurrence of methane at this site was recommended.

The geology of the site consisted mainly of sand overlying a silty layer. The silty layer was found at a depth of approximately 18.3 m below the ground. Random sampling of gases in and around the adjacent homes indicated that methane existed in the soils at volumes of 60 percent methane-in-air. This prompted the monitoring of gases indoors. No excessive concentrations were ever discovered indoors.

Despite a lack of methane indoors, the municipal government purchased the houses. The houses were re-located. In the transition period, gas alarms were installed in the home as a safety precaution.

**CMHC SOIL GAS RESEARCH STUDY**
**EASTERN CANADA SECTOR**
**CASE STUDY #9**

**BUILDING TYPE AND LOCATION:** Single Family Dwellings, Moncton, New Brunswick

**GAS TYPE:** Solvent

**SOURCE:** Illegal Dumping

**TYPE OF CONTROL:** Source Control

**STUDY PRÉCIS:**

In November 1989, homeowners in a residential subdivision in Moncton, New Brunswick experienced disagreeable odours emanating from the storm sewer sump. Initially, it was suspected that this odour was caused by a furnace oil leak or a similar product in the immediate vicinity of the site. The intensity of the odour was extremely erratic.

A resident was advised by a plumber to flush the sump pit on several occasions with detergent and water; however, this only temporarily solved odour problems. The water traps and backwater valve were checked and appeared to be functioning properly.

City inspectors found no significant odour problems inside the sump or in the manholes outside. Several days after the inspection, odours were rediscovered in the manhole outside. The sewers were flushed and fumes disappeared temporarily.

As the fumes returned, water samples were extracted from several manholes on four separate occasions. Analytical results confirmed the erratic nature and identified the type of contaminant. High concentrations of alkyl benzenes, xylenes, and napthlene were identified. Based on this characterization, contamination was likely a result of a solvent-based product. After several months, homeowners frequently left their windows open. Several owners also complained of constant headaches. The location of illegal dumping was determined during the fourth round of sampling. The responsible party was ordered to cease dumping and the problem ceased.



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**CMHC SOIL GAS RESEARCH STUDY**
**EASTERN CANADA SECTOR**
**CASE STUDY #10**

**BUILDING TYPE AND LOCATION:** Single Family Dwellings, Cornerbrook

**GAS TYPE:** Gasoline vapours

**SOURCE:** Gasoline transport spillage

**CASE STUDY PRÉCIS:**

In 1983, a petroleum haulage vehicle lost control resulting in a gasoline spill in downtown Cornerbrook. In response to this emergency, an emergency task force was set up to deal with the problem.

As part of the accident, gasoline infiltrated into the ground and emerged in the sewer system. Vapours that resulted from this spill backed up into many nearby homes affecting as many as 10 - 20 houses. The fire department used explosimeters and recommended evacuation based on the explosive levels reported. People were allowed to return to their homes once explosive levels were no longer encountered. No further documentation was available.

**CMHC SOIL GAS RESEARCH STUDY**
**EASTERN CANADA SECTOR**
**CASE STUDY #11**

| | |
|---|---|
| **BUILDING TYPE AND LOCATION:** | Residential Dwelling, Fortune |
| **GAS TYPE:** | Petroleum products |
| **SOURCE:** | Tank leak or fuel line |
| **TYPE OF CONTROL:** | Excavation of soil |

**CASE STUDY PRÉCIS:**

In early 1987, the Ministry of Environment investigated a complaint of oil seeping into a house in Fortune. However, due to heavy accumulation of snow, action was deferred until spring. In April 1987, a plan was developed to determine the source of the contamination.

Several large holes were dug by a excavator to delineate the source of contamination. The most significant contamination existed in the vicinity of the home heating tank which had ruptured and lost a large amount of heating oil. There was also a possibility for line leak at the source. A leak of this sort could be undetected for extended periods of time.

There is a highly compacted clay soil in the area that would impede the lateral movement of oil through the soil. Nevertheless, contamination has been observed. A resident has complained of vapours immediately downgradient of the oil spill. Attempts were made to remove the contaminated soil until access was prohibited by the potentially responsible party.

**CMHC SOIL GAS RESEARCH STUDY**
**EASTERN CANADA SECTOR**
**CASE STUDY #12**

**BUILDING TYPE AND LOCATION:** Three Businesses in Marystown

**GAS TYPE:** Petroleum products

**SOURCE:** Service station

**TYPE OF CONTROL:** Tank removal

**CASE STUDY PRÉCIS:**

In February 1990, the Marystown Fire Chief was informed of gasoline vapours at three businesses. The report was forwarded to the Department of Environment and Lands. When the environment officer investigated later that afternoon, the fumes had apparently dispersed. Only in one storage area did the fumes still appear to be evident. No fumes appeared to be present in the respective sewer vent pipes. Because it was raining at the time of the investigation, it was decided that perhaps the heavy rain caused wash-off to emerge in the sewer drains.

The following morning, the environmental inspector again checked the buildings with the fire chief. The vapours were again strong. A second check of the vent pipes indicated concentrated fumes emerging from them. Strong vapours were also emerging from a nearby sewer manhole. A nearby service station was investigated.

Of three tanks in the ground of the service station, only one was being used. The owner of the service station was ordered to pump out the tanks and complete pressure tests. The tank held its pressure; however, the lines did not. The petroleum company immediately responded and corrected the problem. After the problem was rectified, the fumes disappeared from the sewers and the buildings.

**CMHC SOIL GAS RESEARCH STUDY**
**EASTERN CANADA SECTOR**
**CASE STUDY #13**

**BUILDING TYPE AND LOCATION:** Motel, Port Rexton

**GAS TYPE:** Gasoline vapour

**SOURCE:** Contaminated drinking water

**TYPE OF CONTROL:** Drill another well

**CASE STUDY PRÉCIS:**

The Parkside Inn at Port Rexton experienced a problem with gasoline odours in the private water supply. Several residents in the neighbourhood implicated that a local service station was responsible for the problem. However, after an investigation launched by the Department of Environment and Lands, the results were inconclusive.

Due to the contaminated water that was being used at the motel, the indoor air quality was being affected. The owner of the motel claimed that a loss of business had resulted because the extreme odours. The indoor air quality problems occurred when the tap or showers were being used. The owner of the motel was advised to drill another well.

**CMHC SOIL GAS RESEARCH STUDY**
**EASTERN CANADA SECTOR**
**CASE STUDY #14**

**BUILDING TYPE AND LOCATION:** Single Family Dwelling, Shoal Harbour

**GAS TYPE:** Gasoline

**SOURCE:** Gas bar

**TYPE OF CONTROL:** Tank replacement, excavation

**CASE STUDY PRÉCIS:**

Based on complaints received by the Shoal Harbour Fire Department, the Department of Environment and Lands investigated a case of gasoline vapours migrating from a well into the basement of the house. The house was located approximately 60 m downgradient of a gas bar and convenience store. The owner of the house had covered the well with plastic in order to prevent the fumes from migrating into the rest of the residence.

Pumping of the well revealed that about 40 litres of gasoline had been pumped from the well. Strong vapours were recorded in the well with the use of an explosimeter. Measurements inside, however, revealed that no fumes were evident. Excavations outside the home indicated high levels of gasoline vapour were also evident in the surrounding soil. The Fire Commissioner's Office in St. John's ordered that the gas bar and the convenience store be closed and the area cordoned off.

Investigations in April, 1988 confirmed that a tank leak was responsible for the problem.

The petroleum company has carried out extensive restoration work to the affected house. The basement was dug out, a concrete floor was installed, the front yard was sodded, and excavation of soil outside of the house was completed. By September, 1988, no vapour problems were reported. The site had been restored.

## CMHC SOIL GAS RESEARCH STUDY
## EASTERN CANADA SECTOR
## CASE STUDY #15

| | |
|---|---|
| **BUILDING TYPE AND LOCATION:** | Single Family Dwellings, Longarbour |
| **GAS TYPE:** | Radon? Gamma Radiation? |
| **SOURCE:** | Backfill material |
| **TYPE OF CONTROL:** | Removal of backfill materials |

**CASE STUDY PRÉCIS:**

In a residential subdivision in Longarbour, a fill material containing approximately 50 ppm of uranium was used as backfill material around the houses. The Chief Mine Inspector indicated that the indoor air quality was contaminated due to radon ingress. However, a consultant hired to deal with this problem indicated that a condition existed with respect to gamma radiation. Although gamma radiation is not seen as a health problem, residents were uneasy in regards to this radiation. The fill was removed primarily for political reasons.

**CMHC SOIL GAS RESEARCH STUDY**
**EASTERN CANADA SECTOR**
**CASE STUDY #16**

**BUILDING TYPE AND LOCATION:** Newfoundland Taxation Centre, St. John's

**GAS TYPE:** Methane, carbon dioxide

**SOURCE:** Landfill

**TYPE OF CONTROL:** Crawl space venting

**CASE STUDY PRÉCIS:**

The Newfoundland Taxation Centre, located within city limits, is situated on a closed municipal landfill site. The structure is supported by a series of casons drilled to bedrock. The bottom floor of the taxation centre rests on a suspended slab that is supported by the underlying casons.

A crawl space between the suspended slab and the landfill site creates a buffer zone for the soil gases. The crawl space is enclosed with pony walls and measures from 1 to 5 m in height in various places. A low flowrate ventalization system was installed to create a constant air exchange in the crawl space. Additional methane detectors set at 5 percent of the low explosive limit activate a larger ventilation system. Both of the ventalization systems effectively control methane ingress into the taxation centre.

**The Problem**

The crawl space in the Taxation Centre was designated as a hazardous area by Labour Canada in 1987 or 1988. As a result, a consulting firm was contracted to identify the source of the problem. Upon inspection, the crawl space was observed to contain patches of wet, gelatinous reddish material, and in the more heavily contaminated areas, ponded water. The crawl space area was brought up to grade with gravel fill.

Ten air and soil samples were collected. Water samples taken from the ponded water regions were collected in hexane rinsed bottles. Air samples were collected in either nitrogen-purged 1 litre glass cylinders with stopcorks at each end, or in nitrogen-purged 1 litre Tedlar bags.

Air sample results for carbon monoxide revealed concentrations ranging from <1 ppm to 3 ppm; carbon dioxide from 640 ppm to 890 ppm, with a mean of 743 ppm; methane from 2.2 ppm to 3.3 ppm, with a mean of 2.42 ppm; and propane being non-detect. Table A.1 shows the analytical results of the air samples. Soil sample results revealed a concentration for oil and grease ranging from 0.1 mg/kg to 19.5 mg/kg; polychlorinated biphenyls ranging from <10 to 15 ppm; mercury ranging from 0.04 mg/kg to 0.48 mg/kg; cadmium ranging from 0.17 mg/kg to 1.18 mg/kg, lead with a mean of 375 mg/kg; and zinc with a mean below 800 mg/kg. Table A.2 shows the analytical results of the soil samples.

**Table A.1**
**Analytical Results - Air Samples**

| Sample Number | Carbon Monoxide | Carbon Dioxide | Methane | Propane |
|---|---|---|---|---|
| 1 | <1 | 760 | 2.3 | <1 |
| 2 | 1 | 640 | 2.2 | <1 |
| 3 | 3 | 850 | 2.4 | <1 |
| 4 | <1 | 890 | 2.2 | <1 |
| 5 | 1 | 700 | 2.3 | <1 |
| 6 | 2 | 730 | 2.3 | <1 |
| 7 | 3 | 780 | 2.6 | <1 |
| 8 | 2 | 680 | 2.3 | <1 |
| 9 | <1 | 750 | 2.3 | <1 |
| 10 | <1 | 650 | 2.3 | <1 |

All concentrations are reported in parts per million (ppm)

**Table A.2**
**Analytical Results - Soil Samples**

| Sample | Total Oil & Grease (mg/kg) | Polychlorinated Biphenyls (mg/kg) | Total Organic Carbon (%) | Mercury (mg/kg) | Cadmium (mg/kg) | Lead (mg/kg) | Zinc (mg/kg) |
|---|---|---|---|---|---|---|---|
| 1 | 3.2 | 15 | 1.29 | 0.23 | 1.18 | 86 | 229 |
| 2 | 3.0 | <10 | 0.88 | 0.33 | 0.41 | 131 | 1,460 |
| 3 | 4.9 | 10 | 1.21 | 0.04 | 0.43 | 300 | 209 |
| 4 | 19.5 | 15 | 2.24 | 0.23 | 0.36 | 175 | 176 |
| 5 | 0.7 | <10 | 0.73 | 0.23 | 0.26 | 73 | 122 |
| 6 | 9.3 | 15 | 3.23 | 0.48 | 0.42 | 287 | 250 |
| 7 | 9.0 | 15 | 2.51 | 0.28 | 0.34 | 259 | 181 |
| 8 | 0.1 | <10 | 0.12 | 0.09 | 0.17 | 14 | 74 |
| 9 | 6.5 | <10 | 3.47 | 0.31 | 0.74 | 2,030 | 401 |
| 10 | 6.3 | <10 | 1.87 | 0.35 | 0.70 | 390 | 508 |

All air and soil samples, with the exception of lead and zinc, were well within ministry guidelines. One lead sample contained a concentration of 2,030 mg/kg, and one zinc sample contained a concentration of 1,460 mg/kg.

**Conclusions/Recommendations**

All of the samples except for one of lead and one of zinc, were below ministry guidelines. The source of the high lead and zinc concentrations was believed to be either leachate (since adsorption is a strong attenuation mechanism for dissolved metals), or natural mineralization in parent rock. High TOC concentrations in 5 out of 10 samples were consistent with contamination from landfill leachate.

The crawl space was believed to be an area of contaminated fill material or an area which intercepts a groundwater leachate plume from an old landfill. According to the data, it appeared that the crawl space contains a highly dilute, well-aged leachate.

The reddish stained areas of unknown origin and composition were recommended for monitoring on a yearly basis to determine size distribution changes. Further soil sampling and water sampling was also recommended.

**REFERENCE:**

Jacques Whitford and Associates, 1989. Report to Public Works Canada on Soil and Air Quality Investigation Revenue Canada Taxation Centre.

**CMHC SOIL GAS RESEARCH STUDY**
**EASTERN CANADA SECTOR**
**CASE STUDY #17**

**BUILDING TYPE AND LOCATION:** Single Family Dwelling, St. John's

**GAS TYPE:** Undetermined

**SOURCE:** Paint manufacturer

**TYPE OF CONTROL:** Unknown

**CASE STUDY PRÉCIS:**

A house located on Temperate Street in St. John's was identified as having indoor air quality problems. Due to odours building up within the home, a child developed an unknown illness and was hospitalized. When the Department of Environment and Lands investigated the case, a paint manufacturer next door was suspected as being the potentially responsible party.

The City of St. John's funded the monitoring program. The exact extent of the program is not known; however, the source was traced back to cracks in the basement floors and wells.

**CMHC SOIL GAS RESEARCH STUDY**
**EASTERN CANADA SECTOR**
**CASE STUDY #18**

**BUILDING TYPE AND LOCATION:** Single Family Dwellings, St. John's

**GAS TYPE:** Perchloroethylene

**SOURCE:** Spillage

**CASE STUDY PRÉCIS:**

At a dry cleaning facility in St. John's, spent solvents were being discharged through holes in the basement floor. Perchloroethylene was the main contaminant. As a result of this discharge water, soil and vapour contamination occurred. The surrounding area was residential.

Vapours were detected in several area homes primarily by olfactory methods. The Department of Environment and Lands conducted sampling with draeger tubes for confirmation. An extensive sampling program also confirmed the present of PERC within the soil and water. Excavation of the contaminated soil was completed. Further information was not retrieved.

**CMHC SOIL GAS RESEARCH STUDY**
**EASTERN CANADA SECTOR**
**CASE STUDY #19**

| | |
|---|---|
| **BUILDING TYPE AND LOCATION:** | Multiple Housing Units (6 to 8 units) (The Miron Quarry) |
| **GAS TYPE:** | Methane and other landfill related gases |
| **SOURCE:** | Landfill |
| **TYPE OF CONTROL:** | Gas interception system within the landfill, permeable trench around the landfill, monitoring set up at the landfill and monitoring program inside and outside nearby houses |

**CASE STUDY PRÉCIS:**

A quarry has been used as a landfill since 1969. The landfill was privately owned and operated until 1984, before the Municipality acquired the site. In 1988, the Municipality took over the management of the landfill operation; it is expected that the site will be closed in 1994.

The landfill occupies an area of 75 ha. The depth of refuse reaches 70 metres at some locations. As of January 1st, 1991, 32 million tonnes of refuse had been disposed at the landfill; the actual predictions indicate that the landfill will contain 38 million tonnes of refuse by 1994. The landfill is used by the municipalities of the greater metropolitan region and the suburb. The Municipality also operates an incinerator used to eliminate most of the refuse of domestic origin.

It is estimated that by 1994, the landfill will produce an approximate 20,400 cubic metres of gas per day. Some houses are located within 50 metres of the edge of the landfill (Figure A-2). There is concern that gas from the landfill may migrate into the nearby houses through the fractures of the bedrock. The Municipality is presently installing an extensive network of interceptor wells within and around the edge of the landfill (Figure A-3). Monitoring wells (about 40) will also be bored around the quarry to monitor the chemical composition of the leachate and of the migrating gas. An interceptor trench, extending down to the level of the water table, will also be constructed around the site to intercept gases migrating through the overburden. The network of interceptor wells installed at the periphery of the landfill was first operated in January 1991; the wells installed at the core of the landfill will become operational progressively as sections of the landfill are closed.

The Municipality has received complaints from nearby residents alleging that gases from the landfill had migrated into their houses. Measurements of the quality of the air ($CO_2$, $CH_4$, $O_2$, CO, and methane) were taken inside and outside the houses and results indicated that although there was migration of gas from the landfill, levels were below dangerous levels.

In the fall of 1990, the Municipality initiated a more systematic monitoring program for houses located east of the landfill (Mr. Gerald Tremblay; personal conversation). A total of 120 houses were sampled; houses sampled were those located on the nearest seven streets east of the landfill. The quality of the air was monitored at the entrance of each house. It was attempted to determine if a concentration gradient existed within each house. Measurements were subsequently taken in the basement near drains, cracks in the foundation, or in washrooms. Outside air quality was also monitored. A Gastech Model GX-86 portable gas detector was used to monitor the Lower Explosive Limit (LEL) for methane ($CH_4$), the percentage of oxygen ($O_2$), the concentration (ppm) of hydrogen sulphide ($H_2S$), and the concentration (ppm) of carbon monoxide (CO). The percentage of carbon dioxide ($CO_2$) present in the air was also measured using the portable ADC model PM3 gas meter. Finally, the concentration of $CH_4$ was measured with the portable Gasurveyor-4 meter which gives concentrations in ppm, percent Volume Gas, and LEL.

Results of the study indicated that there was migration of soil gas produced by the landfill in some of the houses located along the nearest street east of the landfill (Figure A-2), but none of the houses located along farther streets were affected (Personal conversation; Mr. S. Tremblay). In all the houses affected by the landfill, however, concentrations monitored were below dangerous levels.

The Municipality intends to initiate a major research program to characterize the gas produced by the landfill and to determine its effect on: the environment, the health of the landfill workers, and the safety of the nearby residents. Within the research program, it is anticipated to take indoor air quality measurements inside nearby houses. The project will be carried out by several academic and government institutes. A proposal was presented to both the provincial and federal governments.

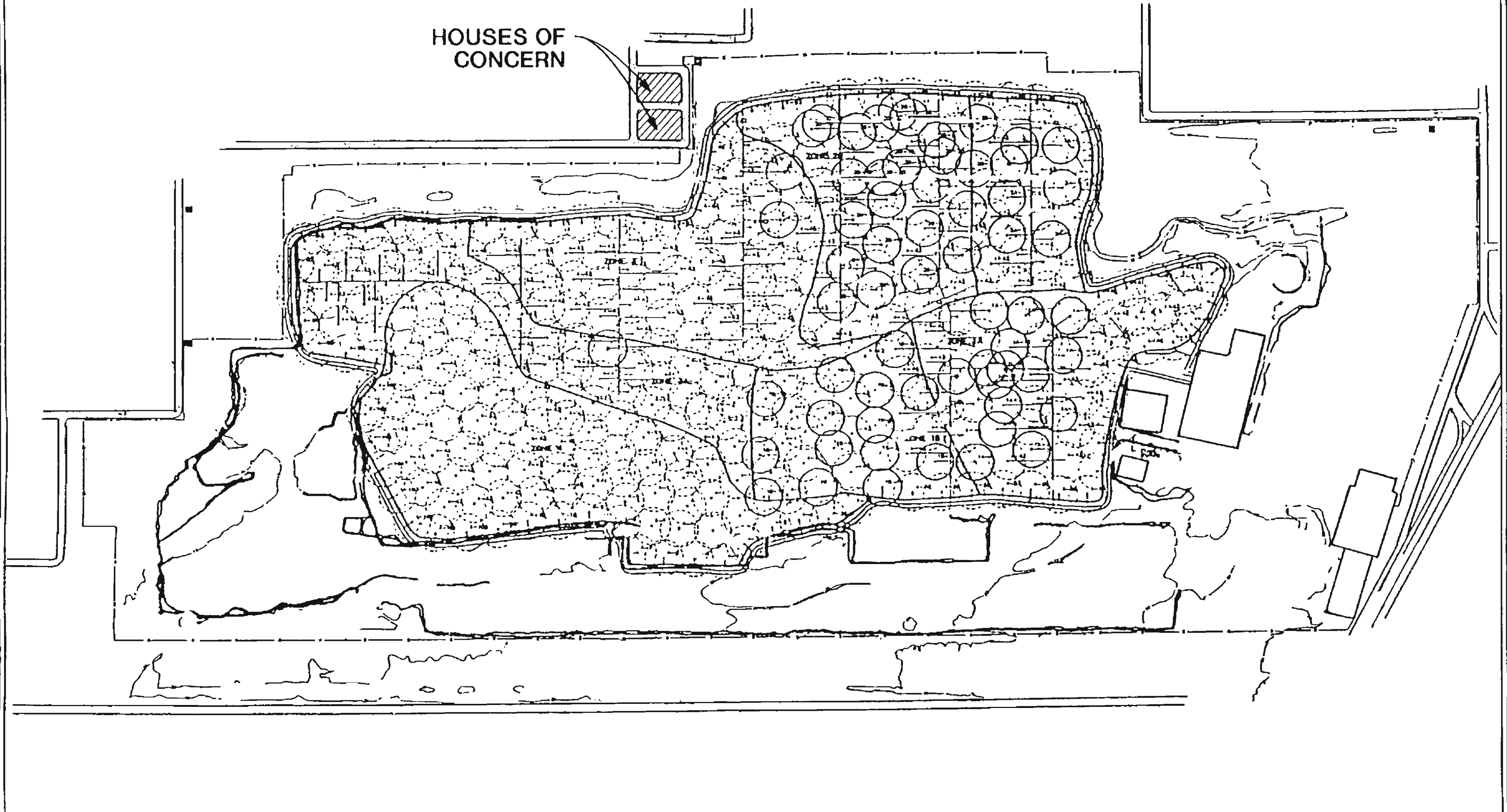


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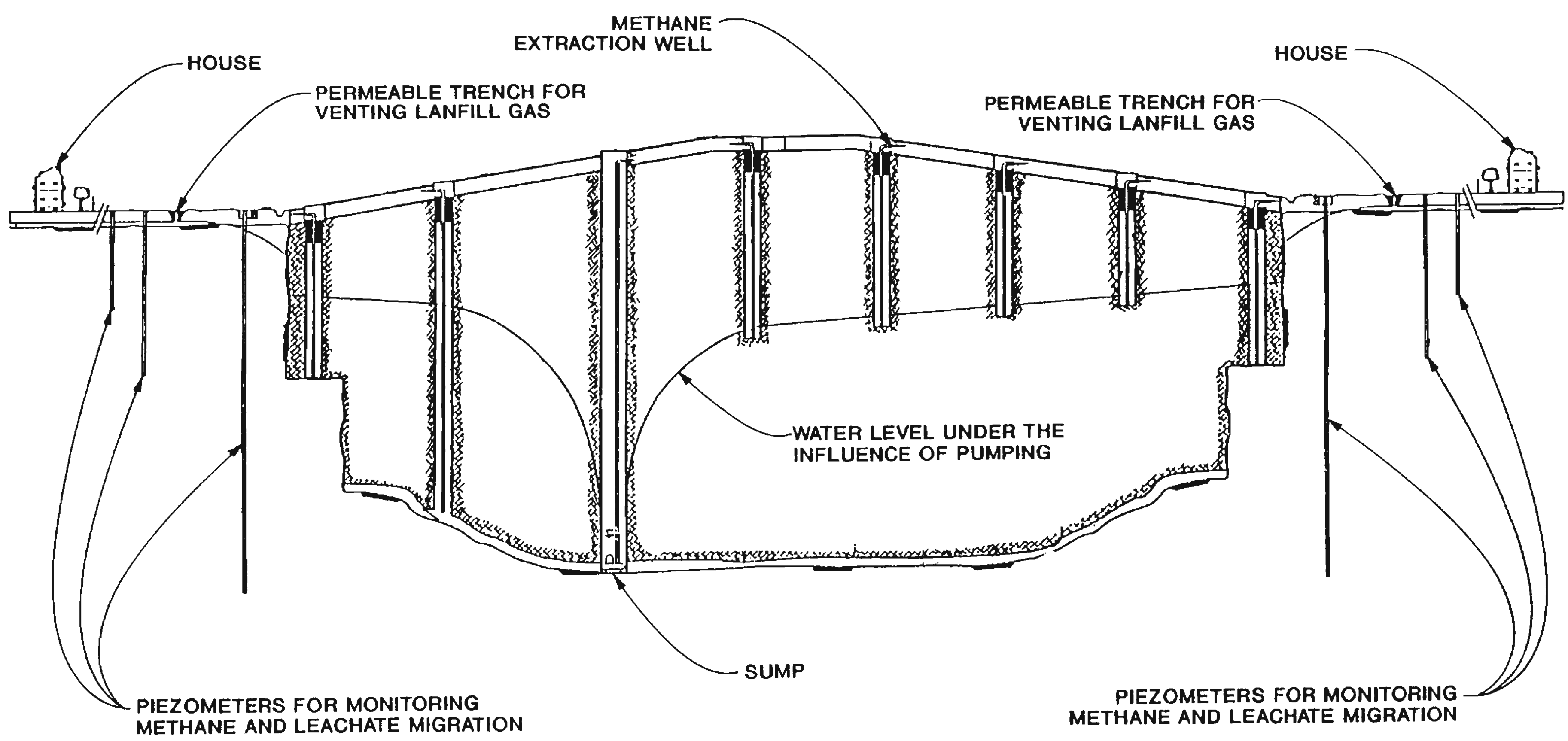
**FIGURE A-2:**
**MIRON QUARRY LANDFILL**




| | |
|---|---|
| CH2M HILL ENGINEERING LTD.<br>WATERLOO ONTARIO<br>PROJECT No. **ONT29396.AO** | **FIGURE A–3:**<br>**MIRON QUARRY LANDFILL** |

**CMHC SOIL GAS RESEARCH STUDY**
**EASTERN CANADA SECTOR**
**CASE STUDY #20**

| | |
|---|---|
| **BUILDING TYPE AND LOCATION:** | Duplexes built in the mid-sixties (Ville Lasalle Industrial Dump) |
| **GAS TYPE:** | Methane and other related landfill gases |
| **SOURCE:** | Old dump site (Sanitary and industrial waste) |
| **TYPE OF CONTROL:** | Extensive monitoring program (groundwater, soil, inside and outside air quality, and detailed statistical analysis) and demolition of houses |

**CASE STUDY PRÉCIS:**

In 1985, MENVIQ and Environment Canada initiated a study to assess the quality of the air inside residential houses built on an old municipal dump at Ville Lasalle, Quebec. This municipal dump received industrial waste between 1940 and 1959 that is now considered toxic. The study was initiated following a preliminary investigation showing the presence of some volatile organic compounds at depths between 2 and 6 m in the soil of some residential lots situated near or on the landfill (Gonthier, 1986).

The objectives of the study were to:

- Verify if volatile organic compounds originating from the buried toxic waste had entered houses
- Assess the potential health hazard resulting from the possible migration of toxic gases into houses located in the vicinity or in the dump.

This study involved the monitoring of the indoor air quality of 36 residential houses in Ville Lasalle. The first 18 houses were located near or within the area where soil had been found to be contaminated (Target houses; Figure A-4). The remaining 18 houses were uniformly distributed over the municipality of Ville Lasalle (Control houses). Houses used as controls were similar to those selected as a target. A questionnaire was given to the residents to determine the construction characteristics of the houses (heating system, wall insulation, ventilation, type of windows, use of paint) as well as to determine the habits of the residents (number of smokers, use of perfumes or deodorants, use of air purifiers). The majority of the houses selected for the study were duplexes built in the mid-sixties with a garage in the basement.

Sampling was performed in July 1985 and a total of three samples were collected in each house (1 sample for light VOCs and two samples for heavier VOCs). Air samples were collected in a central room in the basement, 1.5 m above the floor. Residents were evacuated 24 hours prior to sampling, windows and doors were kept close during that period, and ventilation was interrupted. Sampling of the target and control houses was done simultaneously to eliminate variables associated with fluctuating weather conditions. The air was sampled for aliphatic, aromatic, and chlorinated hydrocarbons. The method used to sample and analyze the air of the residences for volatile hydrocarbons was that developed by Environment Canada (Wang 1984).

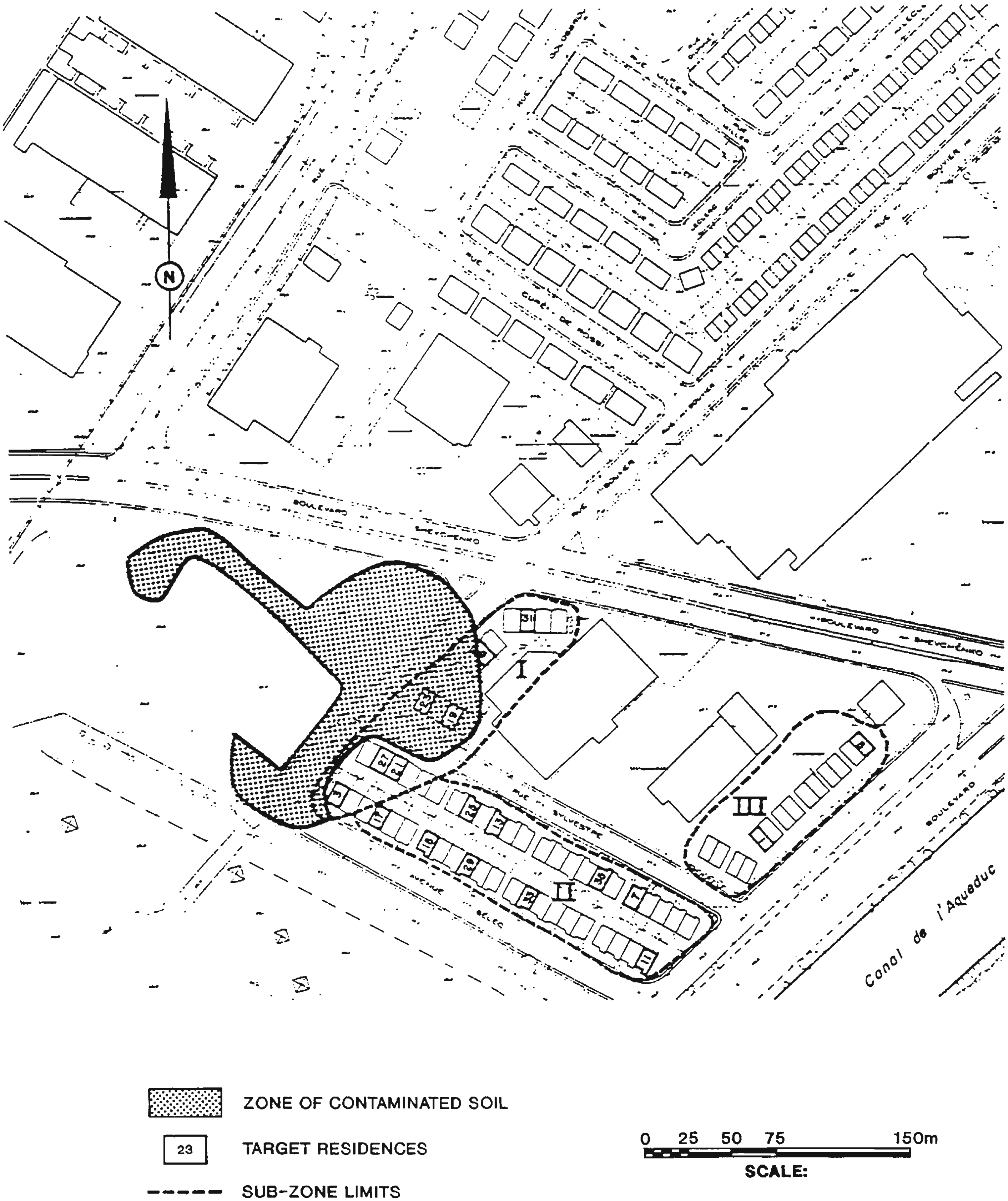
Ambient air was drawn through a cartridge containing molecular porous coal (Spherrocarb) to identify the more volatile hydrocarbons (2 to 6 carbon atoms). Sampling for heavier hydrocarbons was done by drawing air through a sampling cartridge containing approximately 10 g of Tenax GC resin. Ambient air samples were drawn through the cartridges using a modified Metrex Model AS-5/2 sampler. Sampling lasted 4 hours and the total volume of air sampled was 36 l for the resin cartridge and 14 l for the coal sample. Cartridges were then shipped to the River Road Laboratory of Environment Canada in Ontario. The VOCs collected samples were thermally desorbed in an automated thermal desorption system. The cartridges were heated and purged with helium; the compounds were desorbed, cryofocused and subsequently introduced into a high-resolution glass capillary column. A Perkin-Elmer Sigma 3B gas chromatograph equipped with Flame Ionization Detector (FID) and Electron Capture Detector (ECD) was used. The limit of detection for this method was 0.01 $ug/m^3$ and was used to determine the concentration of 55 hydrocarbons.

Results of a detailed statistical analysis (Gaucher, 1985) indicated that there was no significant differences between the concentration of VOCs detected in the ambient air of the target and control houses. In the majority of cases (89 percent of parameters analyzed), concentrations measured in the target houses were equivalent to those obtained at the control houses.

Following this detailed study, it was decided to demolish houses built directly on contaminated soil to avoid residents' direct contact with the contaminants, but no additional remedial measures were implemented at the other duplexes surrounding the dump (Personal conversation; Mr. B. Gaboury, MENVIQ).

**REFERENCES:**

Gaucher, M. 1985. Qualité de l'air ambient des résidences contruites sur l'ancien dépotoir de Ville Lasalle. rapport préliminaire. MENVIQ, Direction des substances dangeureuses. Québéc.

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# OLD LASALLE DUMPSITE

## FIGURE A-4: ZONE OF CONTAMINATED SOIL AND TARGET HOUSES WITHIN STUDY AREA

Gonthier, Claude. 1986. Étude de la qualité de l'air à l'intérieur des résidences construites sur le terrain de l'ancien dépotoir de la ville de LaSalle. Environnement Canada, Service de la protection de l'environnement - Région Québec.

Wang, K.W. 1984. Development of sampling and analytical techniques for measuring trace volatile organic compounds in Canadian urban areas, Part I and Part II. Environment Canada.

## CMHC SOIL GAS RESEARCH STUDY
## EASTERN CANADA SECTOR
## CASE STUDY #21

**BUILDING TYPE AND LOCATION:** Multiple housing units and a school (The Père Marquette site)

**GAS TYPE:** Methane and other landfill related gases

**SOURCE:** Old dump site

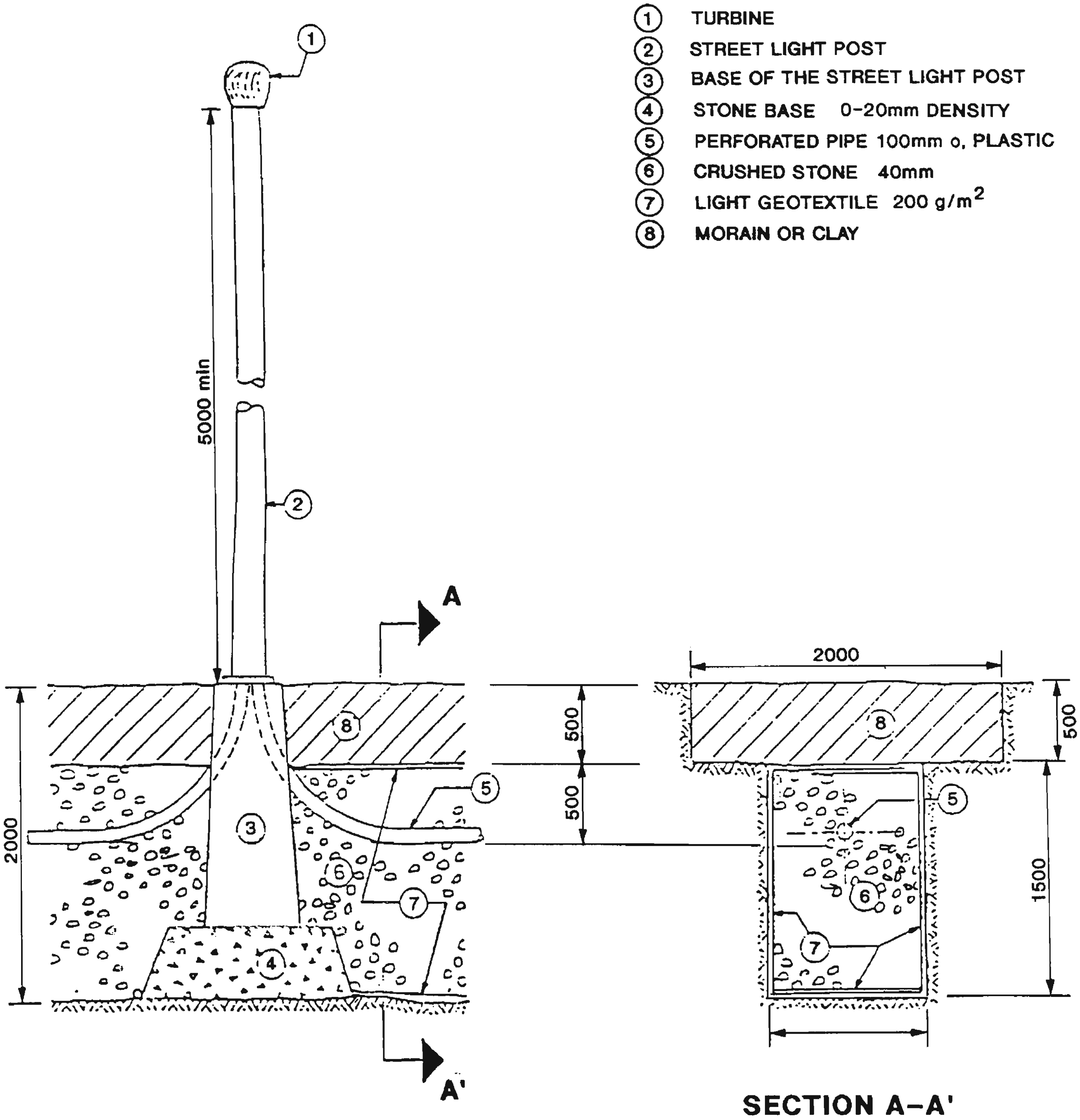
**TYPE OF CONTROL:** Passive venting trench between houses and the landfill, active venting system underneath the school

**CASE STUDY PRÉCIS:**

Montreal Quarry Co. used to operate a quarry in the Parc Marquette area. The quarry was later used as a dump site on which a park was developed and a school was constructed. Most of the old quarry is surrounded by multiple housing units built in the 1950s. Following complaints by residents located west of the landfill, the local gas utility company (Gaz Métropolitain) took some gas measurements around the landfill and detected landfill gases building up under the pavement of Chambord Street. Measurements taken by the Municipality later confirmed the presence of such gases.

It was decided that a passive venting trench between the landfill and Chambord Street be built to intercept the gas leaking toward the houses (Figure A-5). Three vents were installed above the 2.0 m deep trench to allow evacuation of the gas from the trench. Each vent consisted of a turbine placed on the top of a street light post. The trench is efficient and cost-effective due to its simplicity and the availability of the material.

Special measures were also implemented when building the Père Marquette Highschool, located on the north-eastern portion of the landfill property (Personal conversation; Mr. R. Bombardier, CECM). Underground parking was added to the school and was used as an active venting system. Explosion-proof blowers were added to create a negative pressure underneath the parking lot. Chimneys were built at the south-west corner of the school for the evacuation of the gas. Gas detectors (unknown specification) were also installed in the parking lot to detect any build-up of methane. The Montréal Catholic School Board (CECM) used similar corrective measures at other schools; they were found to be effective.




(SOURCE: INTERNAL CORRESPONDANCE; CITY OF MONTREAL)

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**FIGURE A-5: PASSIVE VENTING TRENCH USED ALONG RUE CHAMBORD IN MONTREAL**

**CMHC SOIL GAS RESEARCH STUDY**
**EASTERN CANADA SECTOR**
**CASE STUDY #22**

**BUILDING TYPE AND LOCATION:** Multiple housing units (4 to 6 units); (The Beaubien Langelier Park)

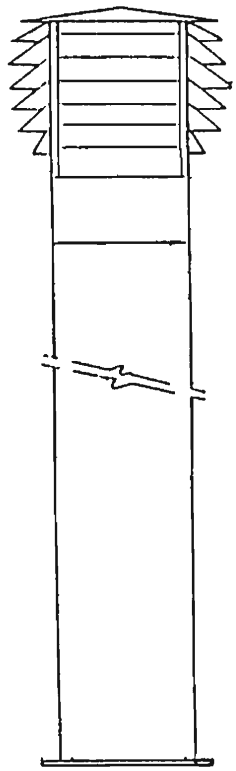
**GAS TYPE:** Methane and other landfill related gases

**SOURCE:** Old dump site

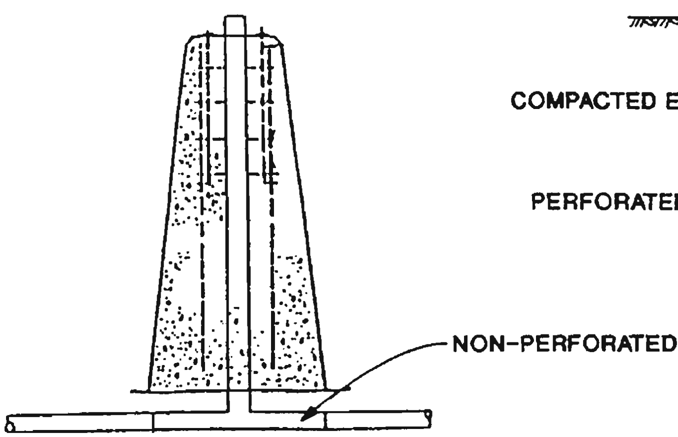
**TYPE OF CONTROL:** Permeable trench between houses and landfill (Preventive measure)

**CASE STUDY PRÉCIS:**

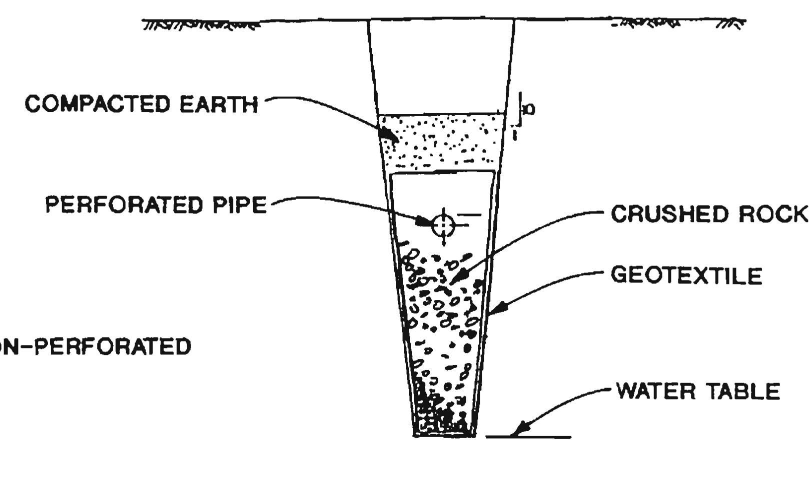
The Municipality is developing a park on an old quarry that was used as a municipal dump between 1951 and 1975. Multiple housing units are located on the east and west sides of the park. The City is presently installing a passive venting trench around the landfill to avoid migration of gases into nearby houses. The trench extends down to the water table and chimneys are placed along the trench to allow for the evacuation of the gas (Figure A-6). The south-western segment of the interceptor trench is already in place and the remaining segments will be constructed as development of the park progresses.



**VENT PIPE DETAIL**




**CONCRETE BASE DETAIL**




(SOURCE: INTERNAL CORRESPONDANCE; CITY OF MONTREAL)

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## FIGURE A–6: DETAILS OF THE PASSIVE VENTING SYSTEM AT THE BEANBIEN LANGELIER PARK

**CMHC SOIL GAS RESEARCH STUDY**
**EASTERN CANADA SECTOR**
**CASE STUDY #23**

**BUILDING TYPE AND LOCATION:** Triplex

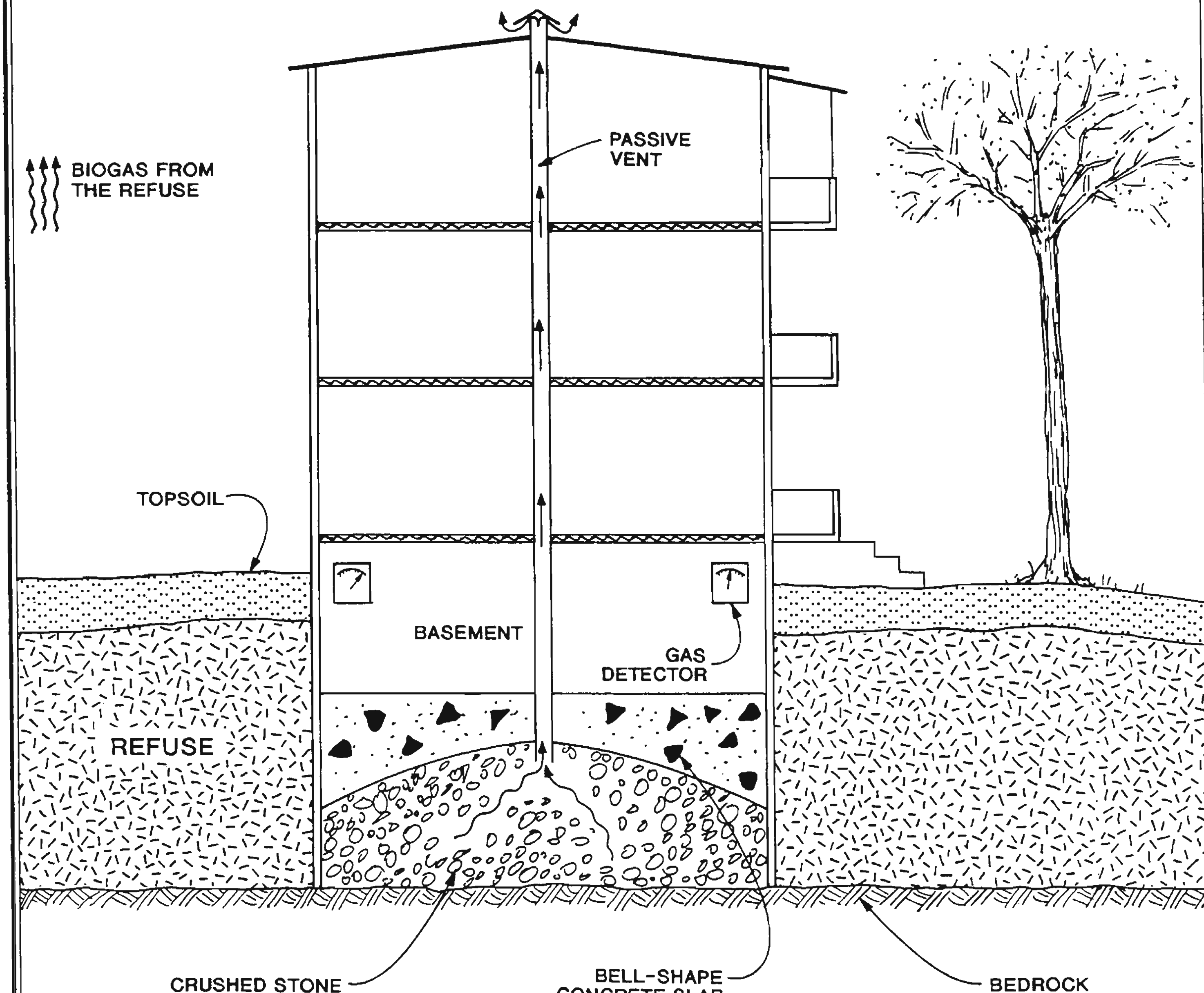
**GAS TYPE:** Methane and other landfill related gases

**SOURCE:** Old dump site

**TYPE OF CONTROL:** Passive venting system underneath the basement

**CASE STUDY PRÉCIS:**

In Montréal, a triplex was built on a small quarry that had been used as a dump site. A passive venting system was installed underneath the basement to intercept gases released by the refuse. The venting system consisted of a bed of clean crushed stone laid in an oval shape overlain by a slab of concrete serving as the floor of the basement and an impermeable layer (Figure A-7). A chimney, penetrating into the crushed stone, was added to the system to allow the release of the gas accumulating in the venting system. Finally, gas detectors were placed into the basement to detect any concentration build-up of methane. The remedial measure has the added advantage of not requiring any moving mechanical part and is reported to be working effectively (Personal conversation; M. S. Barbeau, City of Montréal).




(SOURCE: PERSONNAL CONVERSATION WITH
MR. SERGE BARBEAN, Ville de Montreal)

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**FIGURE A-7:**

**PASSIVE VENTILATION SYSTEM FOR A TRIPLEX BUILT ON A SANITARY DUMP IN MONTREAL, QUEBEC**

## CMHC SOIL GAS RESEARCH STUDY
## EASTERN CANADA SECTOR
## CASE STUDY #24

**BUILDING TYPE AND LOCATION:** Industrial Buildings; The Adacport site

**GAS TYPE:** Landfill related gases

**SOURCE:** Municipal and industrial waste

**TYPE OF CONTROL:** Adapted construction design

**CASE STUDY PRÉCIS:**

Between the late 1800s and 1966, the City of Montréal has disposed of unclassified refuse on the bank of the St. Lawrence River, between the Victoria and the Champlain bridges (Foratek Intl. 1985). Over the years, approximately 140 ha of land have been developed at the expense of the St. Lawrence River. The Ministry of Transportation built a major highway across the site. A Hydro Québec Viger substation, CN Rail locomotive maintenance centre, the Adacport airport runway, and a wastewater treatment plant have also been built on the site. Recently, the City of Montréal acquired the site and is developing the TECHNO PARC, a 75 ha park for hi-tech industries. Téléglobe Canada is presently building its international communication centre in the park.

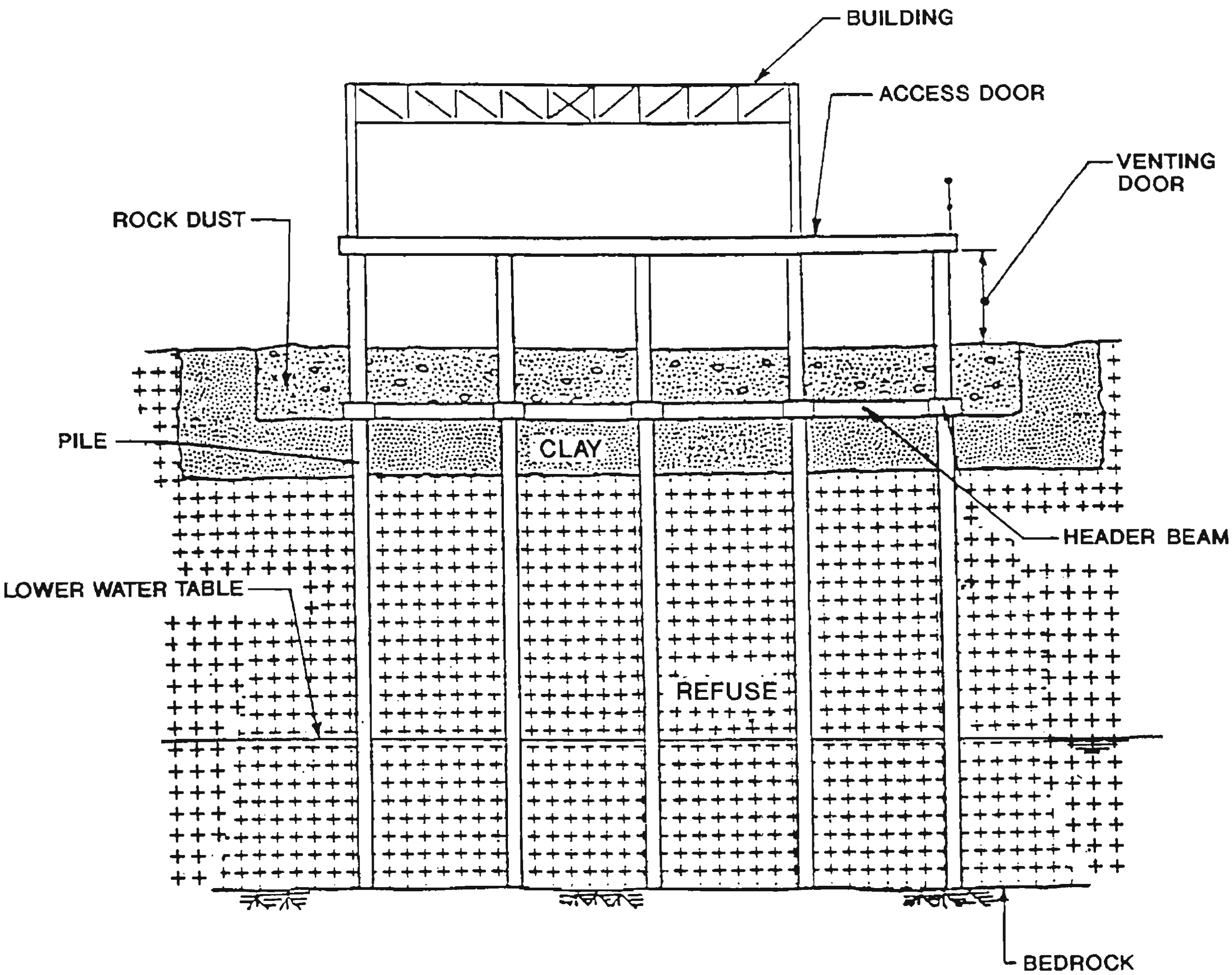
Many studies have been conducted on the site to characterize the type of refuse and to evaluate the potential impact of the refuse on people and the environment. ADS (1988) presents various corrective measures related to: the decontamination of the sensitive areas of the site; the construction of municipal infrastructures such as sewers, aqueducts, lighting, and roads; and the construction of industrial buildings.

To minimize the migration of toxic gases into the industrial buildings, two sewer systems will be built: a pressurized plastic sewer system for sanitary sewage, and a conventional passive concrete sewer system for the storm water sewer system. Remedial measures for the industrial buildings include: construction on posts with an air space between the original ground level and the floor of the building (Figure A-8) and construction of posts at ground level with a active venting system under the building (Figure A-9).

**REFERENCES:**


ADS, 1988. Caractèrization du site et des environs de l'Adacport. Rapport No. N/D 36-136, V/D 88f33A. Ville de Montréal, Service des travaux publics. Montréal, Canada.

Foratek Intl. 1985. Étude des gaz - Site de l'Adacport. Environnement Canada - Région Québec, Rapport No. 664, Projet No. FF 85015.




SOURCE: BEAK 1979

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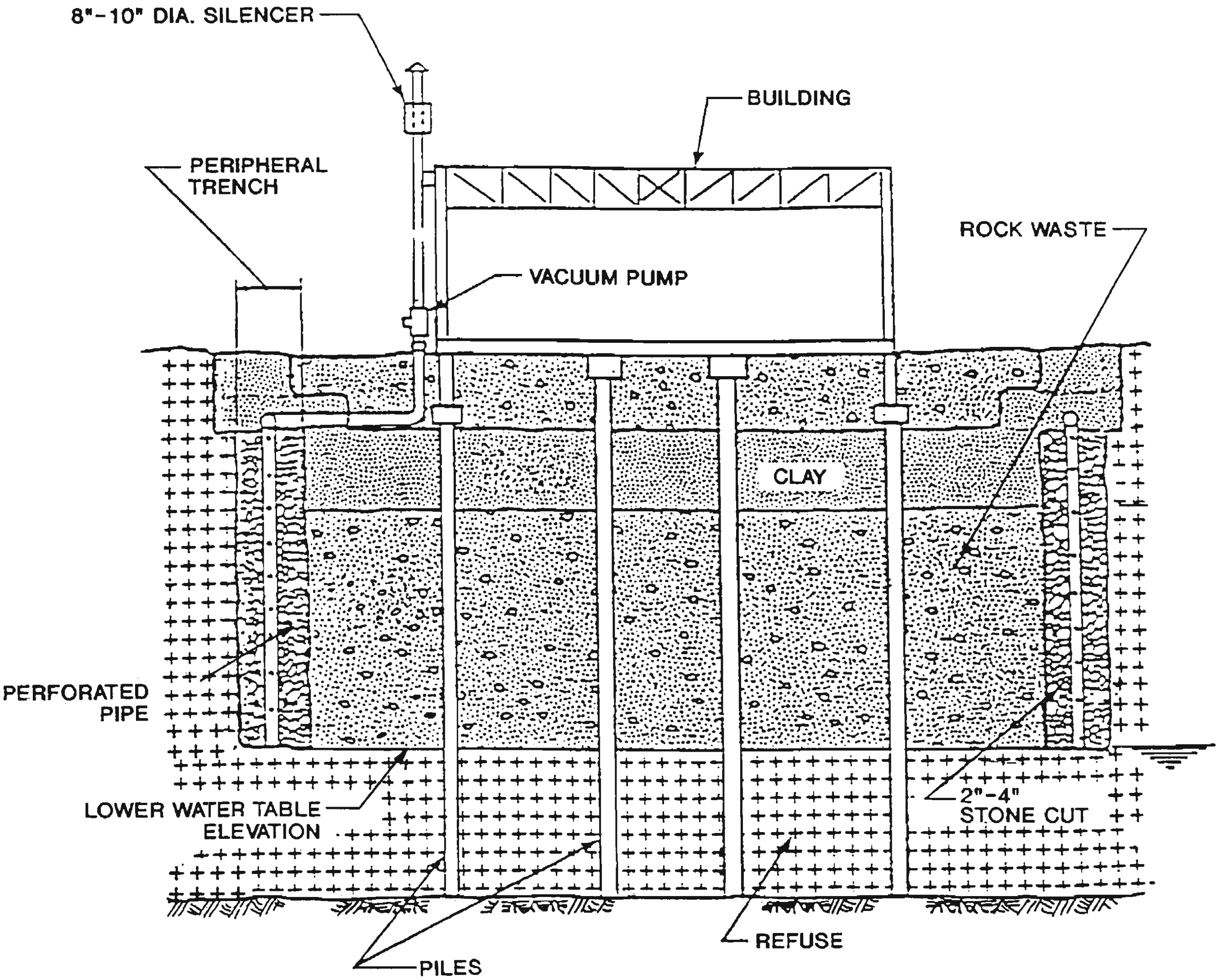
**FIGURE A–8: GAS CONTROL USING STRUCTURAL PILES AND A VENTILATION SPACE**




SOURCE: BEAK 1979

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**FIGURE A-9:**
**GAS CONTROL WITH THE USE OF AN IMPERMEABLE BARRIER AND PERIPHERAL VENTILATION TRENCH**

**CMHC SOIL GAS RESEARCH STUDY**
**EASTERN CANADA SECTOR**
**CASE STUDY #25**

**BUILDING TYPE AND LOCATION:** Four commercial buildings

**GAS TYPE:** Petroleum

**SOURCE:** Leaking underground piping

**TYPE OF CONTROL:**

**CASE STUDY PRÉCIS:**

Some time on the night of April 18/19, 1986, a pipe between some gasoline storage tanks and pumps broke at a local service station leaking an uncertain quantity of gasoline. The spill found its way into a connector drain which joined to the main sewer. Gasoline vapours backed up through the drain connectors of at least four buildings, forming an explosive mixture. The explosive vapour reached the upper levels of some of the buildings, making its way through stud spaces into spaces above false ceilings.

The source of ignition, probably the starting of oil furnaces in basements, occurred some time after the explosive mixture spread. The gasoline vapour caught fire and caused deflagration through the vapour cloud. The blast pressure caused damage wherever the concentrated gasoline vapour cloud existed. The explosion ignited other combustible material and, in one case, caused a major fire.

Immediately following this incident, a consultant was brought in to advise the City Emergency Measures Organization on this matter (Cooke, 1986). The consultant was brought in to advise the Organization on what happened and what should be done to prevent a reoccurrence of such an event.

Shortly after the explosions, it was suspected that the spill originated at a local gas station. The tanks and pipes in the station were pressure tested. The tanks did not leak; one of the pipes did not pass the pressure test. A backhoe was used to dig up the strip between the sewer and the service station. A collector drain was uncovered and found to contain gasoline; the collector eventually made its way to the sewer. City plans of the sewers in the area showed several collectors joining to the sewer. Further excavation revealed that a leak in the pipe joint from the gasoline storage tank was the origin of the spilled gasoline. The pipe in question had been laid over rubble which existed from previous buildings on the site. This constituted a contravention of the National Fire Code of Canada. (The code states, "Underground piping shall be supported on undisturbed or compacted soil and shall be backfilled on top and sides with at least 300 mm of pea gravel or clean crushed stone or at least 300 mm of clean sand, free of cinders and stones and compacted in layers not greater than 300 mm thick...". A similar stipulation exists in the Gasoline Handling Act of Ontario.)

As noted above, the pipe cracked at a joint and consequently a large quantity of gasoline entered the ground. According to the consultant, this should not have occurred. Given that the gasoline was dispensed with a submersible pump installed in the tank, a leak detector must have been provided with the pump. If a leak should have developed, a properly operating leak detector device would have restricted the flow emerging from the pipe. As such, the large quantity which was believed to have been lost at this site would not have occurred. The conclusions reached by the consultant was that there was no leak detector or simply it was not functioning properly.

Figure A-10 shows the plan of the sewer system in the locality of the gasoline spill, indicating the location of the spill area, the connecting sewer and the buildings which were damaged. It was believed that as the gasoline ran down the sewer, some of the gasoline volatilized. As this happened, the gasoline vapour could make its way up out of the sewer system via the storm drain located along its path or alternatively through an open connection within a building. In the various buildings shown on Figure A-10, such openings were believed to exist.

Building #1

In the basement of building #1, it appeared that gasoline vapours entered the building through a pipe which was found to be open. The consultant speculated that a toilet likely existed on this pipe. Figure A-11 is a sketch of the suspected gasoline vapour pathway in building #1.

Building #2

In the basement of building #2, the seepage water from the weeping tile of the building was pumped through flexible hoses into a ceramic tile sewage connector which joins to the main sewer. Figure A-12 shows how the plastic hose was simply pushed through a hole which had been broken into the top of the tile drain. The hole was suspected of allowing free passage of gas vapour to the inside of the building. The plastic pipes had partially melted and burned where they were inside the ceramic tile.

Building #3

In the third building, the basement was found to contain a large rectangular drain which ran the length of the basement. At the front of the building, it dropped down through a sump which was connected to the sewer system. It was suspected that arrangements for the trap on this sump were inadequate, since vapours had come through it.

Building #4

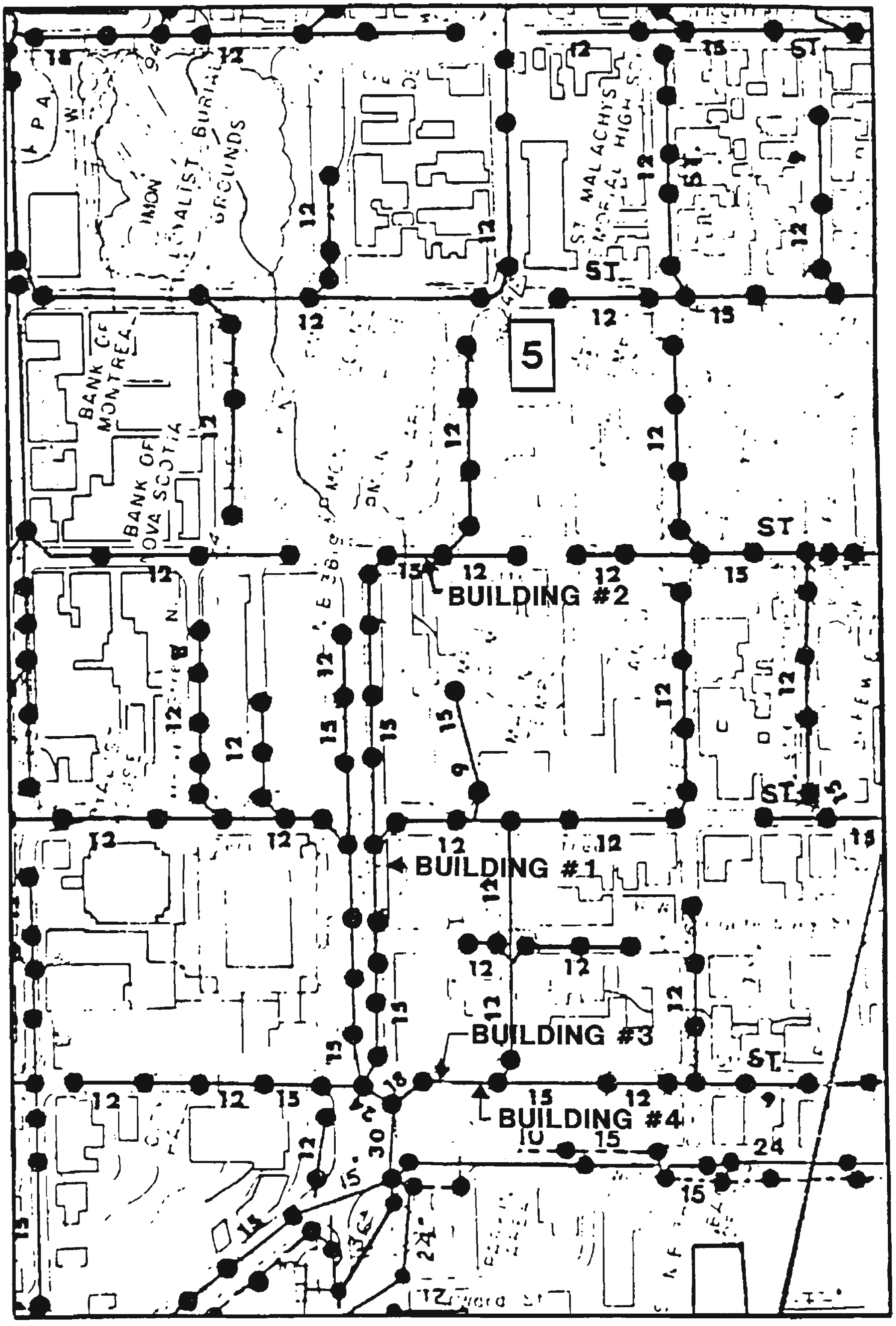
This building was completely demolished by the explosion and resulting fire. It could not be investigated in detail due to the extensive damage. In view of the damage, it was likely that a large amount of gasoline vapour had entered into the building. Since building #4 had been vacant for some time, there was a real possibility that the sealing water on the traps in the toilets had evaporated. This would have allowed free passage of the gasoline vapour into the building.

Summarizing the cases, the consultant indicated that in the case of buildings #1, #2, and #3, the plumbing installations contravened the Canadian Plumbing Code, 1985. Furthermore, in the case of buildings #1 and #3, the gasoline vapour made its way up through the basement through the stud spaces into the upper reaches of the building. In both cases, the stud space were open above a false ceiling, and the false ceilings were blown downward. If properly constructed fire separations existed in the stud space and above the false ceilings, this likely would not have occurred. In building #2, the basement had recently been refinished and the new construction prevented the vapours from progating up to the floor above. The consultant advised that it was important to localize and minimize the spread of vapours entering the building. There are many provisions (i.e. sealed fire separations) in both the National Building Code and the National Fire Code to this effect.

Recommendations to further prevent such disasters also included guidelines for gasoline service stations. Cooke (1986) recommended that all gasoline service station owners comply with API installation guidelines or the National Fire Code of Canada (1985). Both of the above codes deal with the proper installation of the connecting piping and both require the installation of an approved leak detector. The Ontario Gasoline Handling Code also requires an annual inspection, which was also recommended.

**REFERENCE:**

Cooke, N.E., 1986. Report on the Causes of the Explosions and Fire... and Recommendations to Prevent a Reoccurrence of the Event.




***LEGEND:***

5 GASOLINE STATION

● STORM SEWER DRAIN

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**FIGURE A-10: PLAN OF SEWER SYSTEM IN THE VICINITY OF THE SPILL (Source: Cooke, 1986)**

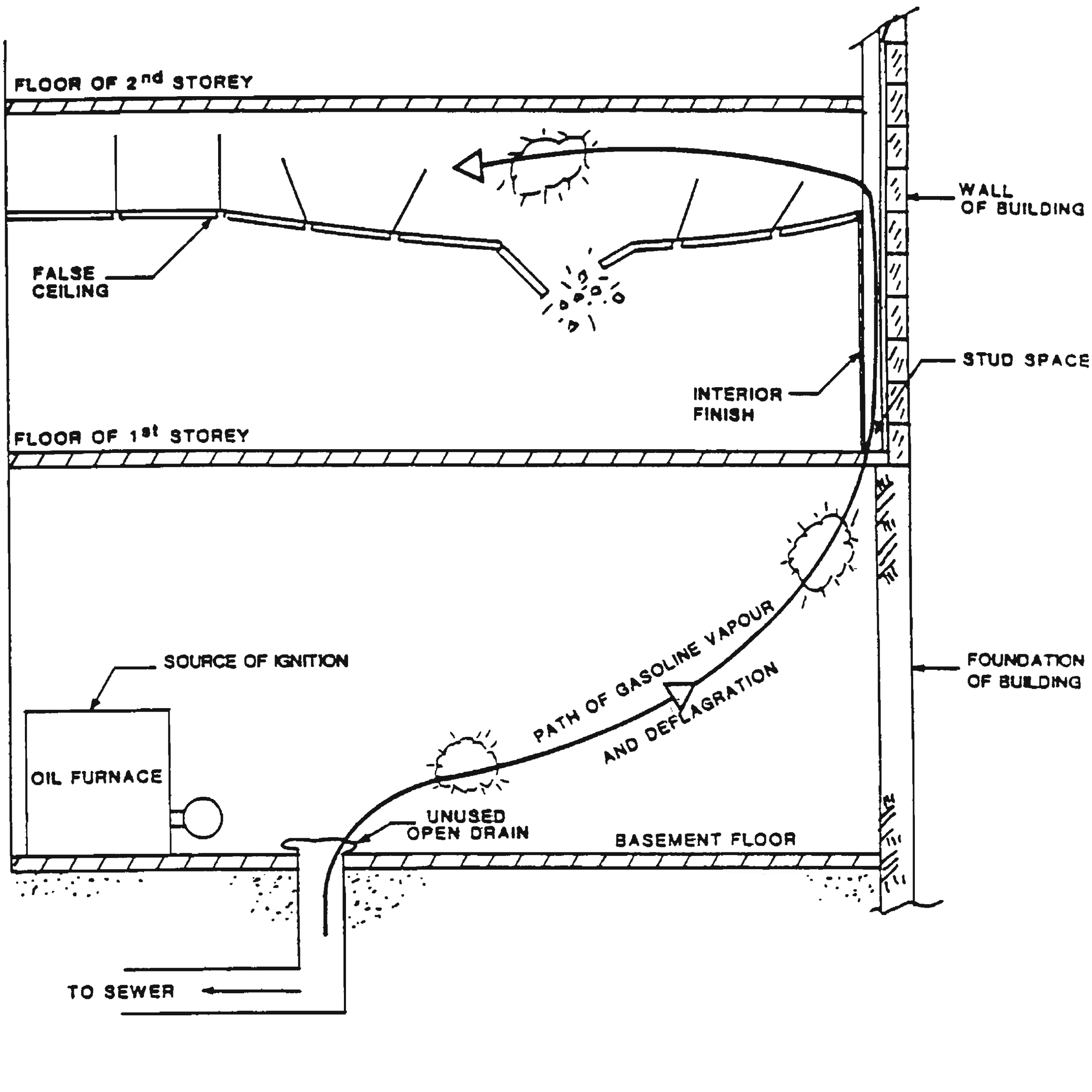


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**FIGURE A-11:**
**SUSPECTED GASOLINE VAPOUR PATHWAY IN BUILDING #1**
**(Source: Cooke, 1986)**

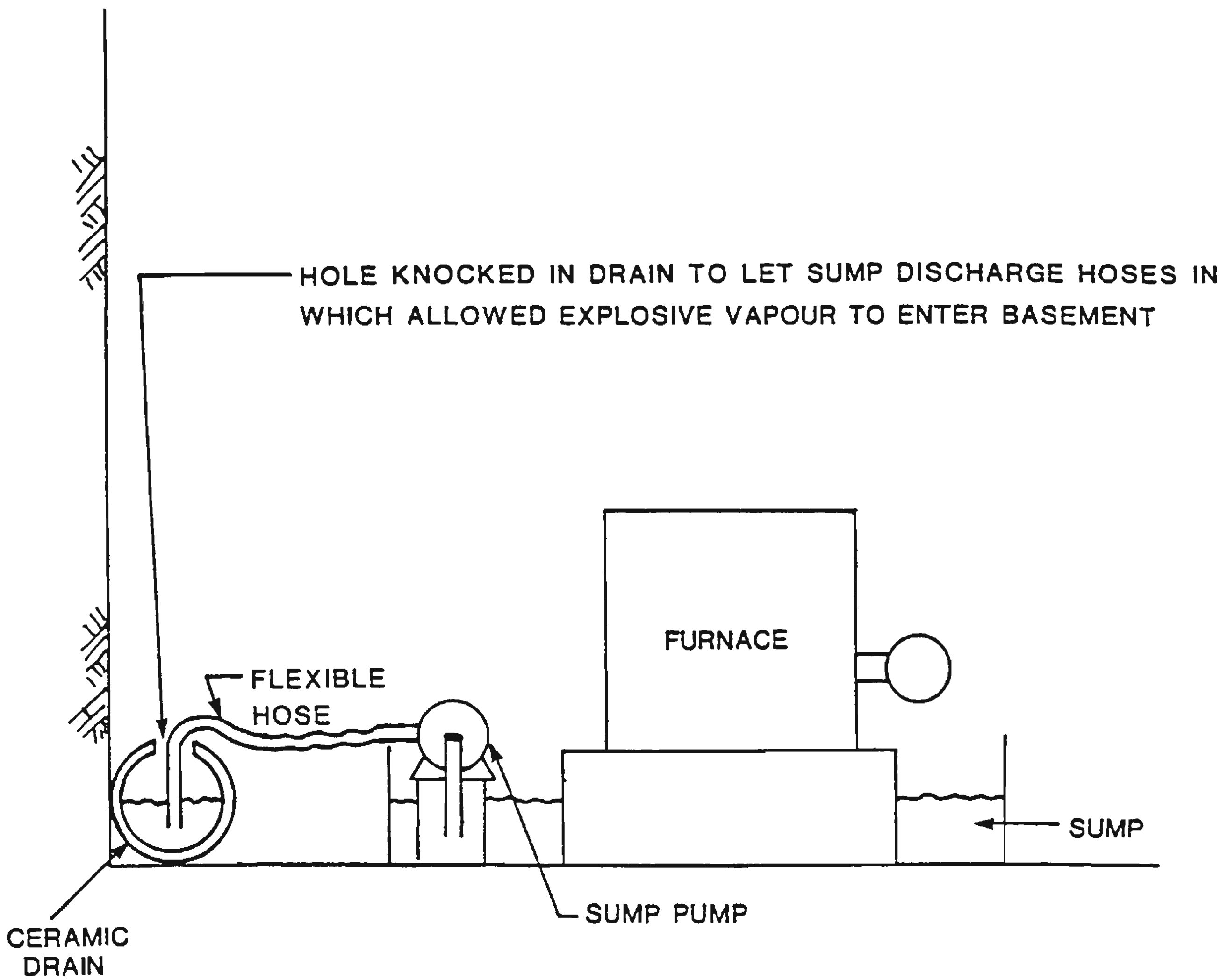


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**FIGURE A–12: DIAGRAMATIC SKETCH OF ARANGEMENT IN BUILDING #2 (Source: Cooke, 1986)**

# Appendix B

# CENTRAL CANADA CASE STUDIES

## CMHC SOIL GAS RESEARCH STUDY
## CENTRAL CANADA SECTOR
## CASE STUDY #1

| | |
|---|---|
| **BUILDING TYPE AND LOCATION:** | Residential houses, Greenwood Avenue |
| **GAS TYPE:** | Methane |
| **SOURCE:** | Native fill material |
| **TYPE OF CONTROL:** | Passive venting systems for each of the 32 semi-detached homes. No indoor monitoring system was deemed necessary. |

### CASE STUDY PRÉCIS:

Methane concentration in the neighbourhood of 0.1 percent to 30 percent was detected in the subsurface of a proposed residential development. No monitoring details were available at the time of writing this report. A subsequent study revealed that the methane gas was a product of the property's underlying fill material. As a result, a passive venting system was installed in each of the 32 semi-detached homes to control the methane gas problem. Post-construction monitoring revealed that no methane gas had penetrated the homes and as such, no further monitoring was conducted.

### The Problem

The houses typically were wood-framed, three-storey backsplits with brick veneer walls. Each contained a forced air furnace. Basement depths were designed to provide a maximum height of 2.1 m and a minimum height of 1.4 m in the crawl space with basement walls of an 200 mm thickness.

The passive venting system was chosen because the methane gas production rate was low. No rationale was given as to how the generation rate was assessed. The installation of a gas interceptor system in each of the 32 houses was supervised since the trades were unfamiliar with the venting equipment. The gas interceptor system consisted of:

- an inlet for fresh air flow to the space enclosed by the internal vertical faces of the exterior footing and the floor slab
- a granular base with void ratio to allow the circulation of soil air
- a collection pipe for the soil air containing landfill gas

- an outlet for the landfill gas
- a driving force to induce negative pressure in the collection pad and, thus, flow up the riser pipe (stationary exhausts)
- probes to monitor system effectiveness

The only brand name piece of equipment was an Eveco blank fixed vane (stationary) exhauster.

**Post Construction Test Results**

Monitoring for soil gas emissions was conducted prior to construction in the fill and once following construction. The maximum concentration detected during sampling after construction was 3,000 ppm in a gas probe. Methane gas was not detected in any of the basements.

As a result of the low gas production rate, no indoor gas monitors were deemed necessary. The only requirement stemmed from the Ministry of the Environment stating the need for a passive venting system on each unit in the development being within the 5 percent methane concentration limit.

Since no methane gas was detected following construction, a monitoring program was determined to be unnecessary. No complaints have been reported in the nine years following construction. However, should a complaint occur, the current protocol would be reviewed, perhaps leading to a monitoring program.

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #2**

**BUILDING TYPE AND LOCATION:** Condominium in a mixed residential-commercial area, Oakville, Ontario

**GAS TYPE:** Methane

**SOURCE:** Fill exhibiting a gasoline smell overlying organic silt

**TYPE OF CONTROL:** An active venting system was decided upon to achieve the appropriate air exchange and negative pressure in the floor slab

## CASE STUDY PRÉCIS:

The Oakville site, located in a residential-commercial area, was designated for construction of a condominium complex. Soil gas monitoring in open boreholes revealed methane gas to be present in explosive amounts (actual data was not made available). These explosive amounts were located in the central portion of the proposed site where 3 to 4.6 m of fill overlaid organic silt. The fill had a gasoline-like smell, the reason for which was not determined.

An active venting system was installed, but no monitoring was initiated subsequent to construction. No records concerning post-construction monitoring or Ministry of the Environment requirements were ever found. Indoor monitors were also deemed unnecessary after construction.

### The Problem

The condominium complex consists of a concrete frame with brick exterior walls, an underground parking garage with a maximum clearing height of 2.1 m and 250 mm thick walls, and numerous storeys of residential units ranging from two to six across the site. Each unit contains a forced air furnace.

The active venting system installed under supervision consists of:

- an air inlet sub-system, complete with screen, piping and valve
- an air exhaust sub-system, complete with piping, valve, fan, exhaust stack and screen
- an envelope for gas collection below the concrete floor slabs with portions of CPE membrane strips bonded to vertical faces

- a monitoring sub-system with sub-floor probes terminating in an accessible valve and a fan fail switch

The active venting system was chosen over a passive venting system in order to achieve the required air exchange and negative pressure in the envelope located below a floor slab of great length and width. The equipment comprising the venting system is as follows:

- a Buffalo Model "E" exhaust fan
- low modulus 30 mil unreinforced chlorinated polyethylene (CPE) sheeting supplied by the Pantasote Company of New York Inc.
- Terrafix Type 27OR porous filter mat
- butterfly valves of Chemline TBF series
- "Tel-a-Pipe" markers by Safety Supply Canada
- fan vibration mounts by GP Environmental Products (Kitchener)
- Type 313 Warren Controls overflow trap

**Post Construction Test Results**

Post construction test results were not available since monitoring did not occur following construction. Indoor monitors were not installed in the condominium complex, and the Ministry of the Environment imposed no special conditions regarding safe concentrations in the building. No reports of complaints have been recorded following construction.

# CMHC SOIL GAS RESEARCH STUDY
# CENTRAL CANADA SECTOR
# CASE STUDY #3

**BUILDING TYPE AND LOCATION:** Proposed residential area, Oshawa, Ontario

**GAS TYPE:** Combustible gases

**SOURCE:** Due to inadequate provisions of landfill gas venting, combustible gases escaped to adjacent areas

## CASE STUDY PRÉCIS:

Methane gas migration has been the subject of numerous investigations at the privately owned landfill site near Oshawa, Ontario. The landfill had accepted primarily industrial wastes ranging from tires, construction debris, paper and metals, etc. Adjacent properties include Corbett Road to the north, the area of a proposed subdivision to the west, and a conservation area and creek to the south and east.

The landfill encompasses 10 ha with a maximum height of 145 metres in the centre, levelling to a height of 120 metres in the south, and 143 metres in the north. The landfill site and adjacent properties are located on the former Lake Iroquois shoreline which contains a base of sandy silt till with a clay content of 8 percent, overlying a clayey silt till. Sand deposits are shallow in the north with a depth of 1.2 to 1.8 metres, but thicken towards the west to a depth of 9 metres. The water table is believed to fluctuate from the ground surface to the till surface on a long-term basis, and a perched water table rests on the clayey silt and sand till.

Horizontal fissures and fractures are present 4 to 6 metres below the upper till surface. These fractures are believed to be a conduit for lateral gas migration onto adjacent sites. During two investigations at this site, one fact which was particularly notable was the absence of free water within the fractures. In addition, the depth of the fractures coincided with the occurrence of combustible gas found offsite in several gas monitoring probes.

Long-term monitoring at this site revealed gas concentrations ranging from non-detectable to elevated levels in the west, up to 56 percent in the north, and up to 88 percent on the actual landfill site. Typically, monitoring was completed with the use of Detecto Pac II and a Scott D15 combustible gas tester. Chemical analyses of groundwater also revealed elevated readings for chloride, iron and sulphate, with iron oxide staining breakouts occurring along the western boundary of the landfill.

Gas vent stacks were installed on top of the landfill to reduce gas concentration, but have had limited success as exhibited by perimeter gas measurements. As a supplement, a venting ditch was installed along the western boundary of the landfill site to act as a gas barrier. The construction of the ditch involved the removal of all organic matter and sandy soil to the top of the clayey silt till. The width of the trench spanned three metres. The land to the west of the ditch was graded to a gentle slope virtually ensuring limited onsite organic matter. This also would change soil gas flow patterns.

A study was initiated by a development corporation interested in developing some of the neighbouring lands. Based on the data review, the developer's consultant concluded that the landfill in question had both a leachate and a gas migration problem. In order to remedy these conditions, a leachate collection system and a suitable gas venting system was recommended. A suitable gas collection system would preferably create a negative pressure gradient towards the landfill site, i.e. away from adjacent properties. As well, the consultant recommended any mitigative measures considered by the developer should be secondary in nature. Any measures implemented by the developer should be confined to developing "barriers to gas movement and to maintenance of perched groundwater levels close to their present stratigraphic positions". The consultant warned against the construction of any gas control by the developer that would decrease the negative pressure gradient in the soil towards the landfill. The report was filed in March 1982.

As a result of the initial findings, a second investigation was launched of after some action was conducted by the Ministry of the Environment (MOE). Presumably the action by the MOE was a request of the landfill site owner to improve the gas collection practises (this fact, however, is not known). As a condition for ultimate land development, a second set of probes were required to be installed along the inner side of a "Holding Zone" agreed to by the Ministry of the Environment (Information in regards to the "holding zone" were not attainable at the time of writing this report). A condition for approval by the MOE (Nov. 17/83) required that the newly installed probes were free of "significant combustible gas" for a period of one year. After one year of monitoring, the consultant filed the next report.

In the next phase of monitoring, combustible gas measurements were taken using a Scott D-15 combustible gas tester. Gas was manually pumped through the meter via quick disconnect fittings. Monitoring was carried out once a month with biweekly readings during spring thaw conditions. Two series of probes were monitored, one set which was close to the property boundary, and the other set of probes were on the interior of the lands designated as the holding zone. The series of probes closest to the property boundary "generally indicated concentrated gas measurements... during the winter months when the frost cover is complete". The report further stated, "when frost leaves the ground in the spring, noticeable drops in the combustible gas concentration occur. This is graphically noticeable on the graphs presented...". Data from two of the property boundary probes (i.e. probe locations 2 and 6) are presented here on Figure B-1. Although boundary probe location 2 exhibits the above mentioned behaviour, boundary probes 6, 6A, and 6B do not show a similar pattern. No rationale for such behaviour was determined nor was any correlation made with other environmental factors. The consultant further found that "sporadic combustible gas was noted in many of the probes with no consistency..."

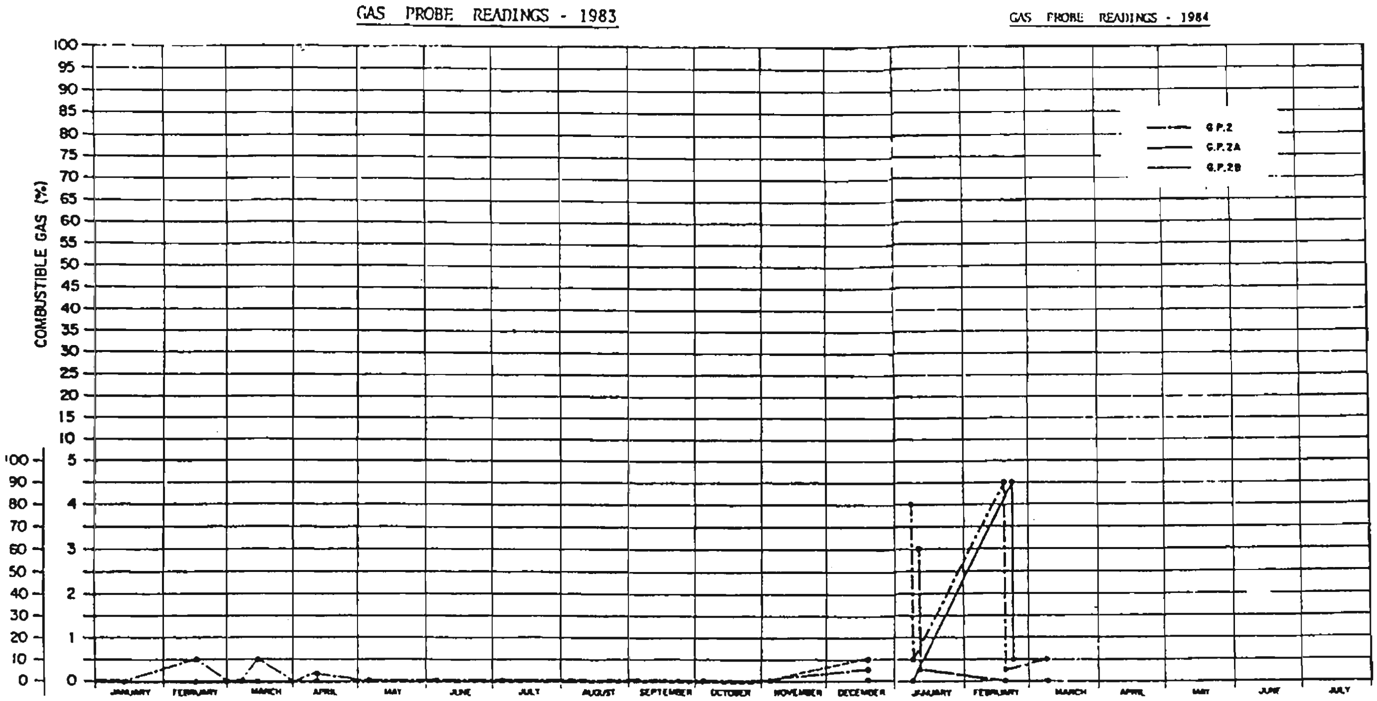
The second series of probes installed away from the property boundary initially had gas combustible gas readings of .5 to 20 percent by volume. The consultant, however, viewed those results as meaningless because of the strong odour of distinctive glue solvent that was used to assemble the probes. After venting and flushing of the probes, zero readings were observed for a period of one year. (It is uncertain how flushing would achieve no "background" concentration.)

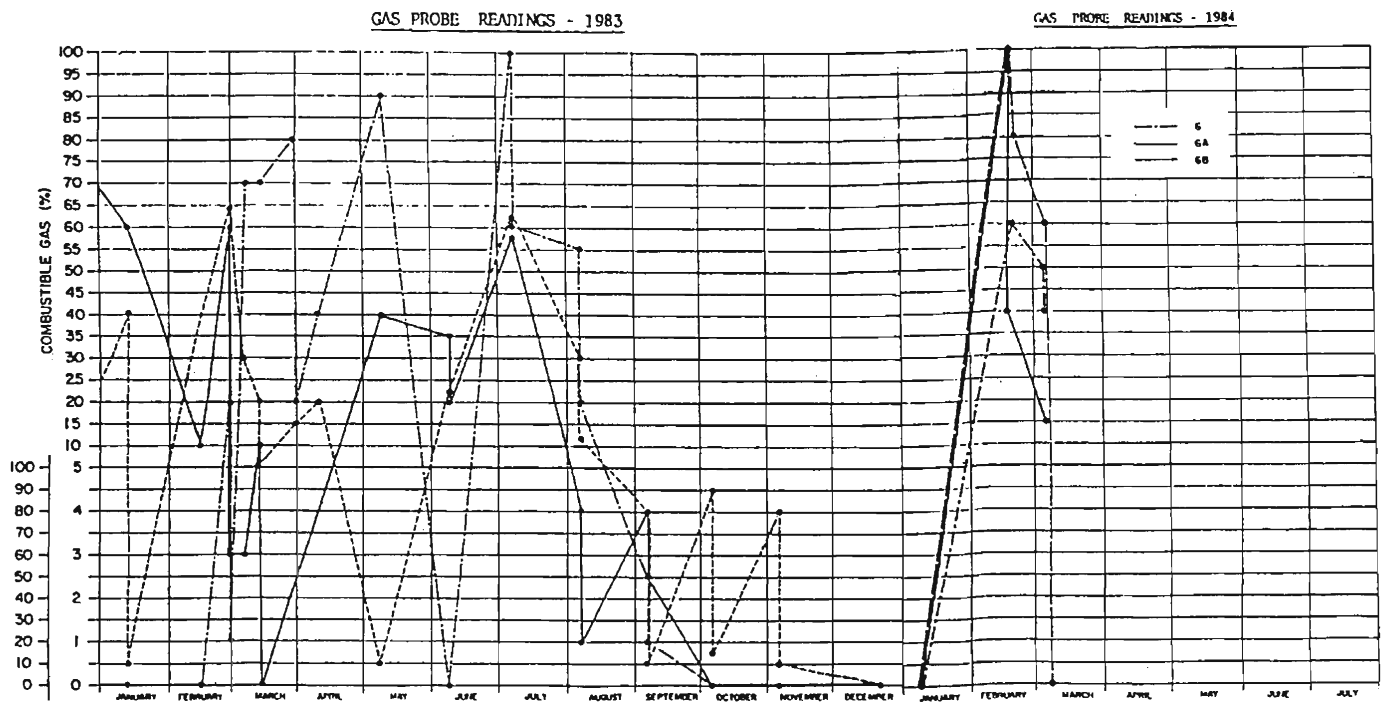
Details were sketchy on subsequent activities in the area; however, subdivisions do presently exist in the proposed areas.

**REFERENCES:**

Marshall Macklin Monaghan Limited, 1984. Report on Gas Monitoring Oshawa Property.

Marshall Macklin Monaghan Limited, 1982. Investigation of Property at Harmony Road and Corbett's Road, Oshawa for Gas Migration.




**NOTE:** ALL PROBES ARE LOCATED AT APPROXIMATELY 4.6m DEPTH (15 FEET BELOW GRADE)

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**FIGURE B–1: PROPERTY BOUNDARY PROBE DATA, OSHAWA PROPERTY**

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #4**

| | |
|---|---|
| **BUILDING TYPE AND LOCATION:** | Residential homes, Oshawa |
| **GAS TYPE:** | Methane |
| **SOURCE:** | Organic fills, landfill |
| **TYPE OF CONTROL:** | Buffer Barrier |

**CASE STUDY PRÉCIS:**

The closed landfill on the City of Oshawa's properties is located on the east side of Ritson Road just north of the Taunton Road. In the autumn of 1979, the City of Oshawa, in conjunction with the Ministry of the Environment, excavated the refuse out of a 23 m wide zone running along the total length of the southern landfill boundary. This excavation extended to the underlying natural glacial till soils. The trench was then backfilled and compacted with clean, earth fill. The buffer fill was composed of mostly compacted, slightly gravelly, clayey and silty fine sand fill. In one section, 30 m of plastic sheeting was placed on the southern excavation face before backfilling. It was intended that this buffer barrier would prevent the lateral migration of landfill gases onto the neighbouring private property.

Upon completion of this buffer, several gas monitors were installed by the City within the barrier and on the private property to the south. Routine monitoring by the City of Oshawa detected combustible gases at five installations within the barrier and one installation on private property outside the landfill and barrier. Some of these levels exceeded the lower explosive limit of methane.

In response to these results, a consultant was retained by the City to assess the effectiveness of the existing buffer barrier in retarding gas movement offsite, to determine where gas is apparently moving and to assess the impact on the proposed residential development abutting the south side of the site. Figure B-2 shows the location of the landfill site, barrier and nearby homes.

As part of the investigation, the consultant did a soil stratigraphic analysis, mapped the water table, and performed combustible gas and pressure testing. The study revealed that migration of combustible gases into the subdivision may have been the result of gas movement through the buffer and methane coming from an alternate source on the private property. The conclusion was based primarily on the fact that no permeable zones in the buffer had been identified during drilling which could have accounted for the rapid migration of explosive methane levels to the private lands. As a result of this discovery, study priorities were redesigned to include checking for methane in neighbouring homes and underground service outlets, to complete test pits on private property in search of alternative methane sources, to implement remedial measures, and to investigate potential avenues of gas migration through the buffer. Potential avenues of a gas migration were to observe if fracturing and/or sand seams existed, and to complete a gas pumping test to induce pressure gradients across the buffer barrier.

Twenty gas monitors consisting of a 1.9 cm diameter PVC pipe slotted from approximately .60 metres below surface to the bottom of the boring with a cement seal 45 cm thick had previously been installed by the City to monitor gas concentration levels. Nine additional monitors of identical design were installed to further monitor gas concentration levels. The slotted sections of the nine monitors were wrapped in fibreglass cloth to prevent siltation. The boreholes were then backfilled with gravel and an 45 cm seal of bentonite/concrete mix. Ten test pits were also dug to determine if methane gas was being produced in these specific areas. The pits were 0.6 m wide by 4.57 m long and varied in depth between 1.8 to 3.7 metres. No methane gas was detected in the test pits. Figure B-3 shows the range of soil gas pressure and Figure B-4 shows the range of combustible gas concentrations in the vicinity.

The soils on the private lands were generally fills overlying a thin layer of silty sands followed by a glacial silty sand till. The fills varied in depth to a maximum of 3.7 metres. Outside of the fill area, the private property soils were found to be a thin veneer of natural sand soils overlying till. Further to the south, the till reaches the surface. The water table is shallow at less than 3.05 metres, and drops off gradually to the southwest. The water table was generally at a higher elevation than the bottom of the buffer barrier fill.

The maximum methane concentration observed within the refuse next to the buffer was 25 percent. One monitor, located in the refuse near the centre of the landfill, recorded methane concentrations as high as 65 percent. On private lands, the maximum concentration was 12.5 percent. No methane was detected in the monitors on either the buffer side or the private property side of the plastic barrier, and therefore not in the house themselves. No combustible gases were detected in any of the underground service outlets or within the houses (in five monitoring events) adjacent to the study area. Soil gas pressures taken at various locations varied between 0 and 230 Pa (refer to Table B.1). The pressures seldom exceeded 76 Pa and usually averaged less than 25 Pa. In general, the barometric pressure remained relatively constant during monitoring.

The pathway for methane migration was discovered during pit excavation. A breach in the buffer barrier, through the sandy horizons and through fractures in the buffer till, had permitted the migration of methane. A minor component of this migration was also believed to be occurring through the upper fractured section of the barrier. The main area of gas migration, however, was through the buffer north of Pompano Courts. Alternate sources for methane gas migration were not discovered.

Methane breaching the buffer barrier migrated into the adjacent sandy soils and fills to the south. Combustible gases did not appear to be migrating across Palmetto Drive or Pompano Court. However, should houses be built on the north side of Pompano Court and the west side of Palmetto Drive, there would be potential concerns of the migration of combustible gas towards these dwellings.

A passive venting system (see Figure B-5) was proposed to control any migrating gases. The passive venting interception system would consist of a trench extending from the surface to below the minimum water table backfilled with permeable material such as granular or crushed stone, and sealed with an impermeable barrier (usually plastic) on the private property side of the trench.

Another consulting firm was contracted to examine alternative venting systems and proposed three possibilities: a passive system, an active system and a hybrid system. The three options had seven common elements:

- the venting system should be installed in the middle of the 23 m buffer barrier
- the trench should be excavated to 0.3 m below the minimum water table or 0.3 m below undisturbed till, whichever is higher
- the trench should be a minimum of 1 m width
- the trench should be backfilled with compacted granular material of high permeability
- a cap of clay or approved material should run the entire length and width of the trench
- the trench should run the entire length of the barrier or approximately 360 m, with a depth varying from 1.5 m to 3.5 m averaging about 2 m (refer to Figure B-6).

The passive venting system was discovered to be the most economical of the three choices. It was implemented soon after.

**REFERENCE:**

Gartner Lee Associates Ltd. 1981. Ritson Road Landfill Evaluation of Methane Gas Buffer Barrier for the Corporation of the City of Oshawa.

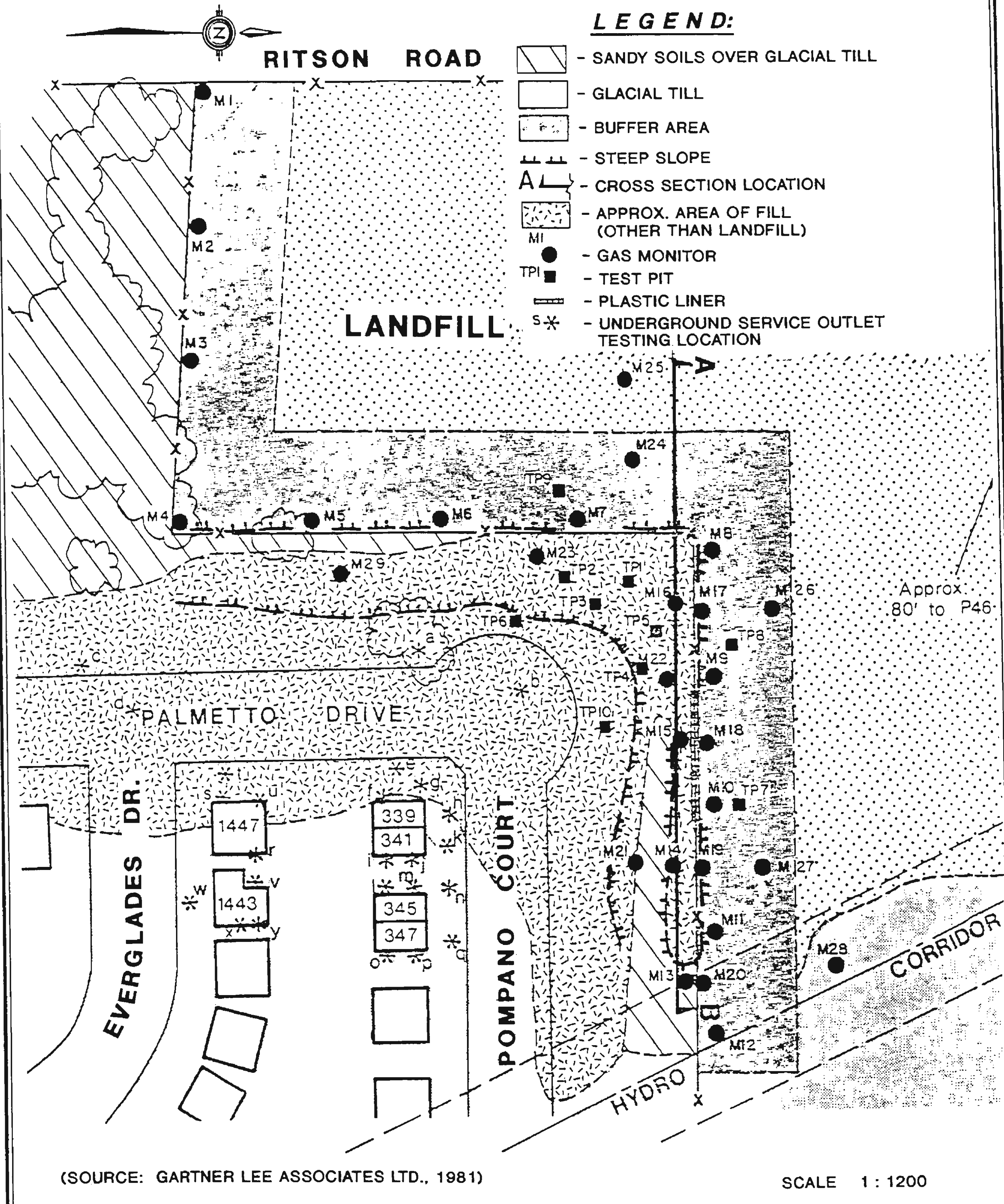


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**FIGURE B-2:**
**SITE SETTING**
**RITSON ROAD LANDFILL**
**METHANE GAS BUFFER EVALUATION**

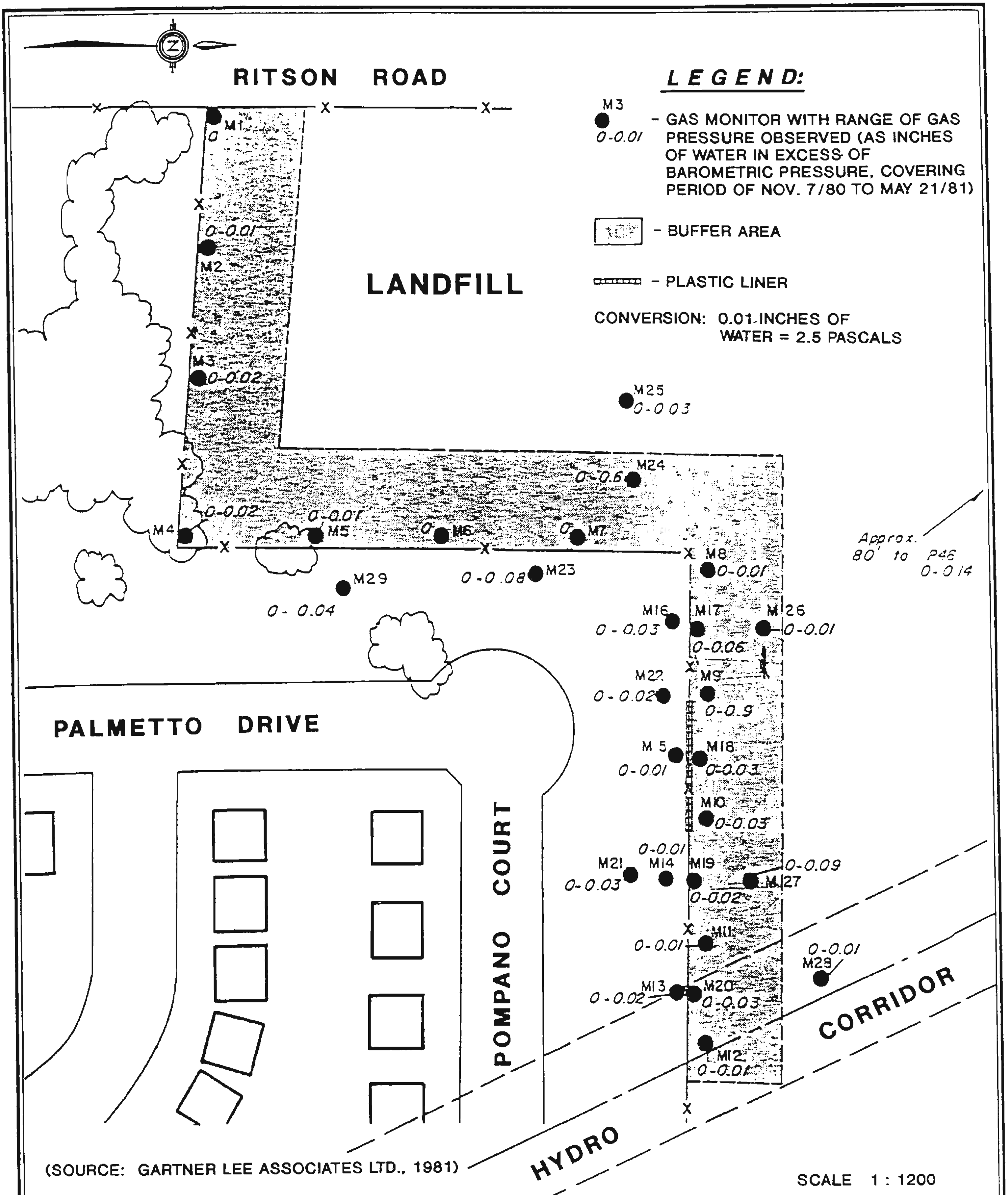


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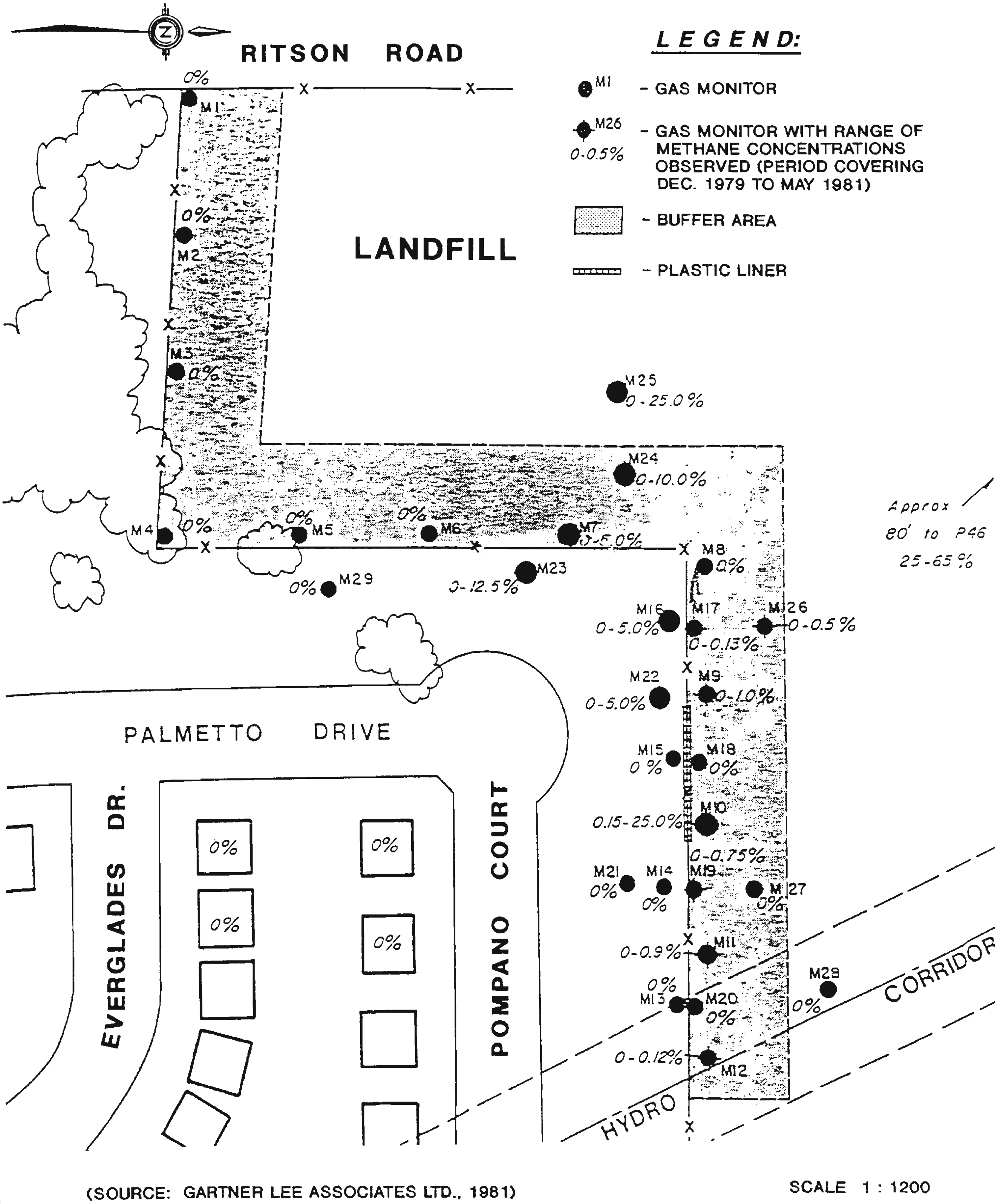
**FIGURE B-3:**
**RANGE OF SOIL GAS RESSURE**
**METHANE GAS BUFFER EVALUATION**

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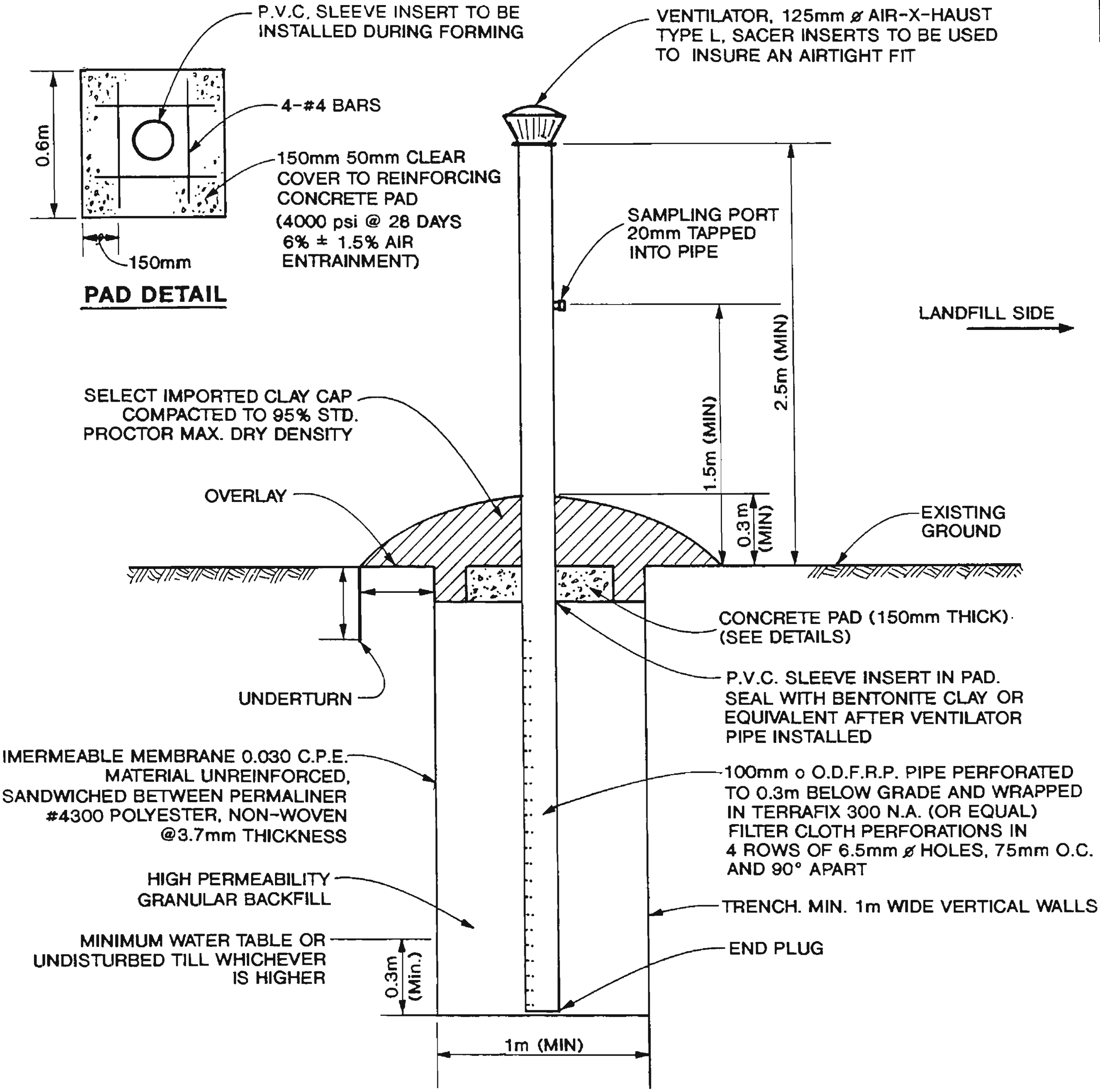
# FIGURE B-4: RANGE OF COMBUSTIBLE GAS CONCENTRATIONS

## METHANE GAS BUFFER EVALUATION

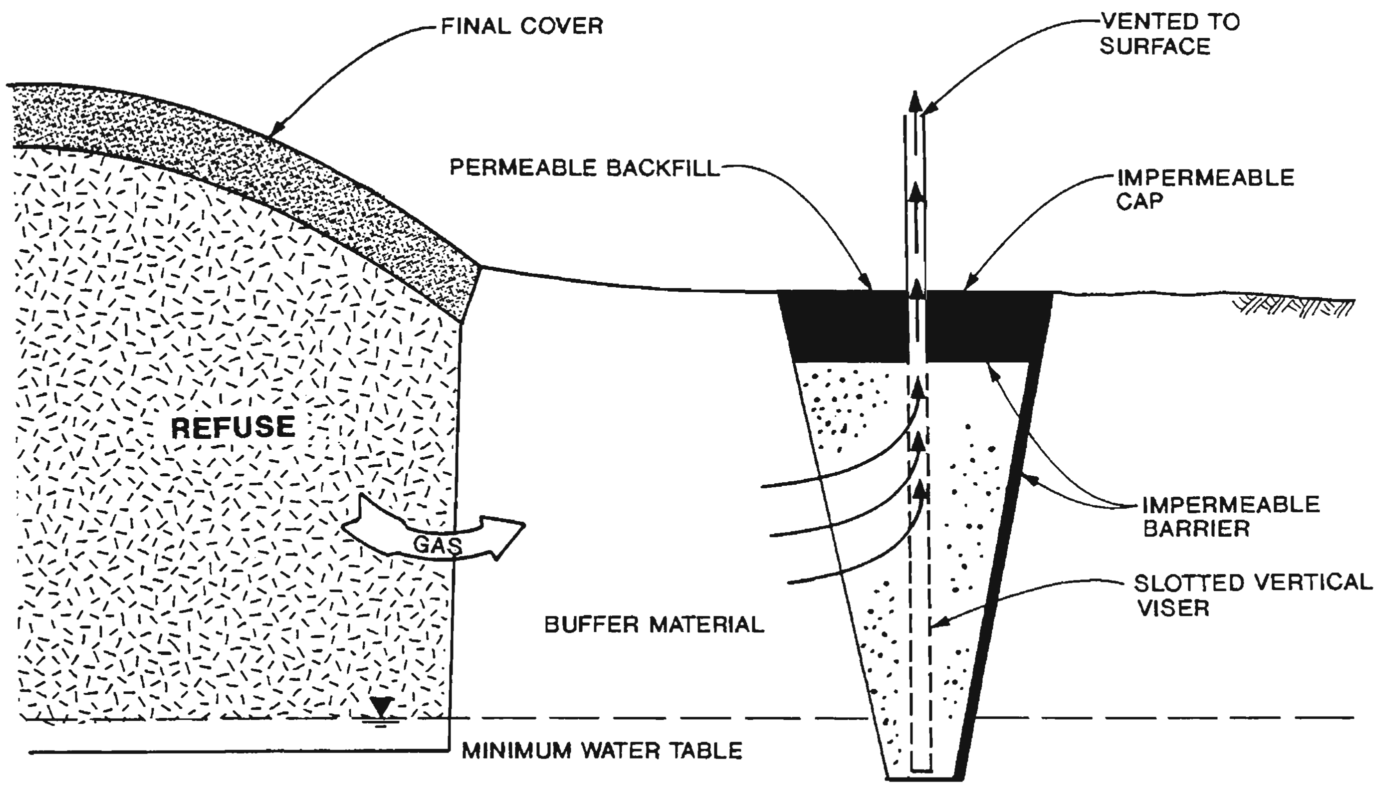



**NOTES:**

DEPTH OF TRENCH VARIES RISER SPACING 30m

(SOURCE: GARTNER LEE ASSOCIATES LTD., 1981)

| CH2M HILL ENGINEERING LTD.<br>WATERLOO ONTARIO<br>PROJECT No. **ONT29396.AO** | **FIGURE B-5:**<br>**OPTION 1 – PASSIVE SYSTEM**<br>**(TYPICAL TRENCH DETAIL–NOT TO SCALE)** |
|---|---|




(SOURCE: GARTNER LEE ASSOCIATES LTD., 1981)

| | |
|---|---|
| CH2M HILL ENGINEERING LTD.<br>WATERLOO ONTARIO | **FIGURE B-6: SCHEMATIC SECTION THROUGH A PASSIVE VENT SYSTEM** |
| PROJECT No. ONT29396.AO | |

OSHAWA LANDFILL EAST OF RITSON ROAD
GAS – WATER LEVEL – PRESSURE DATA

| DATE | PARAMETER | M1 | M2 | M3 | M4 | M5 | M6 | M7 | M8 | M9 | M10 | M11 | M12 | M13 | M14 | M15 | M16 | M17 | M18 | M19 | M20 | M21-1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ELEVATION (l.a.s.l.) | 491.63 | 492 | 494.93 | 498.06 | 497.84 | 498.29 | 497.77 | 497.44 | 500.6 | 504.63 | 507.44 | 508.54 | 510.41 | 512.21 | 505.63 | 503.15 | 499.62 | 502.73 | 506.55 | 508.34 | 508.68 |
| 07-Nov-80 | %CH4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 20 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | DEPTH (FT) | 11.33 | 6.25 | 5.58 | 5.25 | 5.67 | 6 | 5 | 7.75 | 3.58 | 7.42 | 7.75 | – | 10.17 | 13.42 | 8.5 | 8.5 | 4.33 | 5.58 | 8.42 | 6.67 | 11.17 |
| | PRESSURE | 0 | 0.01 | 0.01 | 0.01 | 0.01 | 0 | 0 | 0 | 0 | 0.02 | 0 | – | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0 | 0 |
| | BAROMETRIC PRESSURE | Steady between 29.15 and 29.20 inches of Hg | | | | | | | | | | | | | | | | | | | | |
| | TEMPERATURE | Cloudy, occasional shower, mild, no frost, 13 to 15 Celsius | | | | | | | | | | | | | | | | | | | | |
| 26-Nov-80 | %CH4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | DEPTH | 11.33 | 6.5 | 5.75 | 4.75 | 5.42 | 6 | 4.5 | 6.33 | 3.42 | 6.75 | 7.25 | 7.67 | 9.75 | 12.17 | 8.25 | 7.67 | 3.58 | 5.25 | 8.42 | 6.67 | 10.58 |
| | PRESSURE | 0 | – | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0.03 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0.01 | 0.02 | 0 | 0.04 |
| | BAROMETRIC PRESSURE | Steady between 29.95 and 30.08 inches of Hg | | | | | | | | | | | | | | | | | | | | |
| | TEMPERATURE | Clear, cool, 3 inches of frost, 3 to 6 Celsius | | | | | | | | | | | | | | | | | | | | |
| 18-Dec-80 | %CH4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.75 | 0 | 0 |
| | DEPTH | – | 5.58 | 4.67 | 3.58 | 4 | 4.25 | 2.08 | 2.75 | 1.58 | 3.67 | 3.08 | 3.42 | 4.67 | 8.33 | 5.75 | 5.42 | 1.67 | 2.5 | 3.42 | 2.25 | 9 |
| | PRESSURE | 0 | 0 | 0 | 0.02 | 0 | 0 | 0.06 | 0 | 0 | 0.01 | 0.02 | 0 | 0.02 | 0.01 | 0.01 | 0 | 0 | 0.05 | 0 | 0.04 | 0.03 |
| | BAROMETRIC PRESSURE | Steady between 29.40 and 30.05 inches of Hg | | | | | | | | | | | | | | | | | | | | |
| | TEMPERATURE | Snow, -1 to 1 Celsius | | | | | | | | | | | | | | | | | | | | |
| 15-Jan-81 | %CH4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | DEPTH | – | 7.08 | 5.67 | 4.67 | 4.58 | 4.67 | 3.75 | 5.33 | 3.33 | 5.58 | 5.17 | 6 | 7.5 | 9.17 | 7.6 | 7.33 | 3.5 | 4.5 | 5.42 | 5.08 | 10 |
| | PRESSURE | 0 | 0 | 0.02 | 0 | 0 | 0 | 0 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0 | 0.01 | 0 | 0 | 0 | 0.01 | 0 | 0.01 | 0 |
| | BAROMETRIC PRESSURE | Steady between 29.80 and 29.90 inches of Hg | | | | | | | | | | | | | | | | | | | | |
| | TEMPERATURE | Snow, -12 to -6 Celsius | | | | | | | | | | | | | | | | | | | | |
| 16-Feb-81 | %CH4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | DEPTH | 7.25 | 5.5 | 2.75 | 3.08 | 0.67 | 1.67 | 1 | 2.75 | – | – | – | 6.25 | 5.67 | 9.17 | 6.75 | – | 2.75 | – | – | 3.58 | – |
| | PRESSURE | – | – | – | – | 0 | 0 | 0 | 3 | 0.17 | 0.02 | – | – | – | – | – | 0 | 0 | 0 | 0.02 | 0.03 | 0 |
| | BAROMETRIC PRESSURE | Steady between 29.85 and 29.95 inches of Hg | | | | | | | | | | | | | | | | | | | | |
| | TEMPERATURE | Damp, cloudy, scattered fog, frost | | | | | | | | | | | | | | | | | | | | |
| 05-Mar-81 | %CH4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | DEPTH | 8.58 | 4.5 | 3.67 | 1.67 | 1.75 | 2.58 | 1.58 | 2.33 | 6.5 | 2.42 | 1.5 | 2.25 | 2.58 | 5.5 | 4.17 | 5.08 | 2.25 | 1.67 | 1.33 | 0.58 | 8 |
| | PRESSURE | – | – | – | – | – | 0.04 | 0.04 | 0.01 | 0.9 | 0.05 | – | – | – | – | 0 | 0.03 | 0.07 | 0.07 | 0.06 | – | 0 |
| | BAROMETRIC PRESSURE | Steady between 29.40 and 29.47 inches of Hg | | | | | | | | | | | | | | | | | | | | |
| | TEMPERATURE | Cloudy, cool, -2 to 4 Celsius | | | | | | | | | | | | | | | | | | | | |
| 15-Apr-81 | %CH4 | 0 | 0 | 0 | 0 | – | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | DEPTH | 11.75 | 6.25 | 4.67 | 2.33 | – | 2.75 | 2 | 3.33 | 2.33 | 4.17 | 1.75 | 4.25 | 4.58 | 7.17 | 5.58 | 5.67 | 2.33 | 3 | 2.42 | 2 | 9.08 |
| | PRESSURE | – | – | – | – | – | 0.04 | 0.14 | 0.04 | 0 | 0.03 | – | – | – | – | 0 | 0.02 | 0 | 0.03 | 0 | 0 | 0 |
| | BAROMETRIC PRESSURE | Steady between 30.28 and 30.37 inches of Hg | | | | | | | | | | | | | | | | | | | | |
| | TEMPERATURE | Clear, cool, 5 to 8 Celsius | | | | | | | | | | | | | | | | | | | | |
| 21-May-81 | %CH4 | 0 | 0 | 0 | 0 | – | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0.13 | 0 | 0 | 0 | 0 |
| | DEPTH | 11.75 | 6.42 | 5.33 | – | – | 3.5 | 3 | 4 | 2.42 | 5.33 | 3.42 | 5.25 | 6.25 | – | 6.42 | 7 | 3 | 3.5 | 3.42 | 3.67 | – |
| | PRESSURE | – | – | – | – | – | 0 | 0 | 0 | 0 | 0 | – | – | – | – | 0 | 0 | 0.06 | 0 | 0 | – | 0 |
| | BAROMETRIC PRESSURE | Slight decline from 29.67 to 29.52 inches of Hg | | | | | | | | | | | | | | | | | | | | |
| | TEMPERATURE | Clear, warm, sunny, 19 to 28 Celsius | | | | | | | | | | | | | | | | | | | | |

| DATE | PARAMETER | M21-2 | M22-1 | M22-2 | M23-1 | M23-2 | M24 | M25 | M26 | M27 | M28 | M29-1 | M29-2 | P46 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ELEVATION (f.a.s.l.) | 506.68 | 504.4 | 504.4 | 502.71 | 502.71 | 497.45 | 495.7 | 498.65 | 506.15 | 509.32 | 503.73 | 503.73 | |
| 07-Nov-80 | %CH4 | 0 | 0 | 4 | 0 | 0.5 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 50 |
| | DEPTH (FT) | – | 4.75 | – | 10.42 | – | 5.5 | 9.08 | 3.17 | 8.25 | 6.5 | 12.08 | – | – |
| | PRESSURE | 0 | 0.04 | 0.02 | 0.06 | 0.01 | 0.01 | 0.01 | 0.24 | 0 | 0.01 | 0.03 | 0 | 0.09 |
| | BAROMETRIC PRESSURE | | | | | | | | | | | | | |
| | TEMPERATURE | | | | | | | | | | | | | |
| 26-Nov-80 | %CH4 | 0 | 0 | 0.5 | 0.25 | 3.5 | 0 | 25 | 0 | 0 | 0 | 0 | 0 | 40 |
| | DEPTH | – | 7.58 | – | 10.25 | – | 6.33 | 9.17 | 3.08 | 7.67 | 6 | 10.58 | – | – |
| | PRESSURE | 0 | 0.05 | 0 | 0.01 | 0 | 0.6 | 0.01 | 0.45 | 0.05 | 0 | 0.15 | 0.01 | 0 |
| | BAROMETRIC PRESSURE | | | | | | | | | | | | | |
| | TEMPERATURE | | | | | | | | | | | | | |
| 18-Dec-80 | %CH4 | 0 | 0 | 5 | 0 | 10 | 0 | 5 | 0.5 | 0 | 0 | 0 | 0 | 50 |
| | DEPTH | – | 5.67 | – | 8.75 | – | 4.5 | 7.58 | 1.5 | 4.25 | 3.67 | 9.25 | – | – |
| | PRESSURE | 0 | 0 | 0 | 0.11 | 0 | 0 | 0.02 | 0.09 | 0 | 0 | 0.15 | 0 | – |
| | BAROMETRIC PRESSURE | | | | | | | | | | | | | |
| | TEMPERATURE | | | | | | | | | | | | | |
| 15-Jan-81 | %CH4 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30 |
| | DEPTH | – | 7.25 | – | 9.75 | – | 6.08 | – | 4.08 | – | – | 10.75 | – | – |
| | PRESSURE | 0 | 0 | 0 | 0.02 | 0 | 0.02 | 0.02 | 0.01 | 0.02 | 0 | 0 | 0 | 0.03 |
| | BAROMETRIC PRESSURE | | | | | | | | | | | | | |
| | TEMPERATURE | | | | | | | | | | | | | |
| 16-Feb-81 | %CH4 | 0 | 0.5 | 0.25 | 3 | 3.5 | | 0 | 0 | 0 | 0 | 0 | 0 | 50 |
| | DEPTH | – | – | – | – | – | – | – | – | – | – | 9 | – | – |
| | PRESSURE | 0 | 0 | 0 | 0 | 0.02 | 0.11 | 0.19 | 0.2 | 0 | – | 0.01 | 0 | 0.05 |
| | BAROMETRIC PRESSURE | | | | | | | | | | | | | |
| | TEMPERATURE | | | | | | | | | | | | | |
| 05-Mar-81 | %CH4 | 0 | 2 | 4.5 | 0 | 12.5 | 10 | 5 | 0 | 0 | 0 | 0 | 0 | 50 |
| | DEPTH | – | 4.67 | – | 8.17 | – | 4.33 | 6 | 0.67 | 3.25 | 2.75 | 7.75 | – | – |
| | PRESSURE | -0.02 | 0 | 0.02 | 0.02 | 0 | 0.03 | 0.02 | 0.2 | 0.04 | – | 0.06 | 0 | 0.08 |
| | BAROMETRIC PRESSURE | | | | | | | | | | | | | |
| | TEMPERATURE | | | | | | | | | | | | | |
| 15-Apr-81 | %CH4 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 65 |
| | DEPTH | – | 5.67 | – | 8.25 | – | 5.25 | 8.25 | 2.25 | 4.17 | 3.68 | 8.25 | – | – |
| | PRESSURE | 0 | 0 | 0.02 | 0 | 0.02 | 0.01 | 0.03 | 0.25 | 0.09 | – | 0.1 | 0.04 | 0.14 |
| | BAROMETRIC PRESSURE | | | | | | | | | | | | | |
| | TEMPERATURE | | | | | | | | | | | | | |
| 21-May-81 | %CH4 | 0 | 0 | 0 | 0 | 1 | 0 | 7.5 | 0 | 0 | 0 | 0 | 0 | 25 |
| | DEPTH | – | 6.42 | – | – | – | 5.58 | 9 | 2.33 | 4.33 | 4.33 | 8.5 | – | – |
| | PRESSURE | 0 | 0 | 0 | 0.08 | 0 | 0 | 0 | 0 | 0.03 | – | 0.09 | 0 | 0 |
| | BAROMETRIC PRESSURE | | | | | | | | | | | | | |
| | TEMPERATURE | | | | | | | | | | | | | |

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #5**

**BUILDING TYPE AND LOCATION:** Apartments, Commercial buildings, Welland

**GAS TYPE:** Landfill gases

**SOURCE:** Landfill in Old Canal

**TYPE OF CONTROL:** Passive and Active venting

**CASE STUDY PRÉCIS:**

For several years prior to 1958, the old Welland Canal was used as an open waterway through the City of Thorold. In the early 1960s, a drainage culvert was installed and solid domestic, industrial refuse and inert fill was used to fill the excavation. Since there was a possibility for methane production, a study was initiated in late 1981 by the City of Thorold to evaluate the limits of refuse, investigate the potential for permeable connection from the canal area to nearby buildings, identify any immediate hazards to buildings on or near the edge of refuse disposal, and develop a field and monitoring program.

The investigation first centred on defining the areas where methane production may exist. Based on the review of geotechnical reports and interviews with local residents, essentially four areas along the extent of the old canal were identified as having methane producing potential. These areas included:

- Battle of Beaverdams Park
- Area in the vicinity of Thorold Fire Hall
- Park area north of Albert Street
- Area northeast of CVL Rubber Industries.

Despite the potential for methane migration, the geological material present would likely limit lateral travel. In the vicinity of the canal, a clay/silt overburden is in the order of 10 to 13 metres in thickness overlying a limestone bedrock. The possibly for lateral gas migration through the low permeability overburden was believed to be minimal and therefore likely having little effect of the indoor air quality of buildings. In general, the water table was between 3.0 and 3.5 metres below ground surface.

Consequently only those buildings that were located partially or fully on a section of the canal were investigated further. Investigations were conducted on the following buildings:

- the Thorold Community Credit Union

- the Lark 1 Apartments
- a senior citizens' apartment
- an office building
- CVL Rubber Industries

In addition, the consultants recommended investigating a small area that was being used as a park as well as some utility corridors which intersected the buried refuse at the site.

As part of the investigation, soil gas probes were installed close to many of the above buildings and monitored seven times over a period of 16 weeks from the time the monitoring probes were installed. The monitoring of the soil gas probes showed that combustible gas was present in high concentrations around the senior citizens' apartments, the Lark 1 Apartments, Thorold Fire Hall, CVL Rubber Industries, the Bandshell, Thorold Community Credit Union, and the Professional Building on Sullivan Avenue. In order to assess migration of landfill gas through the utility trenches, information relating to the subsurface ducts and sewers were obtained. However, it was concluded that due to the low gas generation rate, significant offsite gas migration in the permeable service trenches would be unlikely. No rationale was given on how the generation rate was determined. In addition, no pressure readings were taken during the monitoring process.

It was recommend that gas control measures be implemented in the areas of the affected buildings.

Various gas control measures were implemented in the vicinity of each of the various affected buildings listed above. The gas control measures implemented are summarized below.

1. Senior Citizens' Apartment

   Part of the building has walls that are adjacent to the old Welland Canal boundary. Since the quantity of refuse observed was relatively minor, due to fine grained soils and high water tables, a passive system was recommended. A trench of approximately three metres in depth would contain the passive system.

2. Bandshell (Battle of Beaverdams Park)

   Although monitoring had detected no appreciable concentrations in the immediate vicinity of the bandshell, nearby, high combustible gas concentrations had been recorded. It was recommended that ventilation panels be installed in the doors and ceilings of enclosed rooms. Since the building was not used in the winter, energy conservation was not a concern.

3. Lark 1 Apartment

The Lark 1 Apartments is a multi-storey apartment building located at the edge of the old Welland Canal. The basement is being used as a mechanical room. During construction of the building, refuse was encountered on the southwest corner of the building. Monitoring also showed combustible gas in the range of 0 to 40 percent by volume. A passive gas control system comprised of a three metre tench around the outside walls of the building was recommended.

4. Thorold Community Credit Union

The Credit Union building is a one-storey commercial building with a basement. The east side of the building is located in the buried raceway. Combustible gas was detected in the range from 0 to 17 percent GAS. An asphalt parking lot creates a sealed surface directly adjacent to the building. It was recommended that an active gas control system be implemented. Due to an unknown amount of refuse around the building, it is recommend that a series of gas wells be augured adjacent to the building. A header pipe connecting the wells would be installed in a narrow trench. The header pipe would be connected to a small gas pump. Gases would be vented to the atmosphere above the building.

5. Professional Building

Although combustible gas concentrations were identified, further investigations were recommended. Some area of the property were known to contain refuse; however, the impact was difficult to determine. Further monitoring was recommended.

6. Fire Hall

The fire hall is comprised of a double bay garage and offices situated on a concrete floor slab. Buried refuse was observed along the south side of the building. Gas concentrations ranged from 6 to 63 percent by volume. A passive control system installed along the south, east and north walls was recommended. Seven vertical pipes with rotary vents would be used to vent the gases. No rationale for the passive system was given.

7. CVL Rubber Industries

A one storey industrial building built on a concrete slab had buried refuse identified on the north and east side of the building. Combustive gas concentrations ranging from 4 to 90 percent by volume were recorded. An active system with a series of wells was recommended. Venting of the gases directly to the atmosphere would occur.

Additional monitoring was also recommended in manholes near the canal to determine whether offsite migration via sewer pipes did occur. The systems were installed in 1984.

Only one monitoring report has been obtained to-date which described the operation of the gas control measures. The results were based on monitoring completed in November 1985.

1. Senior Citizens Apartment

   Each of the five passive gas vents and a soil gas monitor were monitored for combustible gas concentrations and pressure. All vents were in good condition and showed no gas concentrations. The gas probe showed no gas and zero pressure.

2. Bandshell

   The gas probes installed for monitoring purposes were damaged. No reading was taken.

3. Lark 1 Apartments

   All three gas vents and one gas probe showed no detectable gas concentrations.

4. Thorold Credit Union

   The active gas collection system was found to be operating well. Measurements confirmed that water had entered the gas extraction wells although a portion of the wells still were extracting soil gases. Vacuum measured in the gas wells ranged between 2.8 and 3.2 kPa. No combustible gas concentrations were encountered. Prior to installation 20 percent by volume was measured adjacent to the building.

5. Professional Building

   No further data was available on this building.

6. Fire Hall

   Based on the monitoring done,only 4 out of the 6 wells were located. Static conditions revealed that two of the four wells were filled with water; another two gas probes were also flooded. No gas was detected likely due to a high water table. Gas wells showed a depressurization of up to 2.8 kPa.

7. CVL Rubber Industries

Monitoring areas were only able to locate two of the six gas extraction wells. When measured, a vacuum of 220 Pa was observed. A trace of 1 percent GAS was measured at the blower. In general, the system was not operating well.

Additional monitoring was recommended.

**REFERENCES:**

Conestoga-Rovers & Associates, 1982. Landfill Gas Study Old Well and Canal, City of Thorold.

Conestoga-Rovers & Associates, 1983. Landfill Gas Study Phase II. Old Welland Canal, City of Thorold.

# CMHC SOIL GAS RESEARCH STUDY
# CENTRAL CANADA SECTOR
# CASE STUDY #6

**BUILDING TYPE AND LOCATION:** Residential houses, potential building locations, Kitchener

**GAS TYPE:** Methane

**SOURCE:** Landfill

**TYPE OF CONTROL:** Passive venting, monitoring

**CASE STUDY PRÉCIS:**

**The Problem**

As a result of an explosion of a duplex on Ralgreen Crescent, a consultant was hired by the City of Kitchener to initiate an investigation on all past and present landfill sites within the City. The investigation was conducted in 1969. In the interest of public welfare and safety, the City of Kitchener wished to determine the location of potentially hazardous conditions and rectify any situations before an incident could occur. The study endeavoured to locate all landfill sites, map and report on the landfill boundaries and soil gas conditions, determine if potentially hazardous conditions existed, and make recommendations where necessary.

To start the investigation, the City supplied maps to the consultant outlining the approximate boundaries of all recorded landfill activities. Many of the areas where landfill sites were located, already had existing dwellings or were zoned for residential purposes. Test holes were placed (depth is unknown) at each site based on a 15.25 metre grid. If buildings were located on any of the sites, indoor methane concentrations were also documented. Methane measurements were all conducted with an explosimeter. In order to determine the type of gas present, a Davis ethane detector was also used.

Of the 24 landfill areas encountered within the city, seventeen sites had either no gas, or "very small pockets of minute concentrations of no concern". (Rationale for "pockets of minute concentrations" was not specified.) Possible reasons cited for a lack of methane may have been due to:

- the type of refuse (or lack or abundance of organic matter)
- oxidation during decomposition
- age of the landfill (i.e. methane production was on the decline)
- site conditions (i.e. a high water table, or good natural venting)

Seven "positive landfill sites" were sited. Each case will be briefly described.

1. Ralgreen-Queens Landfill Site

Combustible gas was first detected entering a hydro vault of the arena in this area on September 3, 1969. Gas was entering the vault at concentrations of 30 percent through the duct system. The ducts were sealed and the flow of gas was consequently stopped. A small concentration of gas was also detected adjacent to the school wall. A trench was excavated to alleviate the problem.

As a result of further testing at the school, methane was found to exist underneath the asphalt parking lot. A consultant installed a series of automatic test inserts and a testing procedure was developed. The school purchased a methane gas detector and the custodian completed the testing. No further action was required.

Further testing revealed that several nearby homes had concentrations of combustible gas entering via the floor drains. As a remedial measure, venting pipes were tied into the weeping tile system. In many of the new dwellings in the City of Kitchener, it appeared that the weeping tile system was tied into the floor drain system before the water trap. Since the weeping tile around the building may act as a natural collection spot for methane gas, the gas would travel along the tile and vent into the ambient indoor air. It was recommended that both systems be installed independently.

Several other homes were found to have high soil gas concentrations at a distance of 4.6 m from the foundation; however, no gas was discovered at the building or indoors. Venting systems for these homes were also recommended as outlined in the paragraph above.

2. Wimpey Subdivision Landfill Site

The gas concentrations in this area were generally in the lower explosive limit range; however, some areas had extremely high concentrations. Since residential construction was just beginning, recommendations were made to include a venting plan into the design. A similar venting plan as for the Ralgreen-Queens Landfill Site was recommended. In the areas of extremely high methane concentrations, a venting plan was "definitely" recommended. It was not clear from the report (Heath Consultants, 1969) whether this "venting plan" was different from the previous plan.

3. Brybeck Landfill Site

This area had mainly been occupied by two large warehouses. Since small pockets of methane gas been detected beneath the asphalt parking lot, it was suggested that vent stacks be installed adjacent to the building to release potential gas build-ups which may occur below the parking lot.

In another part of this site, combustible gas readings were obtained within 300 mm of the building foundations of several apartment blocks. However, an interior investigation indicated that no gas was observed in the conduit or sewer pipes. Nevertheless, a "venting plan" was recommended. It is unclear from the report specifically what type of venting should take place.

4. Knell-Westwood Landfill Site

This area was a previous low, swampy area with evidence of peat conditions. During the investigation, there were indications of combustible gas; concentrations were found to be high.

At the time, several of the homes were being constructed; most were uninhabited. Recommendations for venting included checking the tie-in of the weeping tile and the floor drains as well as an exterior venting arrangement. The exterior venting arrangement recommended by the consultant consisted of installing a trench around the building below the basement slab. The trench bottom should be in a flat "V" profile with the centre of the "V" at the centre of the building. A rise of 1:10 should exist in the trench. The trench would then be filled with gravel, and installed with a 100 mm diameter perforated pipe. The perforated pipe would be connected to a vent stack located at the corner of each building. The vent stack would be installed with a wind rotator which would "maintain a slight vacuum on the venting system". The consultant recommended that the weeping tile could be tied into this venting system for maximum results. The gravel trench was filled with gravel to 300 mm at the surface, covered with a heavy gauged polyethylene and backfilled with loam.

The consultant further recommended that the interior foundation wall could also be painted with an epoxy paint which would "form an airtight seal to seepage of marsh gas through hairline cracks in the foundation". In addition, the consultant recommended that services entering the building be adequately sealed.

5. Campbell Avenue Landfill Site

The site was being used as a garbage incinerator. High concentrations of methane were detected throughout the south section of the property. No permanent buildings were located on the site; as such, no recommendations were made.

6. Jansen-Fairway-Red Wing Landfill Site

   This site had very little history. A 15 m grid pattern was tested indicating several small pockets of methane. Since the concentration was in the neighbourhood of LEL and the nearest building was some 15 m away, no concern was noted.

7. Ottawa Street Landfill Site

   In an area away from the landfill site property, high concentrations of methane were detected. This area was at one time used as a landfill. Although housing development had not begun at the time of study, construction was expected to commence shortly. Recommendations as outlined for areas 1 and 4 as described above were given.

All recommendations as listed above were issued to private homeowners whose homes were affected. Further information was requested from the City concerning these properties; no further information was provided.

**REFERENCE:**

Heath Consultants, 1969. Heath landfill site investigation for the City of Kitchener.

## CMHC SOIL GAS RESEARCH STUDY
## CENTRAL CANADA SECTOR
## CASE STUDY #7

| | |
|---|---|
| **BUILDING TYPE AND LOCATION:** | Commercial Building, Office, Kenora |
| **GAS TYPE:** | Petroleum hydrocarbon & perchloroethylene |
| **SOURCE:** | Underground gasoline tank |
| **TYPE OF CONTROL:** | Passive vents, active vents, sub-slab ventilation and excavation of surrounding contaminated soil |

**CASE STUDY PRÉCIS:**

Gases entered an office in Kenora through the building's weeping tiles and the drainage system. Because the area was previously wetland, the land surrounding the building was fill (including sand). People were evacuated from two buildings. Soil testing was conducted by the Ministry of the Environment and air quality testing was performed by the Ministry of the Environment, the Ministry of Consumer and Commercial Relations (Fuel Safety Branch), and the Fire Department. Analytical tests were taken before and after remediation. Passive vents, active vents, and sub-slab ventilation were used in the two affected buildings. As well, the surrounding contaminated soil was removed and then replaced. There was litigation associated with this problem.

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #8**

| | |
|---|---|
| **BUILDING TYPE AND LOCATION:** | Single family dwelling and store |
| **GAS TYPE:** | Gasoline |
| **SOURCE:** | Gasoline station |
| **TYPE OF CONTROL:** | Vapour extraction units onsite at the store and across the street at the gasoline station. Some contaminated soil was excavated. |

**CASE STUDY PRÉCIS:**

Gas entered a single family dwelling and a store through a sump hole, after migrating through the subgrade of a road near a gas station. The soil surrounding the buildings was clay. People were evacuated from the buildings when the problem became evident. Contamination was detected in the indoor air. Soil and indoor air quality were monitored by an engineering consultant and analytical tests were taken before and after remediation. Vapour extraction units were placed at the store and the gasoline station. Some contaminated soil was removed. A Certificate of Approval was required for the vapour extraction system. The investigation and subsequent remediation began in June 1988 and was to be completed by December 1989. The vapour extraction system is still in use (Nov 1990).

## CMHC SOIL GAS RESEARCH STUDY
## CENTRAL CANADA SECTOR
## CASE STUDY #9

**BUILDING TYPE AND LOCATION:** Multi-family dwelling, Oakville

**GAS TYPE:** 1-methylnaphthalene

**SOURCE:** Land on which the dwelling was built had been contaminated with petroleum waste.

**TYPE OF CONTROL:** Home demolished, soil excavated and replaced

**CASE STUDY PRÉCIS:**

No fumes were detected in a multi-family dwelling in Oakville; however, soil testing indicated that there were traces of petroleum-based waste in the soil (1-methylnaphthalene). Although in the opinion of the Ministry of the Environment, the contaminated soil did not pose a risk to human health or plant life, the levels did exceed the recommended cleanup level. The home was demolished and all contaminated soil was removed.

# CMHC SOIL GAS RESEARCH STUDY
# CENTRAL CANADA SECTOR
# CASE STUDY #10

**BUILDING TYPE AND LOCATION:** Residential Complex, Mississauga

**GAS TYPE:** Methane

**SOURCE:** Abandoned Landfill Site

**TYPE OF CONTROL:** Passive/active vents in basements of newer homes, passive/active vents on properties where basements had already been built

## CASE STUDY PRÉCIS:

In the process of construction of the Sunny Hill Estate subdivision in Mississauga, refuse was discovered during excavation operations. Due to this discovery, construction was halted until an assessment of the situation could be made. Some monitoring was carried out at the site with the drilling of several boreholes and the installation of several soil gas monitoring wells. Actual details of this investigation or the results were not available to this study.

Based on the methane gas concentrations observed and the delineation of onsite refuse, various gas control measures were implemented at this site. The developer was required to install the system as described in Table B.2. The "gas collection system" referred to in the table below includes the collector pipe, venting stack, electrical fan, wind vane, and plastic liner.

**Table B.2**
**Gas Collection System**

| Gas Control/Detection Measure | Lot # |
|---|---|
| Installation of several single port gas alarms and a separate gas collection system connected to large diameter collection pipe around and under the footings of the home. | 89, 90, 91, 92, 93, 94, 100, 101, 102, 104 |
| Installation of several single port gas alarms and a separate gas collector system around the footings, above the drainage tiles, on the eastern, northern and southern sides of the home. | 97, 98, 99 |
| Installation of several single port gas alarms and a gas collector system connected to oversized drainage tiles around the footings of the home. | 95, 96, 103 |
| Installation of a single port gas alarm. | 88, 105, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25 |
| Installation of long-term monitoring probes. | 98, 99, 100, 104 |

No detailed drawings were available of these systems at the time of the search.

The fan that was used as part of each active system was a 3E Blower produced by Canadian Blower. Each fan was equipped with an 20.3 cm diameter non-sparking aluminum wheel and a 1.3 HP 3450 rpm motor with a slip fit inlet collar, which was recommended for the exhaust applications. Each fan was installed with a non-switchable starter. The non-switchable starter ensured that the fan could not be turned off by the occupant; however, it provided access for repair if an electrical overload condition occurred. All fans were located in the rear of the building in locked weatherproof housings. The 10 cm collection pipe and the stack vent was constructed out of ABS plumbing parts. Based on the flow rate generated by the fan, it was estimated that the total transit time for air in the venting system would be about 2½ seconds. The consultants felt that the gas could not be sufficiently warmed in this time for problematic quantities of condensate to precipitate in the pipe. Since active venting was occurring at this site, the developer was required to apply for a Certificate of Approval (Air) (C of A) with the Ministry of the Environment. The application was approved on June 10, 1985 subject to two conditions:

1. The applicant or his representative shall measure and analyze the gaseous emissions from the venting system within three (3) months of the startup of operations. The testing shall be witnessed by staff of the Ministry and the results shall be reported to the District Officer, Halton-Peel District office.

2. The applicant or his representative shall take immediate corrective measures, following the evaluation of the source testing report, should the contaminant emissions exceed any health, odour or safety standards and/or guidelines.

**Post Construction Monitoring**

In addition to the monitoring for the C of A, the Ministry of the Environment (MOE) also requested that monitoring of the indoor air be conducted at this site. McClymon and Rak Engineers Inc. conducted the monitoring. In addition to testing indoor methane levels, the gas detection alarms were checked, and soil probes were monitored.

The homes in the Sunny Hill Estate subdivision were monitored approximately seven times. Monitoring was conducted on or around September 18, 1984; April 29, 1986; July 1, 1986; November 17, 1986; April 13, 1987; October 1, 1987; and February 14, 1989. Methane monitoring indoors was completed in each of the four corners of the basements in the houses designated by the MOE. All measurements taken indoors and outdoors utilized an explosimeter. Although it was recommended that a more sensitive measurement be conducted with regards to indoor methane measurements, such a plan was never implemented.

During the monitoring program no combustible levels of methane were ever detected indoors (i.e. the explosimeter indicated 0 percent LEL). The reports did not state whether or not calibration was routinely implemented in the monitoring protocol. Indoor levels were nevertheless satisfactory. Based on telephone records at the time, the MOE was concerned only if indoor methane levels exceeded 2 percent LEL (or 1,000 ppm). Values greater than 2 percent LEL would have "caused concern".

Testing outdoors was less extensive than the indoor monitoring program. In the initial monitoring event (September 18, 1984), a total of twelve gas probes were checked for methane. Results indicated that methane existed in the subsurface in volumes of 0 percent to 40 percent GAS. Table B.3 summarizes the results from the September 1984 monitoring round.

**Table B.3**
**Test Results from September 1984**

| Soil Gas Monitor No. | % GAS | Soil Gas Monitor No. | % GAS |
|---|---|---|---|
| 87R | 0 | 102R | 24 |
| 90R | 0.9 | 102F | 5.0 |
| 92R | 40 | 105R | 0.4 |
| 94R | 40 | 97F | 0.4 |
| 96R | 0 | 102F | 4.0 |
| 98R | 34 | 122F | 2.0 |

During the remaining five monitoring events, significantly less locations were tested. Only four soil gas probes were checked. Table B.4 summarizes the data from these events.

**Table B.4**
**Summary of Four Soil Gas Probes**

| Soil Gas Monitor | Readings (% LEL) |
|---|---|
| Lot 100 | 0.6, 2,8, 5.0, 0, 0 |
| Lot 104 | 0, 0, NA, 0, NA |
| Lot 98 | 2.3, 2.8, 0, NA, NA |
| Lot 99 | 0.7, 0, 0, 0, 0 |

Note: NA = Not accessible

The reason monitoring wells were not installed in the rear of lot 92 where earlier data suggested values as high as 40 percent GAS is not known. No pressure or barometric data was available.

The performance of the exhaust fans and alarms is summarized below:

- The results of the April 29, 1986 monitoring event indicated that two of the alarms were out of order.
- By the July 31, 1986 event, seven alarms were not working.
- By October 1, 1987, 21 alarms were not working; six residential dwellings had turned off their exhaust fans due to noise.

Based on the current knowledge of this site, no further testing has been completed.

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #11**

**BUILDING TYPE AND LOCATION:** Single family dwellings, Oakville and Burlington

**GAS TYPE:** Petroleum-based

**SOURCE:** Fuel spills

**TYPE OF CONTROL:** Evacuation of homes until vapours dissipated.

**CASE STUDY PRÉCIS:**

On two separate occasions, fuel spills from service stations resulted in the migration of gases and fumes through the sanitary sewers up through the floor traps in the basements of the homes. In both cases, the homes were evacuated until the vapours had dissipated. No further action was required.

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #12**

**BUILDING TYPE AND LOCATION:** Old Age Home

**GAS TYPE:** Methane

**SOURCE:** Landfill

**TYPE OF CONTROL:** Methane alarms installed

**CASE STUDY PRÉCIS:**

The City of Brantford is presently undertaking an inventory of old landfill sites within the city boundaries. The city engineer's office reported no cases of excessive indoor methane levels with the exception of an old age home near one of the closed landfill locations. Methane alarms were installed in the building and are monitored by the maintenance group within the home.

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #13**

**BUILDING TYPE AND LOCATION:** Residential houses, Mississauga

**GAS TYPE:** Methane

**SOURCE:** Landfill site

**TYPE OF CONTROL:** Forced draft ventilation and exhaust system

**CASE STUDY PRÉCIS:**

Methane gas migration was discovered to be the reason for vegetation killed on residential areas bounding a landfill site. The Waste Management Branch of the Ministry of the Environment, alerted to the problem by residents, contracted a consulting firm to determine the severity of the problem, to suggest remedial measures, and to implement the acceptable solutions.

Monitoring was conducted to determine the extent of the methane gas problem. Twenty-seven gas probes were installed on both the landfill site and on the residential properties. The location of the gas probes are shown in Figure B-7. These gas probes consisted of 6 mm diameter polyethylene plastic tubing enclosed in a jacket of fine nylon gauze. Steel clamps and plastic sleeves were also installed to prevent any sliding of the gauze screen, and a 300 mm concrete seal was placed on top of the sand to prevent air contamination.

Monitoring of the gas probes for methane revealed concentrations spanning from non-detect levels to 55 percent. The highest concentrations of methane gas were located along the north-south boundary of the landfill, adjacent to the residential areas. The gas probes located further away from the landfill exhibited decreasing levels of methane concentrations, while those located closest to the landfill exhibited the highest levels of concentration. The average concentration of methane for the gas probes sampled was approximately 17 percent. Nitrogen, argon/oxygen, carbon dioxide, ethylene, ethane, propane, and butane were also sampled. The level of methane varied proportionally to the level of carbon dioxide (0.1 percent to 51.5 percent), ethylene (1 ppm to 80 ppm), ethane (2 ppm to 110 ppm), propane (1 ppm to 30 ppm) and butane (2 ppm to 6 ppm). Conversely, the level of methane concentration varied inversely proportional to the level of nitrogen (8.1 percent to 78.8 percent), and argon/oxygen (1.5 percent to 21.7 percent). This is expected since high nitrogen and oxygen are typical of aerobic environments.

The subsurface of the landfill site and the adjacent residential area is composed of a shallow deposit of sand overlying a gravel pit extending to a depth of approximately 6.1 m. Clayey till overlying shale bedrock may exist, below the layers of sand and gravel.

A forced draft ventilation gas interception and exhaust system was constructed near the landfill boundary. The total gas interception system is comprised of 46 header-connected vent units and approximately 1200 m of header pipe. More specifically, it consists of 7.6 cm diameter vertical vent risers joined to 200 mm diameter header pipes which are connected to the exhaust draft source. The deep vent risers are located 600 mm below the water table.

The sumps and drains in the basements of the residential houses were sealed where high methane concentrations were detected. (Exactly how the drains were sealed is uncertain.)

Following the construction of the gas interception system, completed in 1973/ 1974, short-term monitoring was conducted to determine the system's efficiency. Landfill gases were not detected in any soil-air samples collected from those probes installed on private lands adjacent to the operating interception system. Thus normal soil-air conditions returned to private lands that had previously contained high concentrations of methane and carbon dioxide gases.

Static and velocity pressures, recorded with a U-tube manometer and standard pilot tube, decreased with distance from the exhaust source. Negative static pressures of 150 Pa to 400 Pa were observed at extreme ends of the interception system. A flow volume of approximately 660 L/s was measured at the fan outlet.

Figure B-8 shows the header and pumping system and chemical analyses are documented in Table B.5.

At the time of initial operation, the gas interception system was operating at its maximum to produce an acceptable "barrier" to landfill produced gas migrations.

The only recommendation offered by the consulting firm was to construct a 45 to 60 m greenbelt between the residential properties and the refuse fill limits, if permissible.

Table B.5
Mississauga Sheridan Way Chemical Analyses

| Probe Number | Nitrogen (%) | Oxygen & Argon (%) | Carbon Dioxide (%) | Methane | Ethylene (ppm) | Ethane (ppm) | Propane (ppm) | Butane (ppm) |
|---|---|---|---|---|---|---|---|---|
| 1 | 78 | 21.5 | 0.3 | <1 ppm | - | - | - | - |
| 2 | 78 | 21.2 | 0.7 | <1 ppm | - | - | - | - |
| 3 | 77.4 | 21.7 | 0.2 | 4 ppm | - | - | - | - |
| 4 | 29 | 3.0 | 35 | 34% | 80 | 80 | 9 | 4 |
| 5 | 78.8 | 23 | 0.9 | <1 ppm | - | - | - | - |
| 6 | 38 | 11 | 25 | 28% | 80 | 80 | - | - |
| 7 | 11.5 | 1.5 | 36.5 | 50% | 80 | 80 | 10 | 4 |
| 8 | 35 | 8.6 | 24 | 32% | 70 | 65 | 8 | 2 |
| 9 | 80 | 11.5 | 3.4 | 5% | 10 | 10 | - | - |
| 10 | 8.1 | 1.7 | 35 | 55% | 60 | 70 | - | 6 |
| 11 | 14.6 | 2.3 | 31.3 | 52% | 80 | 110 | 10 | 4 |
| 12 | 10.5 | 1.5 | 51.5 | 37% | 30 | 50 | 3 | - |
| 13 | 56.5 | 11.1 | 14.5 | 17.8% | 40 | 50 | 4 | 2 |
| 14 | 37 | 11 | 21 | 31% | 50 | 64 | 4 | 2 |
| 15 | 77.5 | 21.7 | 0.1 | 325 ppm | - | - | - | - |
| 16 | 21.8 | 4.3 | 36 | 38% | 60 | 50 | 12 | 2 |
| 17 | 77.5 | 21.5 | 0.7 | 0.2% | 1 | 2 | 1 | - |
| 18 | 41 | 2.2 | 23 | 33.2% | 60 | 80 | 30 | 4 |
| 19 | 78 | 20.6 | 1 | 50 ppm | - | - | - | - |
| 20 | 78.5 | 20.1 | 1.4 | <1 ppm | - | - | - | - |
| 21 | 37 | 10.1 | 29 | 24% | 20 | 20 | 3 | - |
| 22 | 77.9 | 21.6 | 0.2 | 3 ppm | - | - | - | - |
| 23 | 78 | 21 | 0.7 | 0.12% | - | - | - | - |
| 24 | 66 | 3 | 21 | 11% | 25 | 30 | 4 | - |
| 25 | 78 | 22 | 0.1 | 5.5 ppm | - | - | - | - |
| 26 | 62.7 | 3.3 | 18 | 16% | 20 | 30 | - | - |
| 27 | 77.5 | 21.7 | 0.05 | 4 ppm | - | - | - | - |

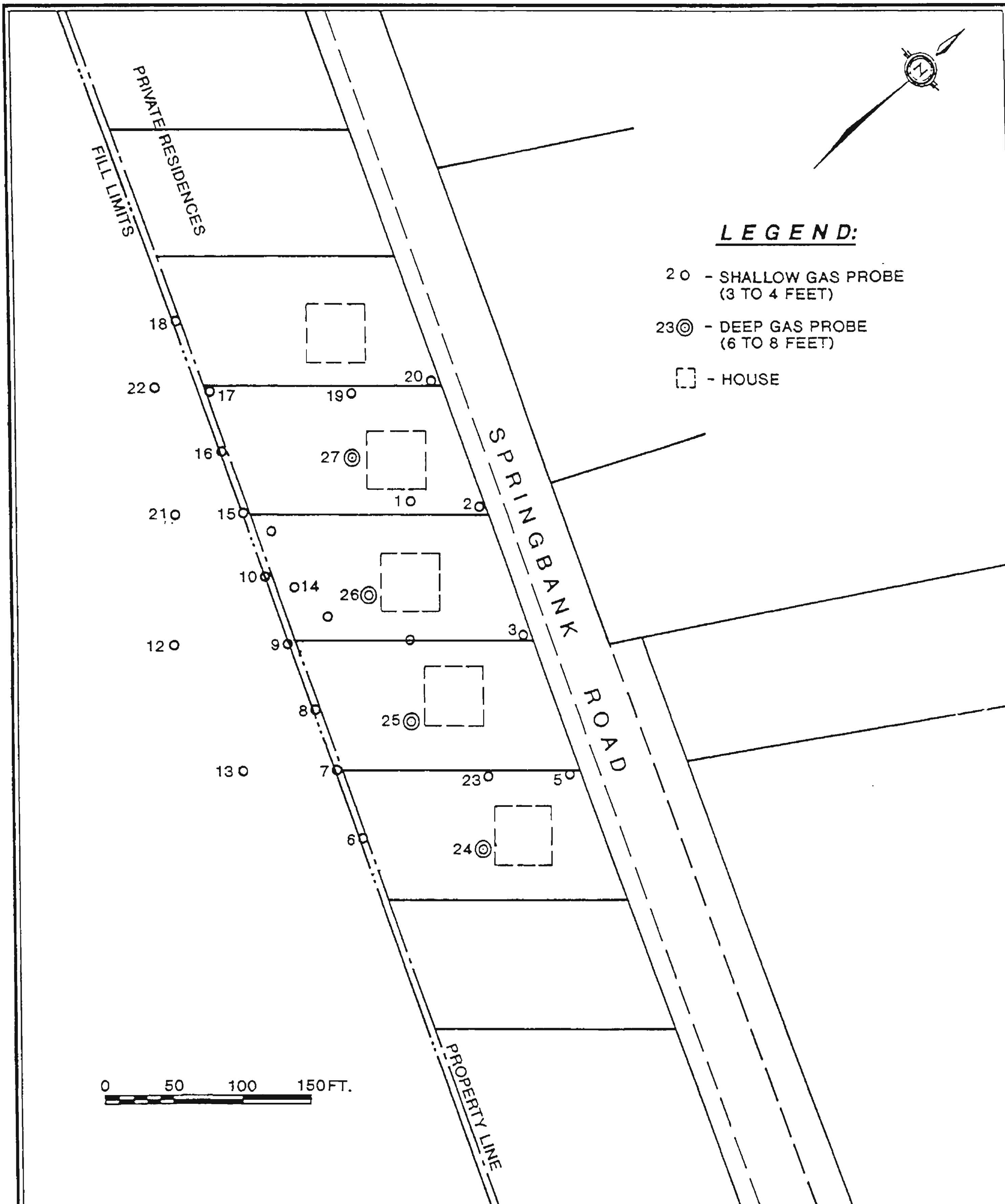



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**FIGURE B–7: GAS PROBE LOCATIONS**

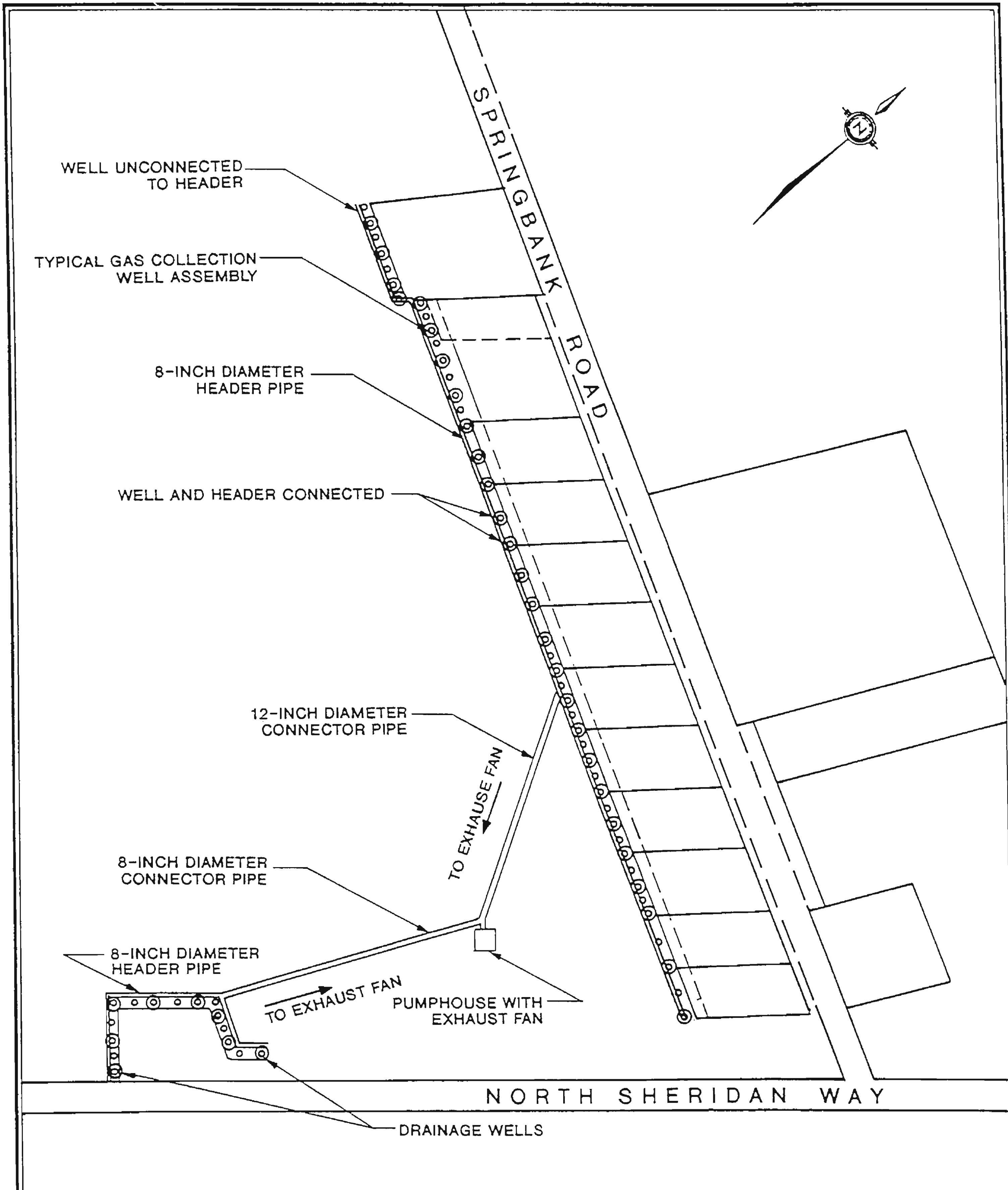


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**FIGURE B-8:**
**GAS MIGRATION CONTROL-HEADER AND PUMPING SYSTEM**

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #14**

**BUILDING TYPE AND LOCATION:** One-storey nursing, six-storey retirement home

**GAS TYPE:** Methane

**SOURCE:** Landfill

**TYPE OF CONTROL:** Active sub-slab, ventilation, passive measures

**CASE STUDY PRÉCIS:**

**System Design**

During the geotechnical investigations of a nursing/retirement home complex, relatively high concentrations of methane were detected. The site of the complex was located on land once used as a municipal landfill site. In order to ensure that harmful soil gases would not enter into the indoor living space, both active and passive measures were implemented. Active preventative measures consisted of an active soil gas pumping system, monitoring and alarms, an interior venting system and regular inspections, testing and maintenance.

The active pumping system consists of 100 mm diameter perforated pipes spread equidistant under the basement floor slab. Surrounding the piping is a 200 mm thick layer of crushed stone (Acres, 1982). The layer of crushed stone acts as permeable media to maximize recovery of soil gases. During the installation of the piping system, polyethylene sheets were placed on top of the crushed gravel to prevent the clogging of the pipes. Additional gravel was also installed next to the exterior walls to prevent a soil gas build-up. The venting system is maintained at a pressure less than atmospheric by an explosion-proof fan located on the roof of the building. Figure B-9 depicts the schematic of the system.

In addition to the sub-slab venting arrangement, the design of the ventilation system included a partial makeup of air from the outdoors. This design would cause the dilution of indoor methane concentrations should an influx of methane occur. To ensure that methane could not build up in small rooms or storage areas (in the basement), individual fans were installed.

In order to monitor the effectiveness of the system, monitors (capable of detecting methane concentrations of at least 10% of the lower explosive limit) were installed near the ceiling of six basement rooms and two stairwells in the lower parts of the building. Additional pressure monitors were installed near the fans to ensure the system was operating. All monitors were connected to a central nursing station. The nursing station is manned on a 24-hour basis. A standby generator is also present to power the venting system and alarm.

In addition to the active measures described above, several passive measures were also applied including sealing, crack control reinforcement, porous landscaping and contingency planning. As part of the construction, all joints in the basement floor and walls were sealed with plastic sealing strips or a flexible sealing compound. This was conducted to limit soil gas entry via these pathways.

Since slab cracking is inevitable, slabs on grade were constructed according to the minimum shrinkage and temperature reinforcement as outlined in CSA standard CAN3-A23.3-M77 Code for the Design of Concrete Structures for Buildings, for basement walls. A "Z" value stipulated in CAN3-A23.7-M77 should not exceed 20 KN/mm for all flexural members at or below ground surface. This corresponds to a maximum allowable crack width of approximately 0.20 mm.

Adjacent to the building, materials such as interlocking bricks or gravel were also recommended to prevent any soil gas build-up.

Finally, a contingency plan was developed in the case of methane detection.

**Monitoring**

Two annual inspections have been undertaken since the system was commissioned (Arthur Scott and Associates, 1989 and 1990). The discharge from all eight fans were monitored for methane and hydrogen sulphide; no measurable concentrations were found. Each sensor was also tested; only small changes in calibration were necessary. After the first year, several failed light bulbs constituted the only problem. During the second inspection, a fan shutdown test registered a delayed signal at the control panel. This was due to a strong wind blowing across the building which caused the pressure sensing device on the fan discharge to measure a non-zero pressure. As such, the controller interpreted this as though the fan was still operating. Pressure sensor adjustment was recommended. Other than these minor adjustments, the system was working fine.

**REFERENCES:**

Acres Consulting, 1982. Soil Gas Protection Systems Report.

Arthur Scott and Associates, 1989. Annual Inspection of the Methane Protection System, November 1989.

Arthur Scott and Associates, 1990. Annual Inspection of the Methane Protection System, September 1990.

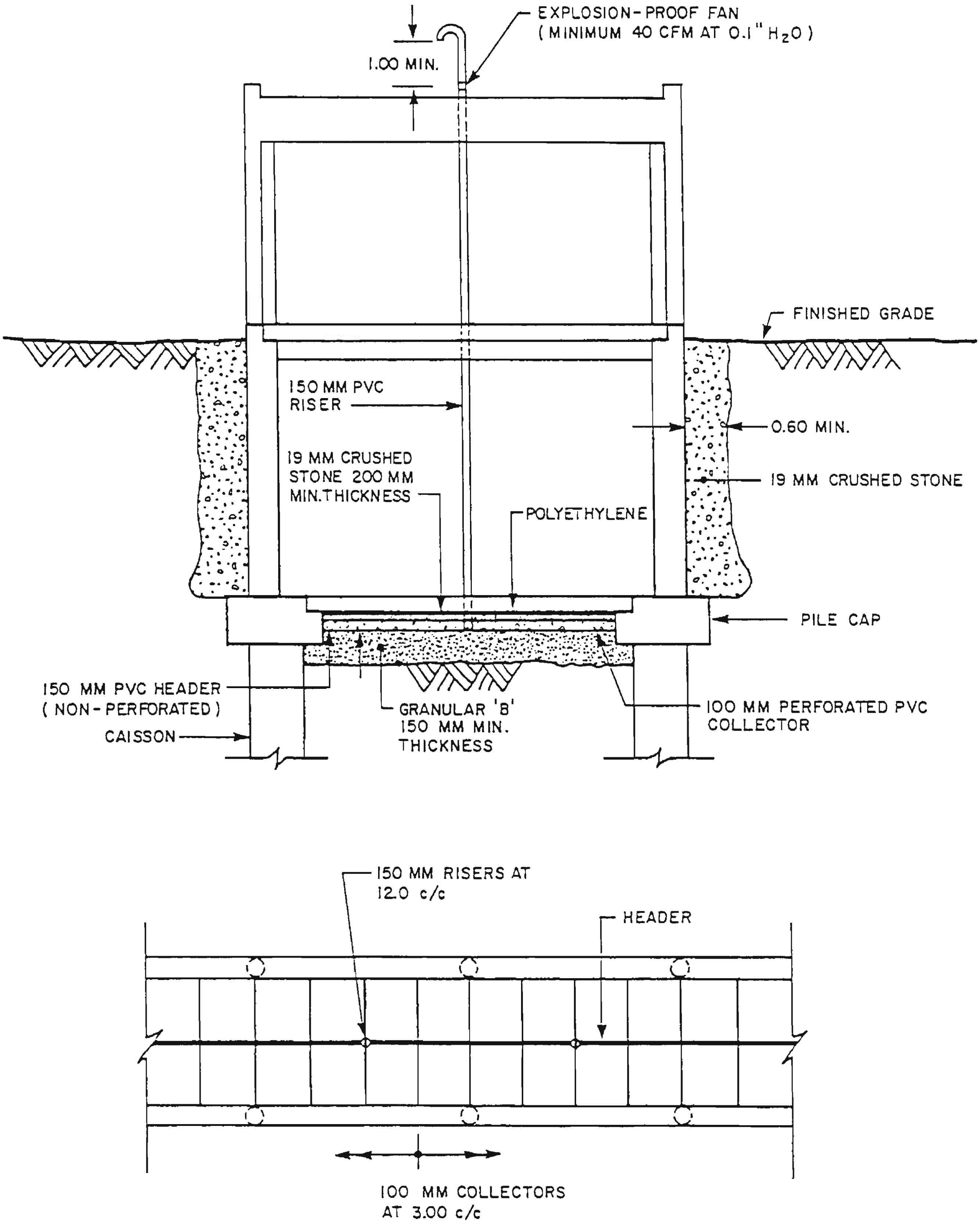


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**FIGURE B-9: SCHEMATIC OF SUB-SLAB RENTING SYSTEM (Source: Acres, 1982)**

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #15**

**BUILDING TYPE AND LOCATION:** Single family dwellings, Hamilton

**GAS TYPE:** Gasoline odours

**SOURCE:** Leaking underground gasoline storage tanks

**TYPE OF CONTROL:** Excavation of tanks, flushing of sewers

**CASE STUDY PRÉCIS:**

Several homeowners living in Hamilton were plagued by the intrusion of gasoline odours via the sewer drains. Inspection by the city crews confirmed the presence of gasoline odours in several homes; however, testing with an explosimeter revealed less than explosive levels indoors. Inspection of nearby sewers also revealed the presence of some gasoline products. A nearby gasoline station (located one block away from the impacted houses) was undergoing tank replacement at the time of the vapour intrusion. The homes where the excessive vapours were found were located upgradient in the sewer network. The homes were affected for a very short period of time as the odour dispersed. As a precautionary measure, one of the service stations had its tanks excavated. Upon removal of one of the tanks, a small hole was observed. Despite the occurrence of this hole, soil samples in the excavation revealed no significant contamination. New tanks were installed.

Approximately two months after vapours were first detected in the nearby homes, emergency crews were again called in because of excessive vapours coming from the sewers. Following heavy rains, significant amounts of liquid gasoline were observed flowing into a nearby manhole. City crews flushed the sewers to reduce downgradient contaminant levels. Within several hours, several additional homeowners complained about gasoline vapours in their basements. Vapour entry via the sewer system was suspected. City crews monitored for explosive levels. Eventually, product ceased flowing into the sewers; vapour problems subsided.



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## CMHC SOIL GAS RESEARCH STUDY
## CENTRAL CANADA SECTOR
## CASE STUDY #16

| | |
|---|---|
| **BUILDING TYPE AND LOCATION:** | Homes, Manitowadge |
| **GAS TYPE:** | Methane |
| **SOURCE:** | Landfill |
| **TYPE OF CONTROL:** | Trench was built around landfill that was filled with gravel to vent the gases. |

**CASE STUDY PRÉCIS:**

A trench was built around the Manitowadge landfill and filled with gravel to vent the gases, as a preventative measure, so that homes built adjacent to the landfill would not experience problems with methane gas infiltration.

The landfill is old and contains mostly ash, and very little organic matter. Some monitoring in the homes was completed; no problems have ever been reported.

# CMHC SOIL GAS RESEARCH STUDY
# CENTRAL CANADA SECTOR
# CASE STUDY #17

**BUILDING TYPE AND LOCATION:** High School, Marathon

**GAS TYPE:** Methane

**SOURCE:** Landfill

**TYPE OF CONTROL:** Active venting system

**CASE STUDY PRÉCIS:**

The high school was built on the land adjacent to an active landfill site. As a precaution against soil gas migration, the foundation of the school was built on a slab, under which there was an air space. Blowers were installed to circulate air beneath the slab.

## CMHC SOIL GAS RESEARCH STUDY
## CENTRAL CANADA SECTOR
## CASE STUDY #18

**BUILDING TYPE AND LOCATION:** Single family dwellings

**GAS TYPE:** Petroleum products

**SOURCE:** Tank leak at service station

**TYPE OF CONTROL:** Floating product recovery from water table, soil vacuum extraction around houses, and positive pressure fans inside houses

**CASE STUDY PRÉCIS:**

In early December 1988, a product volume imbalance was identified between sales and storage of gasoline at a service station located southern Ontario. Concurrently, gasoline vapours were detected along exposed basement walls and in the sumps of two nearby single family dwellings; the homes were evacuated. A leak was confirmed to exist in one of the underground fuel storage tanks, and a review of the product delivery and sales records identified the leak to have resulted in a loss of approximately 9000 litres of gasoline to the subsurface.

Remedial action at the site consisted of:

- removal of the storage tank
- installation of vapour probes and monitoring wells to identify the extent and direction of the gasoline migration
- product recovery through pumping of the gasoline floating on the water table
- installation of a vapour extraction system upgradient of the affected houses
- installation of industrial ventilation fans inside the houses to create a positive pressure environment and reduce vapour infiltration

The vapour extraction system consisted of 50 mm diameter slotted PVC placed at 3 m intervals extending to a depth of 3 m. The probes were connected to a extraction fan drawing 50 to 70 L/s via a 76 mm collection header. The number and configuration of the extraction probes changed as the remedial efforts progress, with a maximum of 24 probes connected to three extraction fans.

During the short period between the detection of the leak and the commencement of remedial action at the site, the residential petroleum vapour concentrations increased to the explosive range and then stabilized in the low LEL range. The vapour levels inside the homes decreased rapidly after the startup of the vapour extraction system on January 13 and 16, 1988. Although the initial hazardous levels were no longer present in the homes, the continued presence of odours forced the relocation of affected residents. Vapour levels inside the two affected homes are tabulated in Table B.6. The residents were authorized to return to their homes by the end of March 1989 by the local Health Unit after benzene, toluene, and xylene concentrations had reduced to ambient levels.

**Table B.6**
**Table Summarizing Vapour Concentrations (ppm) in Two Homes**

| Date | House #1 | | | House #2 | | |
|---|---|---|---|---|---|---|
| | Base | MF | BR | Base | MF | BR |
| Jan 06 | 4500 | 2000 | 1000 | 3500 | 1000 | 0 |
| 10 | 2000 | 600 | 200 | | | |
| 11 | 1000 | 650 | 250 | | | |
| 16 | 660 | 660 | 280 | 700 | 500 | 250 |
| 19 | 40 | 30 | 40 | 10 | 20 | 0 |
| 20 | 10 | 20 | 20 | 10 | 0 | 30 |
| 23 | 10 | 0 | 0 | 0 | 10 | 15 |
| 24 | 10 | 10 | 10 | 30 | 20 | 10 |
| 27 | 1.2 | 1.4 | 1 | 0.8 | 0.6 | 0.6 |
| 31 | 0.9 | 0.6 | | 0.8 | | 1 |
| Feb 08 | 0.7 | 1 | 0.6 | 0.6 | 0.8 | 0.6 |
| 24 | 1 | 0.9 | | 0.7 | 0.9 | 0.6 |
| 28 | 0.6 | 0.5 | 0.6 | 0.4 | 0.4 | 0.3 |
| Mar 06 | 1.2 | 1 | 1 | 1.1 | 1.1 | 1 |
| 15 | 0.7 | 0.5 | 0.5 | 0.7 | 0.6 | 0.4 |
| 27 | 0.6 | 0.6 | 0.6 | 0.8 | 0.6 | 0.4 |
| 31 | 0.7 | 0.6 | 0.5 | 0.8 | 0.8 | 0.8 |

Monitoring at this site was initially completed with a HNu photoionization detector. Later, when levels subsided, vapours in the vapour extraction system, the soil gas probes and the indoor air were sampled with a GMI Gas Surveyor 4. In addition to this monitoring, measurements were also conducted using charcoal adsorption tubes. The adsorption tubes specifically were used to detect concentrations of benzene, toluene, and xylene in various living areas within the affected homes. The results of two-day monitoring effort indicated that the highest benzene and toluene levels were 0.03 and 0.24 mg/m$^3$, respectively.

Through correspondence with the Medical Officer of Health, a guideline for acceptable indoor contamination was established. A theoretical public health limit was established based on the following formula:

$$C = 0.238 \times (1/SF) \times TLV$$

| | | |
|---|---|---|
| C | = | allowable Public Health exposure limit |
| 0.238 | = | conversion to 24 hours/day, 7 days/week |
| SF | = | safety factor (1000 recommended by Ministry of Health for benzene and 100 for toluene and gas vapour) |
| TLV | = | Occupational Health & Safety exposure limit |

Using the Ontario TLV for benzene of 1 ppm, the suggested Public Health Limit of 0.00024 ppm (0.00076 $mg/m^3$) was recommended. The Ontario TLV for toluene (100 ppm) was given a recommended value of 0.240 ppm (0.903 $mg/m^3$). The Ontario TLV for gas vapours (300 ppm) had a corresponding Public Health Limit of 0.719 ppm. Reoccupation of the homes could not be conducted until such indoor concentrations were reached.

However, there were concerns raised about these extremely low theoretical target concentrations. The homes were consequently re-sampled by the Ministry of the Environment (at the request of the Medical Officer of Health). The additional sampling indicated that the highest benzene and toluene concentrations found in the homes was 0.010 and 0.11 $mg/m^3$ compared to ambient concentrations of 0.0024 and 0.0018 $mg/m^3$, respectively.

In response to these new findings (i.e. the elevated ambient concentrations), the Medical Officer of Health indicated that "these levels are what one would expect from normal household activities in North America and are consistent with published household tests from the U.S.A.". The health officer concluded that the homes were no longer being affected by gasoline seepage from the neighbourhood gas station. The owners could reoccupy their homes.

The cleanup efforts are continuing at this site. The product recovery pumping system was removed January 24, 1989, but the vapour extraction is continuing. The service station has been closed since December 1988 and will remain closed for the foreseeable future. The owners are anticipating to decommission the site in the near future.

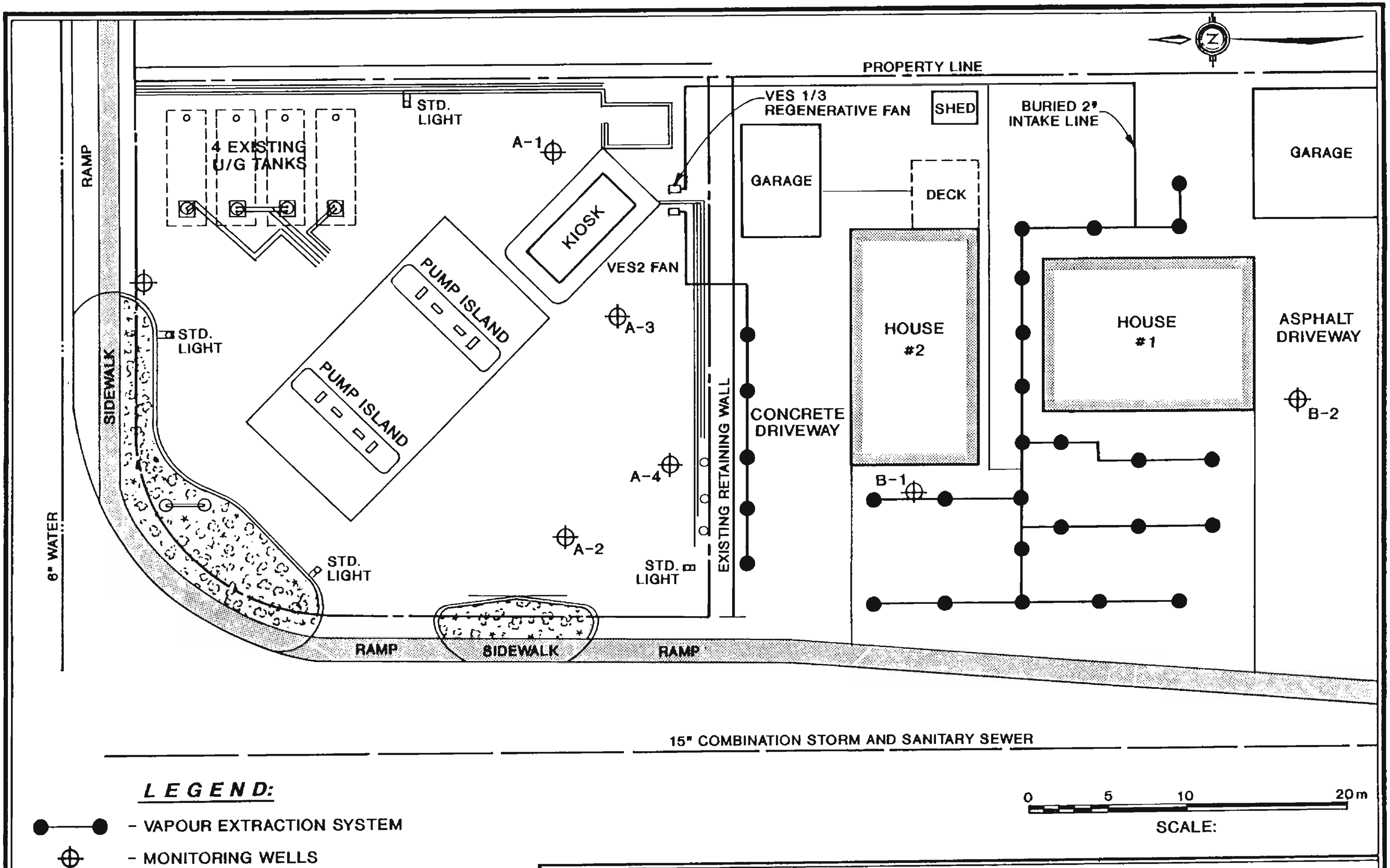


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**FIGURE B-10: SERVICE STATION SOUTHERN ONTARIO**

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #19**

**BUILDING TYPE AND LOCATION:** House adjacent to landfill, London

**GAS TYPE:** Methane, organics

**SOURCE:** Landfill

**TYPE OF CONTROL:** Passive vents

**CASE STUDY PRÉCIS:**

St. Julien Park in London's east end became the centre of controversy in February 1987 when a local citizen expressed concern for the health of nearby residents from potentially toxic wastes buried in the park after two of her brothers developed brain tumours. Around the same time, an employee of former plating plant operating at the site revealed that waste chemicals were dumped into a nearby pond and left to soak into the ground.

Some years prior to the above events, the site where St. Julien Park is now located was the site of a borrow pit operation for sand and gravel. The sand and gravel deposit in the area is approximately 4 to 6 metres in depth overlying a hard till (MOE, 1988). The groundwater elevation is found generally at the upper till boundary. Following excavation of the fill, the area was used for disposal of construction debris and municipal refuse. Figure B-11 shows the location of the buried wastes. A chrome plating plant was also located on the site. The plating operation is believed to have been discontinued in the late 1960s.

As part of a regular monitoring program, the Ontario Ministry of the Environment (MOE) has analyzed both soil and groundwater discharging from the site. Soil samples were taken in the vicinity of the baseball diamonds on the site. Groundwater sampling was conducted at several leachate springs emanating from the shore of the landfill site, and on samples of groundwater. The majority of the approximately 80 chemical compounds measured were either undetected or at acceptable levels (MOE, 1987). Several volatile compounds such as benzene, chlorobenzene, 1,1-dichloroethylene, chloroform, 1,1,2-trichloroethane, and carbon tetrachloride were detected in the leachate; the levels did, however, exceed world drinking water standards. In addition to the volatile compounds, several heavy metals including cadmium, lead, manganese, selenium, copper, zinc, and iron were detected at levels as much as six times the recommended levels.

In view of the complaints generated in regard to the brain tumours, the Middlesex-London Health Unit initiated a study to determine if excessive cancer deaths had occurred in the area. In collaboration with the Department of Epidemiology and Biostatistics of the University of Western Ontario, and the Ontario Cancer Treatment and Research Foundation, a review of specific types of cancer for London and the St. Julien Park area were documented. This included concerns of the brain, respiratory organs, digestive organics, liver, skin, and leukemias. Although the investigators would have liked to document the incidence of malignancies, such data was not readily available in Ontario, and the accuracy of such data, especially from the 1960s was viewed as questionable. Since most malignancies have a high fatality rate, mortality data was used (Pudden et al, 1988). The results of the study concluded that no clusters of cancer were found with respect to St. Julien Park.

In addition to the study initiated by the district health unit, an air toxics study was initiated by the MOE. The study was aimed at determining emissions from five stacks located in the northeast corner of the property. The location of the gas ventilation system is shown in Figure B-11. The vent stacks are connected to a horizontal perforated header pipe which travels along the northeast property boundary. The venting system is a passive system connected to a rotor attached to the top. In order to determine the emission rates of the compounds, concentrations and flow rates were measured by the Air Resources Branch in March, 1987. Sampling was conducted by adsorption tubes and analyzed by GC/MSD. Based on the analysis, 78 organics were found above their respective detection limits. Only 13 of those compounds identified had Ambient Air Quality Standards. Based on air dispersion modelling, contaminant levels were all below their Ontario Ambient Air Quality Criteria (MOE, 1987).

Following the above studies, another study initiated by the Middlesex-London Health unit to determine if the residents near St. Julien Park were being affected by heavy metal contamination. Alder et al (1990) conducted a health study on a total of 304 participants from the St. Julien Park neighbourhood and two other control communities. Hair specimens were obtained and analyzed by atomic adsorption spectroscopy. Participants were also interviewed for lifestyle habits. The results of this study indicated that lead and cadmium concentrations were statistically higher in adults of the St. Julien Park area; there were no statistically significant differences for children. Manganese was neither elevated in children or adults in the St. Julien Park district.

Apart from the various studies conducted as described above, the City of London, through their consultants, conduct regular monitoring of the houses and sewers north of the park. As part of this monitoring activity, soil gases are also sampled by using a punch bar and then measuring methane concentrations. Based on a limited review of data, it appears that methane may have at times infiltrated homes north of the park. For the most part, however, soil gases north of the site contain non-detectable amounts of methane. According to the

City of London, if excessive methane levels are observed inside homes, monitoring activity is stepped up. Based on current knowledge, no organic sampling has been completed indoors to-date.

Currently, a technical committee was formed to deal with problems found at the St. Julien Park. Contingent on funding, the City of London may commission a further study to investigate the impact of St. Julien Park on nearby residents.

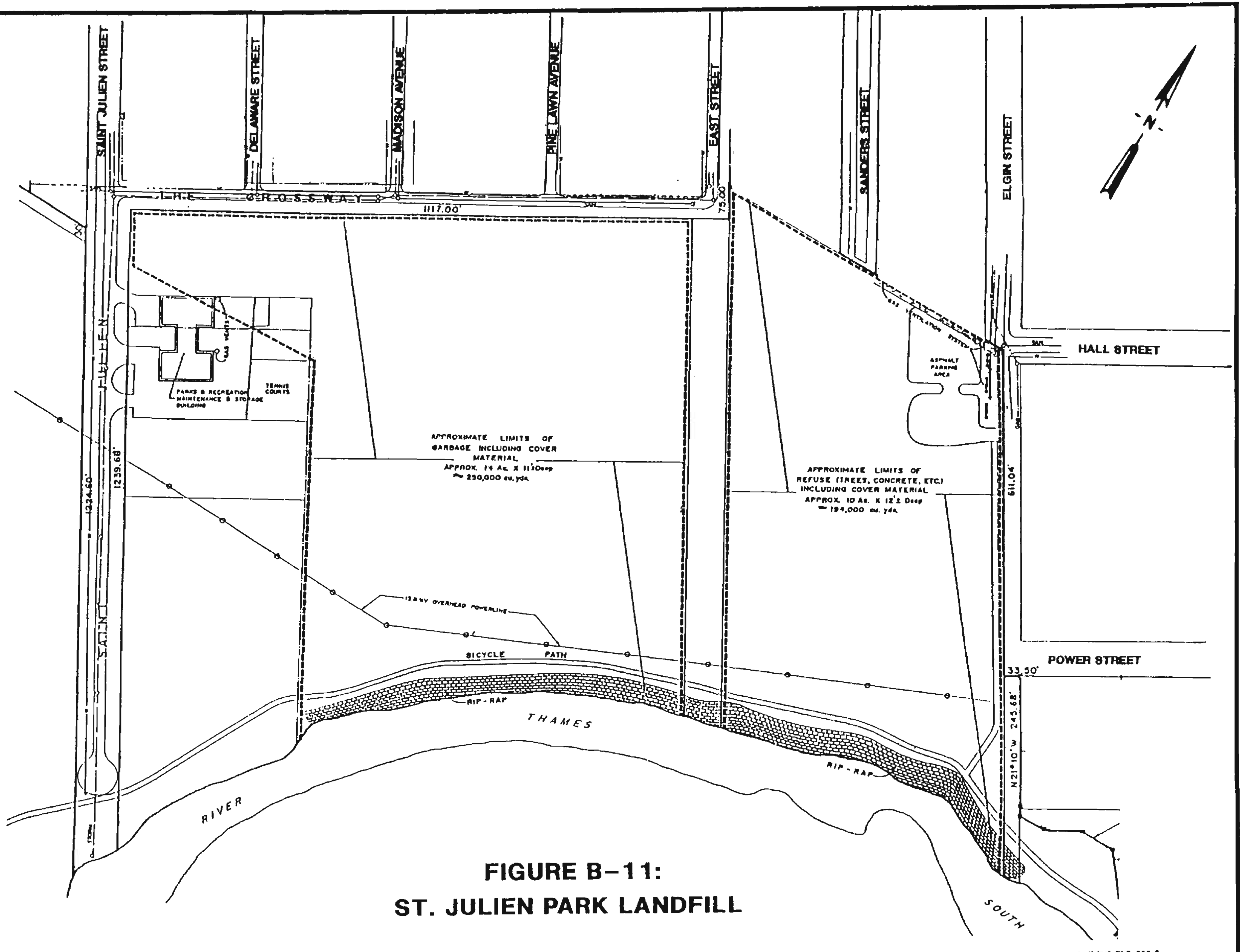
**REFERENCES:**

Pudden, J.D., N.L. Juddle, and J.M. Robertson, 1988. Report of the Medical Officer of Health to the City of London Regarding Community-Environmental Issues: Review of Selected Cancer Mortality in London. Middlesex-London Board of Health, London, Ontario (1988).

Ministry of the Environment, 1987. Draft Report on St. Julien Park Monitoring Results. MOE SW Region July 30, 1987.

Alder, R.J., R. Martin, D. Ogilvie, J.D. Pudden, and N.L. Tuddle, 1990. Exposure to Heavy Metals in Children and Adults Living Near a Former Waste Landfill Site.

Ministry of the Environment, 1988. Report of Subsurface Soil Investigation and a Groundwater Quality Assessment for an Area. Drums containing plating wastes were allegedly buried in St. Julien Park, City of London, County of Middlesex.




# FIGURE B–11: ST. JULIEN PARK LANDFILL

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**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #20**

**BUILDING TYPE AND LOCATION:** Single dwelling home, Cornwall

**GAS TYPE:** Fuel oil

**SOURCE:** Fuel oil tank adjacent to home

**TYPE OF CONTROL:** Soil excavated and the connection fixed.

**CASE STUDY PRÉCIS:**

Fuel oil odours were present in the basement of a home in Cornwall. It was discovered that the connection to the exterior fuel oil tank was leaking. No monitoring was conducted. The contaminated soil was excavated, and the connection was fixed. There has been no reoccurrence of the problem.

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #21**

**BUILDING TYPE AND LOCATION:** Six Locations, Cornwall

**GAS TYPE:** Methane

**SOURCE:** Decomposing woodchips that had been used for landfill

**TYPE OF CONTROL:** Drainage tiles around affected homes are passively vented

**CASE STUDY PRÉCIS:**

An explosion at a college in Cornwall prompted investigation and the subsequent installation of passive gas vents on six different establishments: four private residences, one school, and a college. These locations were identified as locations where wood chips had been used as landfill. These stacks are monitored for the presence of carbon monoxide, lack of oxygen and the explosive level by the City Fire Department once a month during the summer and twice a month during the winter. The monitoring began in the early 1970s. There has never been any need for concern. Several people were contacted to obtain details of the alleged explosion, but only one contact knew of the explosion.



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## CMHC SOIL GAS RESEARCH STUDY
## CENTRAL CANADA SECTOR
## CASE STUDY #22

**BUILDING TYPE AND LOCATION:** Single family dwelling, Cambridge

**GAS TYPE:** Trichloroethane product

**SOURCE:** Solvent that had been used to clean the chimney

**TYPE OF CONTROL:** Contaminated soil removed

**CASE STUDY PRÉCIS:**

The resident of a Cambridge home complained of a chemical odour around the fireplace. Investigations lead to the discovery that the building contractors had cleaned the chimney with a solvent and then poured the waste solvent at the base of the chimney. The owner of the home removed the contaminated soil and the problem disappeared.

## CMHC SOIL GAS RESEARCH STUDY
## CENTRAL CANADA SECTOR
## CASE STUDY #23

**BUILDING TYPE AND LOCATION:** Proposed commercial building, Kitchener

**GAS TYPE:** Methane

**SOURCE:** Landfill site

**TYPE OF CONTROL:**

**CASE STUDY PRÉCIS:**

A contractor had proposed a commercial development on a former sanitary landfill site in Kitchener. The site was bounded by Ottawa Street on the north, the Ottawa Street Landfill Site on the west, and the 440 Strasburg Road Condominiums on the south. The location is shown in Figure B-12. After an initial geotechnical investigation, another consultant was retained by the contractor to conduct an assessment of the character and distribution of landfill gases and provide preliminary designs for gas control.

The boreholes drilled on the site indicated that the western two-thirds of the property contained refuse and refuse/clean fill in various thickness from 1 to 6 m in thickness. Field measurements of methane concentrations and soil gas pressures were conducted by using existing 12.5 mm diameter probes which were installed by the geotechnical consultant. Measurements were conducted with a combustible gas detector, and a portable U-tube, oil filled manometer.

The results summarized on Figure B-13 indicate that the methane concentration in most of the probes were high, i.e. in the 20 to 60 percent by volume range; the maximum soil gas pressure recorded was 25 Pa.

Upon recommendations of the geotechnical consultant, the fill beneath the proposed building was incapable of supporting spread footings. As such, either removal of the fill and replacement with clean fill would be required or piles which could be placed on competent material. The various gas control options were required to adhere to this specification.

Three gas control options were suggested.

Option #1: The first option required the refuse/fill between the proposed parking lot and Ottawa Street be removed. The refuse under the rear parking lot, however, could be left in place and the landfill gas could be vented by an active venting system as shown in Figure B-14. To protect the building from gas intrusion, three lines of extraction wells were recommended. The system would be tied into an already existing landfill gas collection system.

Option #2: In the second option, all waste would be left in place and the building constructed would be constructed on piles or caissons. The floor slab would in this case be constructed at a height of 600 to 900 mm above ground surface. The floor slabs would have to be formed and sprayed on the bottom to prevent gas intrusion. An active system installed on the south side of the property would ensure that southward gas migration would not occur. Option #2 is shown on Figure B-15.

Option #3: The third option recommended would have the building constructed on piles on grade where refuse was located and on spread footings on the unfilled portion of the property. A vapour barrier consisting of a sand fill would be placed on grade followed by a poured slab. Connected to the sand bed would be an active venting system. The configuration is shown on Figure B-16. To date, no construction has taken place. No definite reason for the delay was noted although one unnamed government official indicated that a building permit was denied.

**REFERENCE:**

Hydrology Consultants Ltd., 1977. Control of Landfill Gases, Proposed Commercial Site, Ottawa and Strasburg Road for Paul Tuerr Construction Ltd.

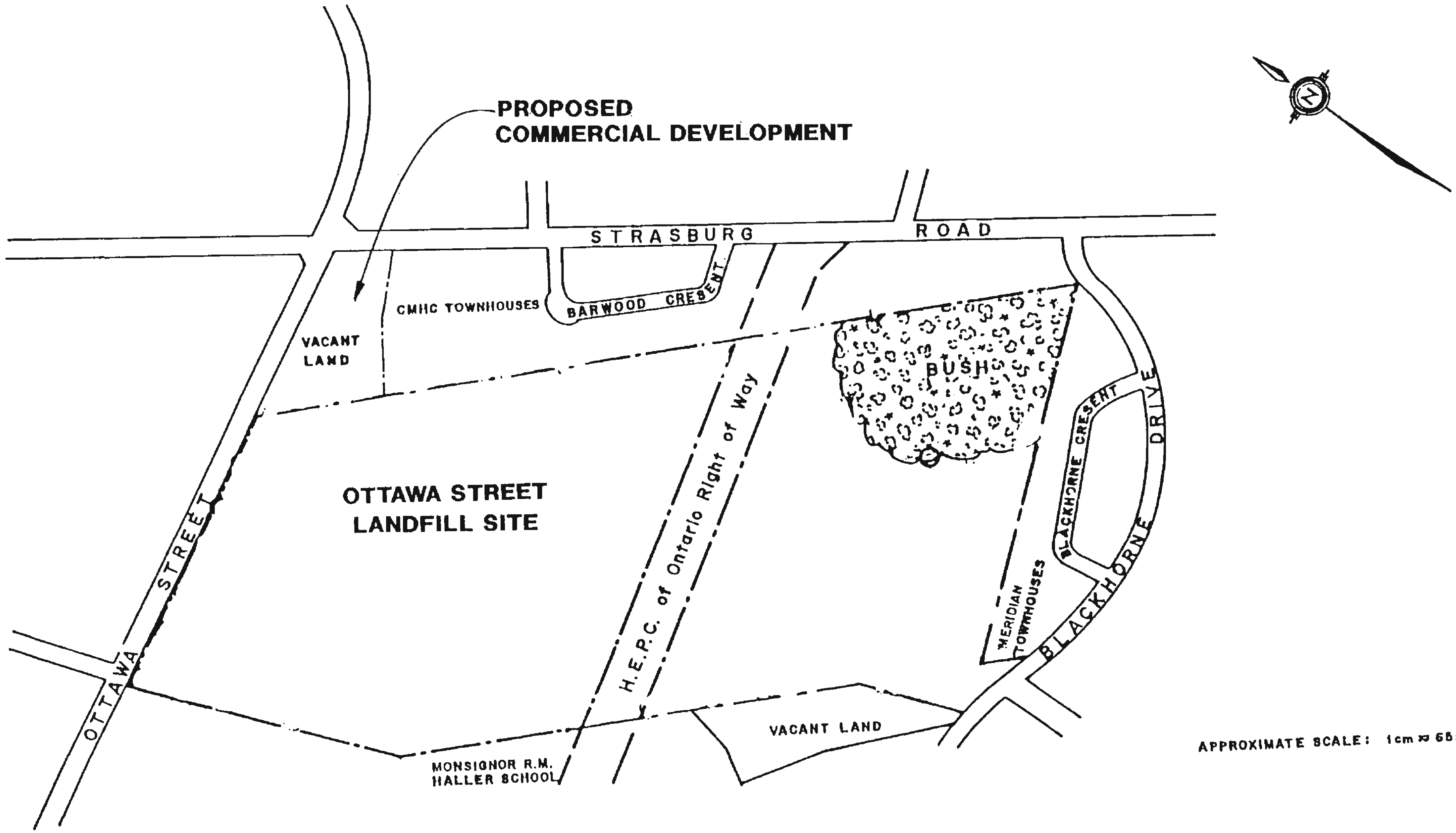


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**FIGURE B–12:**
**LOCATION MAP**


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**FIGURE B–13: METHANE RESULTS**

**(Source: Hydrology Consultants, 1977)**

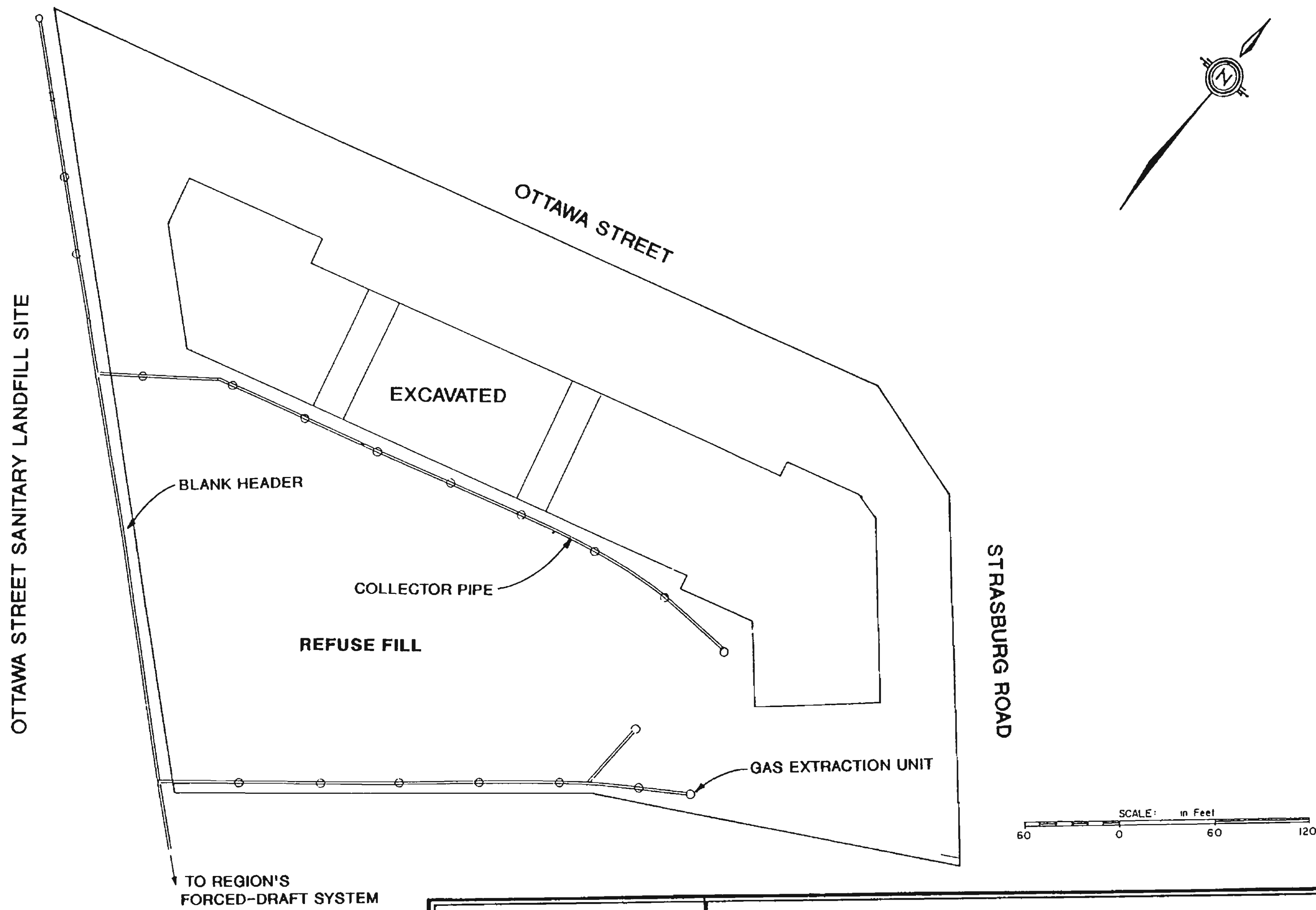


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**FIGURE B–14:**
**OPTION 1 GAS CONTROL SYTEM**
**(Source: Hydrology Consultants, 1977)**

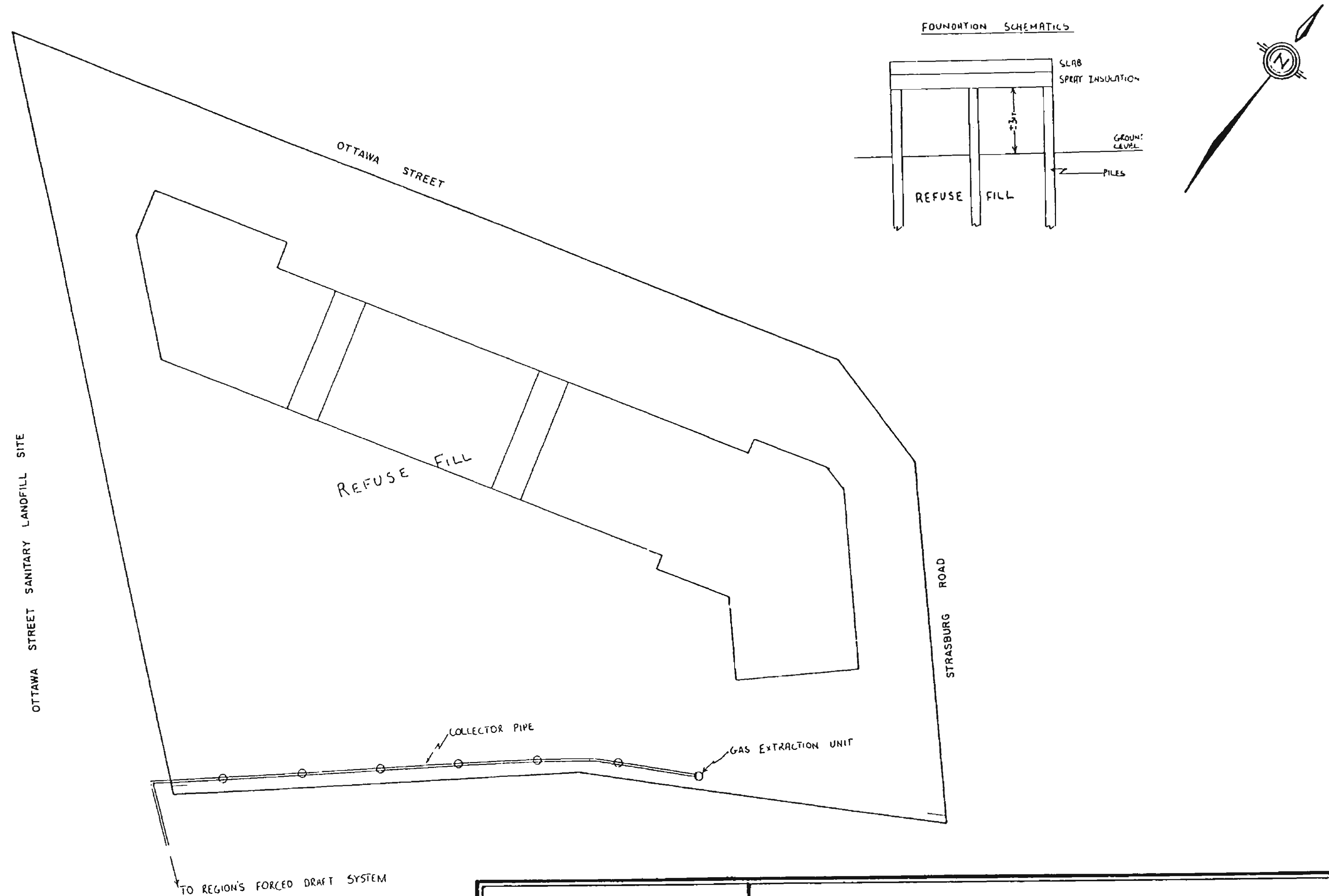


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**FIGURE B-15: OPTION 2 GAS CONTROL SYSTEM (Source: Hydrology Consultants, 1977)**

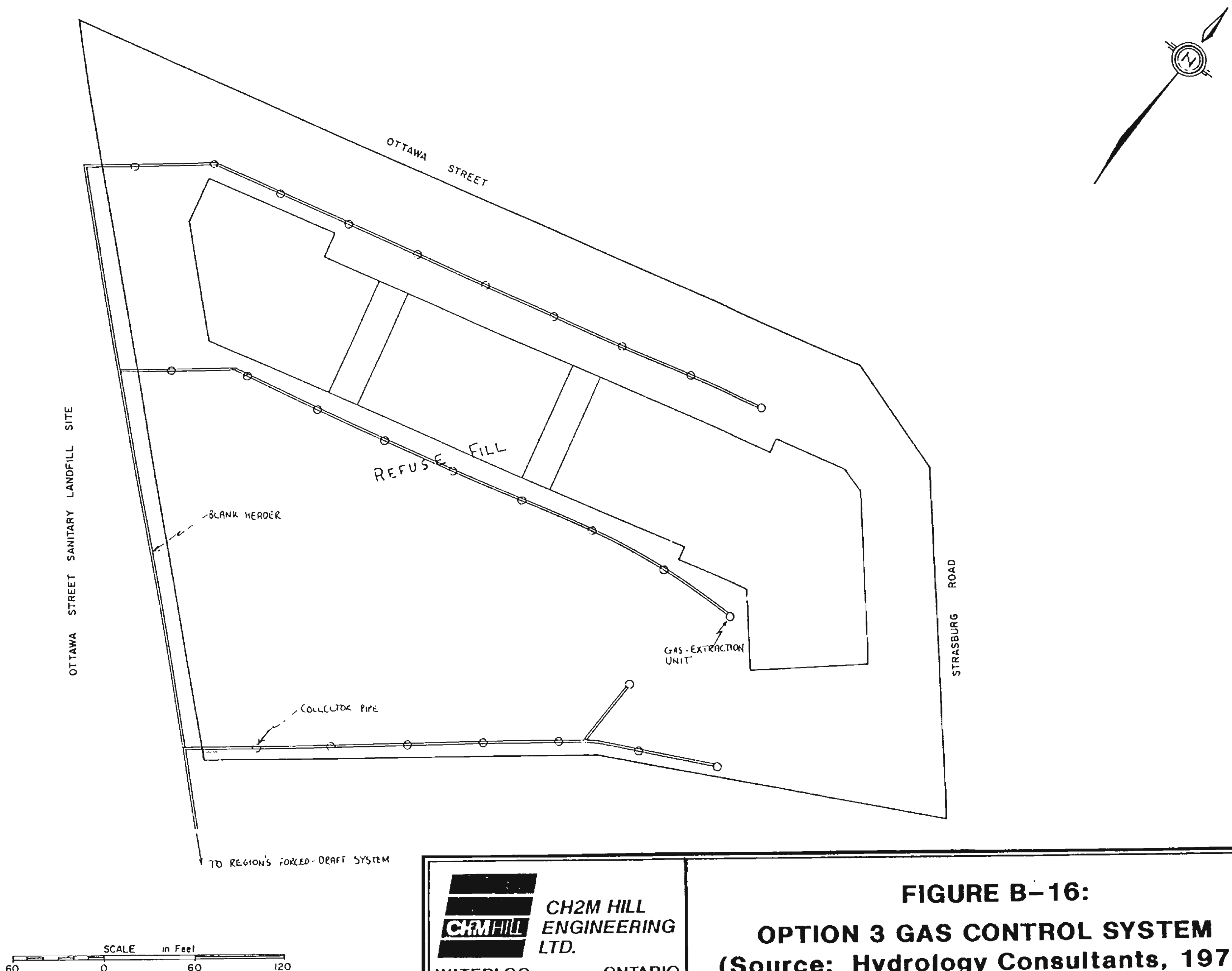


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**FIGURE B-16:**
**OPTION 3 GAS CONTROL SYSTEM**
**(Source: Hydrology Consultants, 1977)**

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #24**

**BUILDING TYPE AND LOCATION:** Commercial buildings, St. Boniface Landfills, Winnipeg

**GAS TYPE:** Methane

**SOURCE:** Landfill

**TYPE OF CONTROL:** Evacuation, partial demolition

**CASE STUDY PRÉCIS:**

**Background**

On June 13, 1979, the Winnipeg Council adopted a Methane Gas Policy and authorized a five-year Landfill Environmental Program to investigate landfill sites within Winnipeg. Prior to this, regular progress reports have been submitted to the Board of Commissioners. On July 9 and 10, 1984, representatives from the City met with an engineering consultant of Emcon Associates, who was acting in a review capacity regarding the program findings and recommendations. The objectives of the five-year program were:

- to reduce the potential of personal injury or property damage arising from the generation and migration of methane from landfill sites, and
- to minimize any special constraints on the use of land adjacent to landfill sites by reducing or eliminating the zones of concern around such landfill sites.

The program methodology involved investigating the limits and composition of the 36 sites, with instrumentation installed inside and immediately outside the fill to allow for gas testing. Buildings and underground structures on and adjacent to the site were also tested. If gas concentrations immediately outside of the fill exceeded the commonly accepted standard of 20% LEL for methane, gas barriers were considered. Previous consulting work identified a potential for methane migration for a distance of 213 m from the landfill boundary, which was designated as the "zone of concern". The "zone of concern" was known as the area around the landfill which is subject to landfill gas migration. If construction was to occur within this zone, soil gas control measures are recommended for incorporation into the design. The zone of concern was identified through long-term monitoring. The zone of concern was calculated by taking the furthest probe that detected methane and doubled the distance of that probe from the waste.

By 1984, the investigations were essentially complete for all 36 sites. Based on the findings, gas migration controls were implemented at two sites: the Kimerly and Margaret Park landfills. The controls appear to be functioning satisfactorily (Committee on Works and Operations, 1984). Three other sites, the St. Boniface Landfills I and II, and the Cordite Landfill required some modification at the site perimeters to ensure confinement of methane within the sites. Another three sites required a final assessment.

Some of the conclusions of the five-year study were as follows:

1. All the sites investigated contained significant amounts of decomposable buried organics, therefore producing methane.

2. Significant methane migration beyond the immediately periphery of filling has been detected and addressed at the Kimerly and Margaret Park landfills. The remainder of the sites were categorized as follows:

   Three sites (Cardite, St. Boniface I & II) required some modifications to ensure gas controls. Two sites required further work to establish need for more controls. Four sites require further definition of site boundaries. Five sites have a higher potential for migration; however, these sites are remote from current development. The remaining 20 sites displayed little or no migration.

3. The program allowed for the reduction of the 213 m zone of concern around the landfill. Monitoring still continued in the zone of concern. Based on the additional work, there was reason to believe that within the next 3 years, most control zones should be in the range of 15 to 45 m.

4. Within the zone of concern, but outside the landfill boundaries, barrier systems or elevated construction with a monitoring program to assess adequate performance, may be used at buildings and at underground services for protection against methane migration.

5. Both gas generation and migration are subject to changes resulting from weather variations and soil disturbances related to development. For the sites that have not demonstrated problems thus far, there is no guarantee that problems will not occur at a future time. It is estimated that gas production at most sites will not be dramatically reduced in the foreseeable future.

6. The frequency of monitoring would be reduced as confidence was gained through testing. Any new or existing structures within the revised control zones would still require regular monitoring as would recently installed gas barriers at the Kimerly and Margaret Park sites.

**St. Boniface Landfill Site I**

The St. Boniface Landfills (St. Boniface Landfill Sites I & II) were selected as a priority area because part of the St. Boniface Industrial Area is situated on landfill material.

As part of an effort to determine the extent of the wastes at the St. Boniface Landfill Site I, a resistivity survey was carried out during the summer of 1977. However, due to the extensive development over St. Boniface Landfill Site I, the interpretation of the distribution of the refuse fill was severely limited. Buildings, service corridors, pipelines and surface equipment, all of which contribute to surficial resistivity interference, resulted in less than 10 percent of the landfill area being covered by the resistivity grid. Consequently, interpretation was made based on drill hole data, previously existing information and limited resistivity data. Figure B-17 indicates the waste boundaries, and the control zone (as of 1984).

The St. Boniface Landfill Site I is in comparison with many other landfills rather shallow in depth. Based on the depth of refuse observed during the installation of four of the soil gas probes (probes 1-4 as shown on Figure B-17), the thickness of the refuse varied between ~1.4 to 6.6 m at probe locations 3 and 2, respectively. The landfill cover was also found to vary. At gas probe 1, only 300 mm of clay cover was present; at probes 3 and 4, 2 m of clay covers the waste.

Methane monitoring at St. Boniface Landfill Site I was completed on 13 gas probes and seven different onsite buildings. The methane content observed at various probes are shown on Figure B-18. The results on Figure B-18 display the methane content at various probes installed in: refuse fill, utility corridors, and natural undisturbed soils. All buildings on the St. Boniface Landfill Site I were also tested. The maximum methane concentration readings obtained in the buildings were as follows:

- 215 Panet Road — 46% methane-in-air
- 76 Fournier Street — 14% methane-in-air
- 70 Fournier Street — 7% methane-in-air
- 33 Fournier Street — 42% methane-in-air
- 65 Fournier Street — 58% methane-in-air
- 150 Warman Road — 58% methane-in-air
- 200 Warman Road — 8% methane-in-air

The above readings were obtained within cracks in the floor slabs of the buildings with the exception of 200 Warman Road where readings were obtained in the crawl space.

The buildings on the St. Boniface Landfill Site I were constructed during the 1969-1976 period using conventional construction techniques such as slab-on-grade floors, without consideration of landfill gas infiltration. (A slab-on-grade floor is usually of cast-in-place concrete and depends on the ground upon which is placed for support.) The one exception to this design was the building at 200 Warman Road which incorporated design considerations for landfill gases. This building used a structural slab and a mechanically vented crawl space. The structural slab itself was capable of supporting its own weight as well as a design load, while spanning the distance between supports which carry its usually aboveground surface.

The data indicates that all the buildings on the St. Boniface Landfill have combustible gases entering the buildings through cracks in the floors, around pile caps, where the buried utility lines entered the buildings, and in crawl space areas. Based on the methane readings observed, the concentrations in combination with oxygen in air could have been capable of supplying enough gas for an explosion or supporting a flame.

Testing was also carried out to estimate methane gas infiltration rates to the buildings located on the landfill. Two methods were used.

The first method involved taking direct readings at the point sources at 150 Warman Road during September 1977. The building was first checked for high level point sources. Five such point sources were located at column bases. Concentrations encountered were 4.5 percent, 8 percent, 28 percent, 50 percent and 58 percent methane-in-air. The point sources were sealed and time-related readings were taken at a fixed distance from the point sources after they were re-opened. The total flow rate into the building from the five point sources was estimated at 30 L/s. Based on other calculations for the landfill gas generation rate at this site, 1.7 L/s, the calculated infiltration rate was 17 times the production rate of the refuse which was directly below the building. This indicated that actual infiltration into the building was a result of landfill gas production from a larger area than the contact area of the building itself.

The second method used to estimate methane infiltration rates was to directly measure the combustible gas concentrations in the exhaust from the crawl space at 200 Warman Road (refer to Figure B-17 for location of this building). Since this building had a crawl space, the air from the crawl space was continuously exhausted by a fan of known capacity. Constant readings of methane-in-air were recorded from the exhaust. Considering the logic that the rate of methane infiltration into the crawl space was related to the methane concentration in the exhaust air, a simple calculation indicates the rate of infiltration.

Testing was carried out at 200 Warman Road during October 1977, using the above method. A consistent reading of 0.32 percent methane-in-air was obtained at the crawl space location. The fan capacity was 2000 L/s and the estimated infiltration rate was therefore determined to be approximately 12 L/s. Landfill gas production calculations indicate that refuse below the building could generate up to 0.8 L/s. The calculated infiltration rate was at least 14 times the production rate of the refuse below the building.

Although the method of calculating infiltration rates at 200 and at 150 Warman Road were different, the calculations did indicate that the infiltration rates of methane gas into buildings on the St. Boniface Landfill may be in the order of 14 to 17 times the maximum rate of methane gas generation of the refuse directly below the building.

As a comparison, testing similar to that which was completed at 200 Warman Road was carried out at another site (the Harold Hatcher School). The estimated total infiltration rate was calculated at 0.08 L/s. Landfill gas production calculations, however, indicated that the refuse below the building can generate 0.04 to 1.3 L/s. The calculation of the methane production was consistent with the infiltration rate. The low infiltration value was believed to be due to either the nature of the refuse or the thickness of the cover material below the structure.

Although monitoring of combustible gases at the point sources had indicated that large concentrations of gases existed at entry points, once it dissipates in the air, concentrations generally fall below the lower explosive limit. For example, at 65 Fournier Street, testing had located point sources at cracks in the floor slab as high as 50 percent GAS, maximum mid-air gas concentrations were only 0.02 percent methane-in-air (200 ppm).

The consultant at the time (UMA, 1978) recommended remedial measures to deal with the problem. If the remedial measures were not carried out, a rigorous monitoring program was recommended. The recommended monitoring program included a daily visit to all buildings on the St. Boniface Landfill Site.

Subsequent to this report, all seven buildings were purchased by the City. Four of the buildings have been demolished because the foundations had or were beginning to fail. The cost of repairing the foundations and adding external gas control measures (including upkeep) exceeded the cost of demolition. The remaining three buildings are being used for warehousing.

**St. Boniface Landfill Site II**

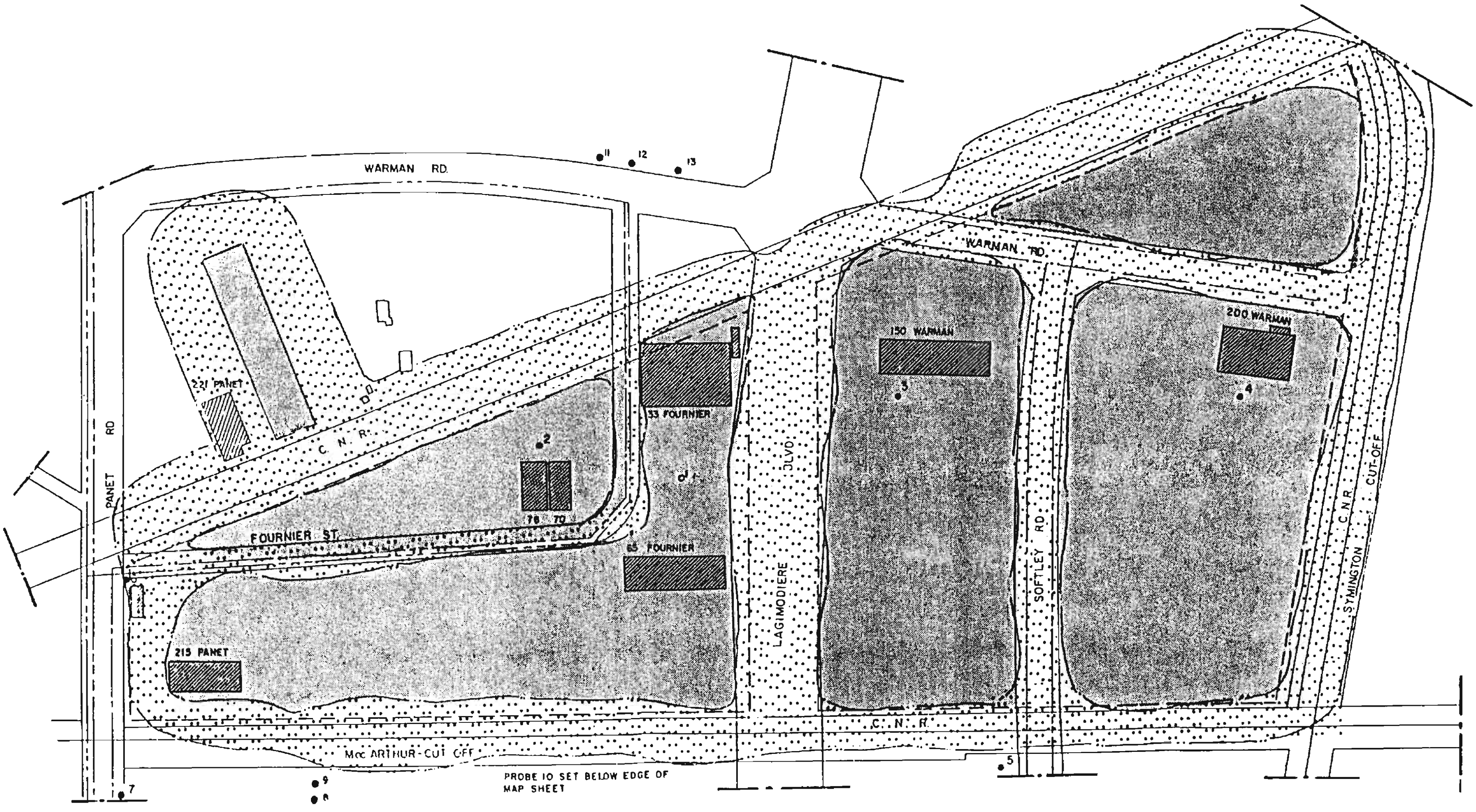
Similar to the procedure discussed with respect to the St. Boniface Landfill Site I, a resistivity survey was also carried out on St. Boniface Landfill Site II. Unlike the results at Landfill Site I, the resistivity survey was successful in defining the distribution of the fill. The entire landfill area was covered by the resistivity survey grid. Figure B-19 shows the landfill boundary and the location of two soil probes. Gas probe 1 was installed in the refuse, whereas gas probe 2 was installed in a silty clay layer. Silty clay layers of this sort are found frequently in the St. Agatha clays around Winnipeg; such layers (or seams) may act as preferential gas pathways. Probe 2 was installed at a distance of 23 m from the edge of the refuse. Methane concentrations for both probes are depicted on Figure B-20.

**REFERENCES:**

Committee on Works and Operations, 1984. Report from committee to City of Winnipeg, October 2, 1984.

Underwood McLellan, 1978. Landfill Gas Study for City of Winnipeg, Department of Environmental Planning.

City of Winnipeg, 1984. Drawing SWD-D-100A. St. Boniface Landfill Site 1 Detail. Map from Works & Operations Division, Landfill Environmental Section.




***LEGEND:***

- AREAS OF LANDFILLING
- CONTROL ZONES
- GAS PROBES
- BUILDINGS TESTED FOR COMBUSTIBLE GASES

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**FIGURE B-17:**
**ST. BONIFACE LANDFILL SITE I SITE PLAN**
**(Reproduced from: Underwood McLellan, 1978 & City of Winnipeg, 1984)**

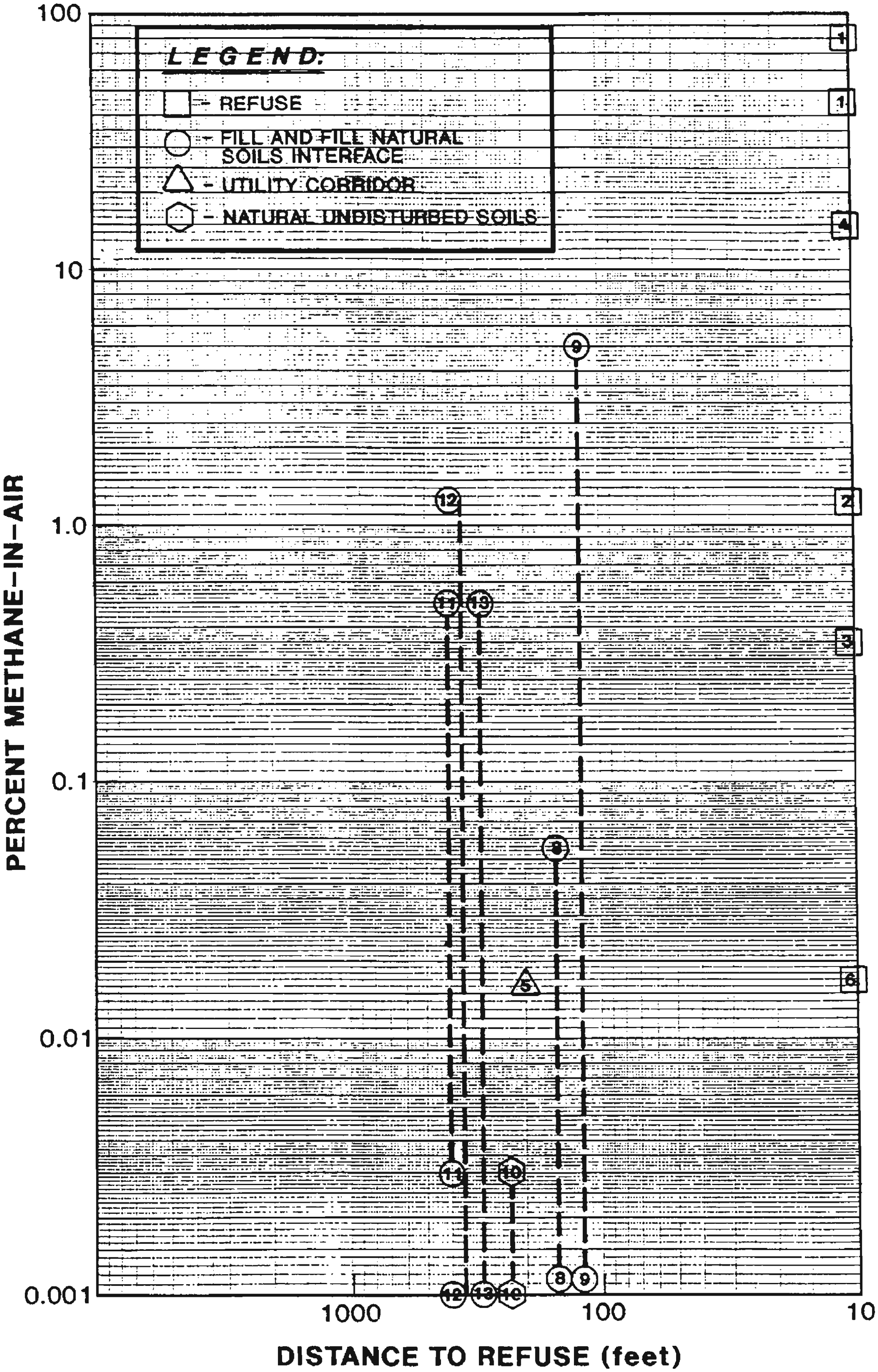


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**FIGURE B-18: ST. BONIFACE LANDFILL SITE I GAS PROBES METHANE CONTENT vs. DISTANCE TO REFUSE (Source: Underwood McLellan, 1978)**

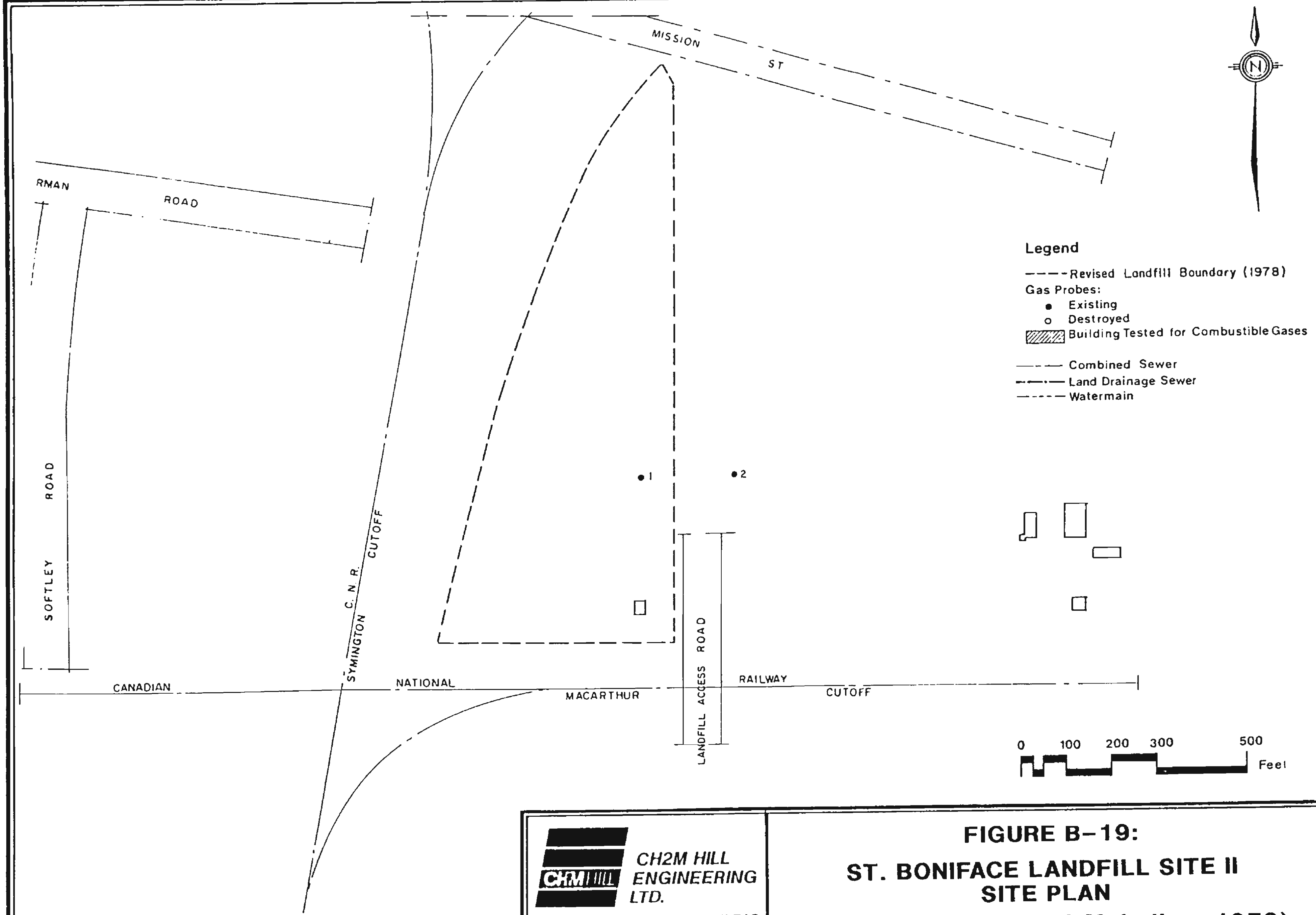


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**FIGURE B–19:**

**ST. BONIFACE LANDFILL SITE II SITE PLAN**

**(Source: Underwood McLellan, 1978)**

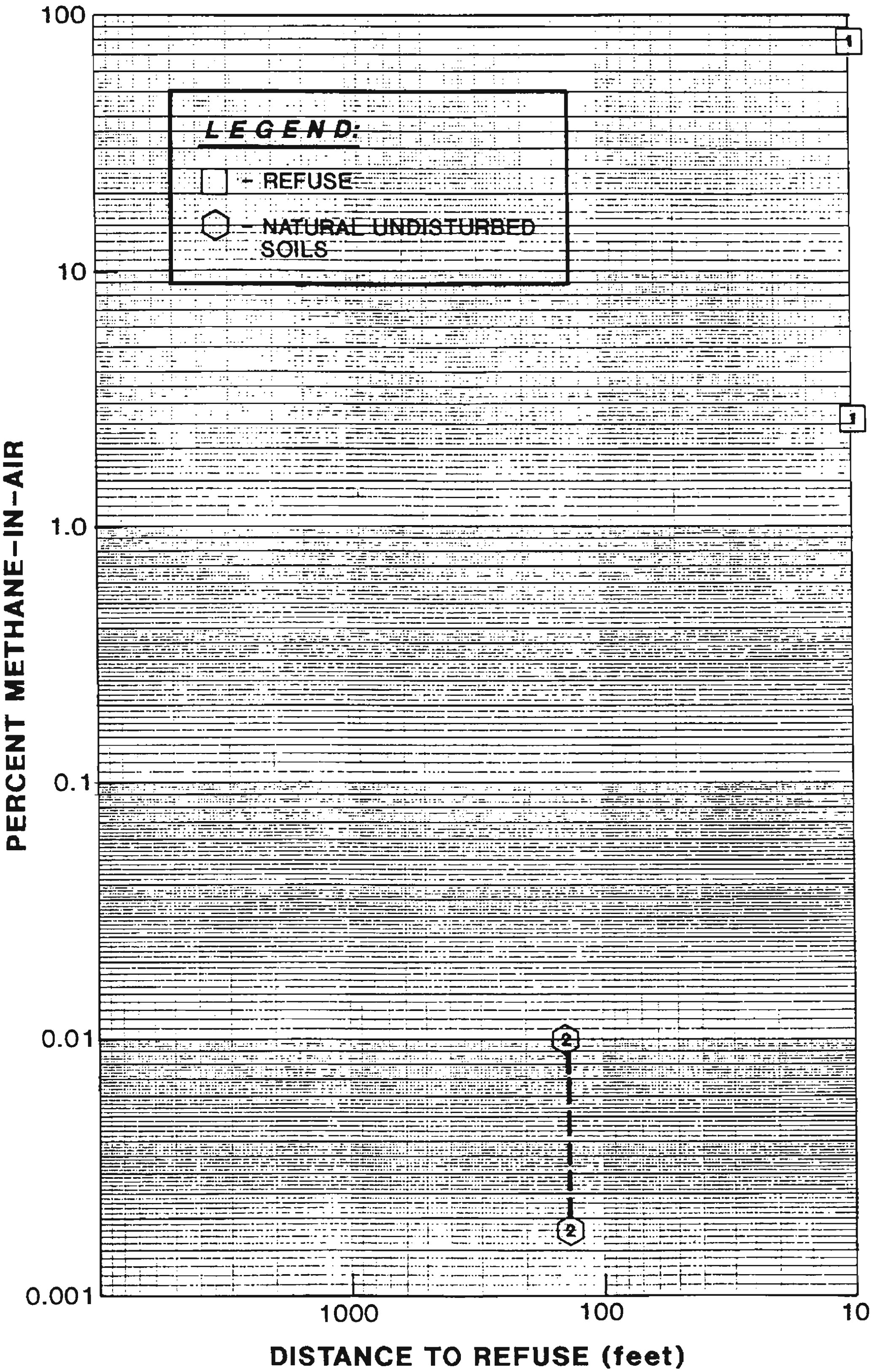


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**FIGURE B-20:
ST. BONIFACE LANDFILL SITE II
GAS PROBES METHANE CONTENTS vs.
DISTANCE TO REFUSE
(Source: Underwood, Melellan, 1978)**

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #25**

**BUILDING TYPE AND LOCATION:** Arena, residential dwellings, Kimberly Ave. Landfill

**GAS TYPE:** Methane

**SOURCE:** Landfill

**TYPE OF CONTROL:** Passive gas barrier

**CASE STUDY PRÉCIS:**

**Background**

As part of an evaluation of all landfill sites in Winnipeg, the Kimberly Avenue Landfill was identified as requiring some form of gas migration control. Details concerning the study are given briefly in the background of Case Study #24. The Kimberly Avenue Landfill was a priority landfill for the City of Winnipeg because of the Incinarena being located partially on the landfill as well as the close proximity of residential homes to the landfill boundaries.

**Site Conditions**

As part of an effort to determine the extent of the wastes at Kimberly Avenue Landfill, a resistivity survey was conducted during July 1977. Unfortunately, a large hill of clay fill, the Incinarena, other nearby buildings, and service corridors resulted in severe surficial resistivity interference at the Kimberly Avenue Landfill Site. These features limited the survey coverage to approximately 20 percent of the total landfill. As a result, borehole data and historical information provided most of the pertinent information for landfilling boundaries. Figure B-21 displays the landfilling boundaries and control area around the landfill (as of 1984).

In total, 18 drill holes were drilled at the Kimberly Landfill site. Stratigraphic mapping of the boreholes indicated that out of 18 holes, only 9 holes intersected refuse. Refuse was found at various thicknesses ranging from 0.8 m thickness with a clay cap of 2.9 m at borehole 7, to 3.5 m thickness with a clay cap of 0.9 m at borehole 9, to a thickness of 4.3 m with a clay cap of 0.6 m at borehole 14. Of the 9 boreholes which intersected the refuse, the average thickness of refuse was 2.7 m with a clay cover of average thickness of 1 m. During the drilling of these exploratory boreholes, the average depth to groundwater was 1.3 m below ground surface (Underwood McLellan, 1978).

Further to the exploratory boreholes, a total of 12 gas probes were installed at the Kimberly Landfill. (Refer to Figure B-21 for the locations.) Three of the probes were installed into the landfill (although one was later destroyed); three probes were installed along the water line south of the landfill and one along the storm sewer line on London Street; the remaining five probes were installed along the outside of the perimeter of the landfill. The methane results found at these probes is summarized on Figure B-22.

Methane readings were primarily recorded during 1976 with a few readings early in 1977. Some of the probes showed extreme variation (e.g. probe 1 had concentrations from 0.057 percent to 21 percent methane-in-air), whereas other probes were relatively stable (e.g. probe 2 had concentrations from 14 percent to 78 percent methane-in-air). Probe 2 was also observed to have the highest pressure. Throughout the summer months, the gas in probe 2 exerted about 250 Pa of positive water pressure. (Other pressure data was not available for this case study.) Given the potential gas migration from this site, a methane containment installation was recommended (Underwood McLellan, 1978).

Gas monitoring was also conducted in the buildings around the site. Three schools, the Incinarena, and homes along the perimeter of the landfill were tested for combustible gases (unknown as to how often). All buildings excluding the Incinarena had trace amounts of less than 0.0025 percent methane-in-air (25 ppm). The Incinarena had readings, on one occasion only, of 0.06 percent methane-in-air within the crawl space area under the ice sheet. This was at a time when the refrigeration unit in the arena was down. Generally, readings were less than 0.0025 percent methane-in-air (Underwood McLellan, 1978).

A gas barrier was also installed on the water line west of the southwest corner of the landfill by a developer. Specifications for a utility line gas barrier were used for the design and installation of the barrier (no details were available).

**The Solution**

There were two possible alternatives for the implementation of gas control at the Kimberly Avenue Landfill site: passive or active. Based on recommendations by an external consultant (Emcon Associates), a passive system was recommended. This decision was made for several reasons including the possible odour problem and the possibility of vandalism. As such, a passive system was chosen. Emcon Associates further recommended that the risers from the ventilation trench could be eliminated from the design, again because of odour and vandalism concerns (E.H. Hanson, 1981). The "current state-of-the-art" (in 1981) involved the total removal of risers from many barrier designs. Emcon Associates in fact plugged off several sets of existing risers at completed landfills due to the above mentioned problems. In so doing, Emcon Associates (who operated mainly in the U.S.) found that the desiccated clay surface cover over barrier trenches does in fact allow landfill gas to dissipate into the atmosphere. In addition, clay surface covers have been found to act as an odour filter by removing odour creating agents from the landfill gas (E.H. Hanson, 1981).

During the design stages of the gas barrier, designers were faced with an additional difficulty, severe space limitations. Since the refuse at the Kimberly Landfill extended to the edge of the property and utility corridors existed on three of the four sides, the typical "vee) trench configuration was deemed infeasible. As an alternative, a vertical trench was recommended. The length of the barrier was 1800 m around the landfill as shown on Figure B-23.

In selecting the material for the gas membrane, several criteria influenced the selection:

- The need of the material to sit in a vertical orientation when in place
- The ability to resist puncturing
- High impermeability to gas diffusion
- Good chemical resistance properties to chemicals typically found in a municipal solid waste site

Two relatively inexpensive membrane materials which were both readily available in Canada and meet the above criteria were considered: chlorinated polyethylene (CPE) and polyvinyl chloride (PVC). CPE material was chosen primarily because of the superior gas transmission properties. The use of supported or reinforced membrane material was recommended because of its ability to resist punctures and tears as well as its ability to sit in a vertical orientation without experiencing excessive strain.

Since the trench would encounter some refuse along its stretch, in order to protect the membrane from sharp objects in the refuse, a filter fabric (Synflex Services 4600) was considered. However, upon review of the alternative, it was felt that the use of the filter fabric may not prevent barrier puncturing in all potential cases, and therefore the high material cost could not be justified. Another viable alternative was suggested by the Works and Operations Department. It involved the placement of the barrier membrane in the centre of the trench with a "roller and cage" assembly as shown on Figure B-24. With the use of the roller and cage assembly, granular material would be placed adjacent to the membrane for protection purposes. The final layout of the barrier wall is shown on Figure B-25.

After reviewing other barrier designs in North America and after discussions with Emcon Associates, several additions were added to the interceptor trench. On the landfill side of the barrier, a gas collection header with vertical riser pipes was installed to be used as a back-up system. Soil gas probes would also be installed to evaluate the effectiveness, and a clay cap would be installed at ground surface. These features are depicted on Figure B-25.

A similar gas barrier was also installed at the Margaret Park Landfill. The barrier in this location, however, was only 550 m. Once this barrier was installed, preliminary field testing indicated that sections of the barrier may not have been completely gas tight. It was found that high landfill gas readings on the downgradient side of the barrier was a result of a tear in the membrane and in another location there was a failure to key the membrane into the clay cover. The improper keying of the barrier into the clay cap was partially the result of a slumpage which occurred during the installation of a trap and a cleanout assembly in a sewer line which crossed underneath the barrier. The slumpage caused a small section of the membrane to be dragged below the clay cap resulting in some gas leakage.

**REFERENCES:**

Underwood McLellan, 1978. Landfill Gas Study for City of Winnipeg, Department of Environmental Planning.

City of Winnipeg, 1984. Drawing SWD-D-104A and 104B. Kimberly Avenue Landfill Site Detail. Map from works & Operations Division, Landfill Environmental Division.

E.H. Hanson, 1982. Kimberly and Margaret Park Landfill Gas Barriers. Prepared for the City of Winnipeg.

E.H. Hanson, 1981. Letter to Mr. John Frye, P.Eng. of the City of Winnipeg regarding Kimberly and Margaret Park Landfill Gas Barriers, July 21, 1981.

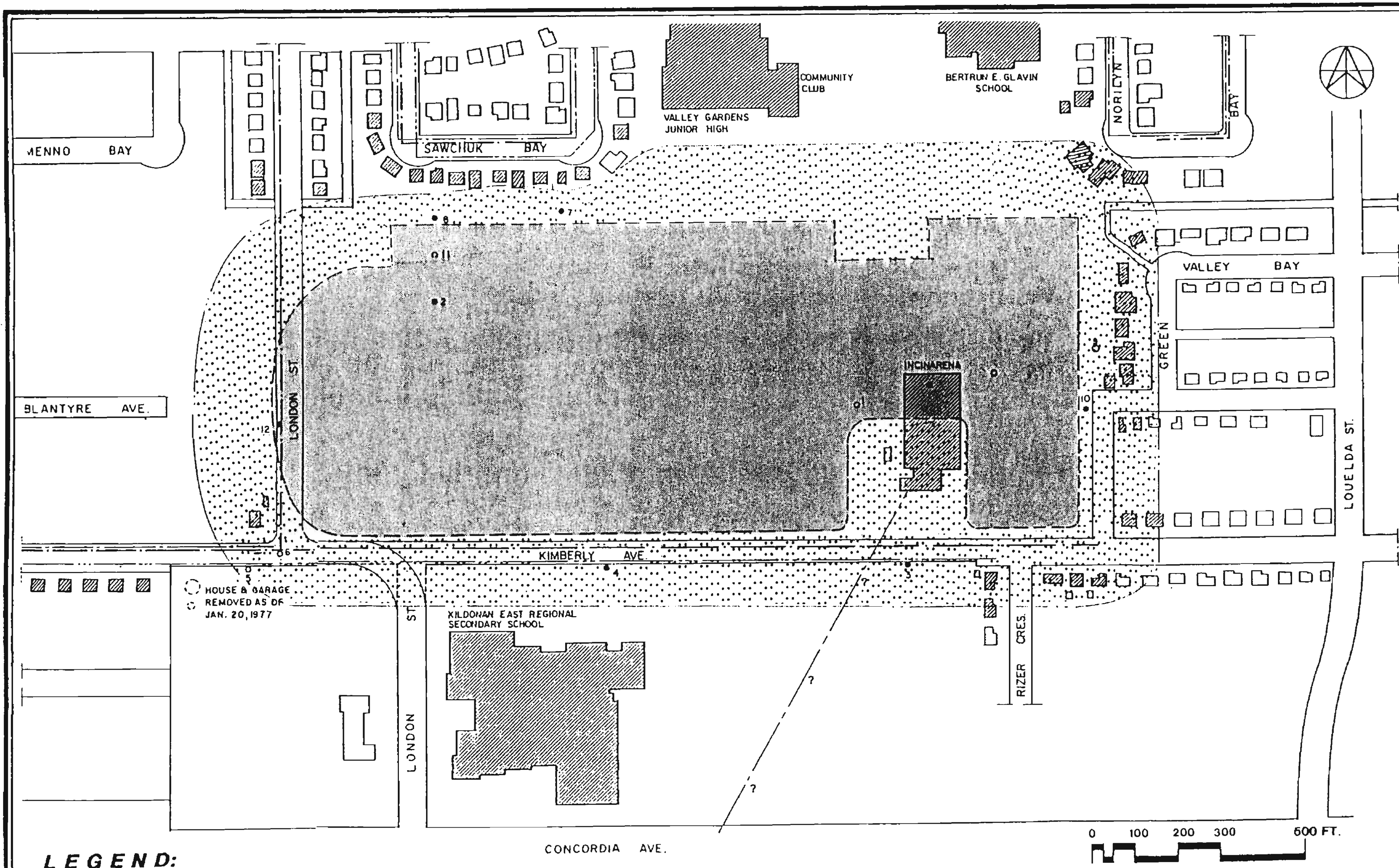


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**FIGURE B-21:**
**KIMBERLY LANDFILL SITE**
**SITE PLAN**
**(Source: Underwood McLellan, 1978 & City of Winnipeg, 1984)**

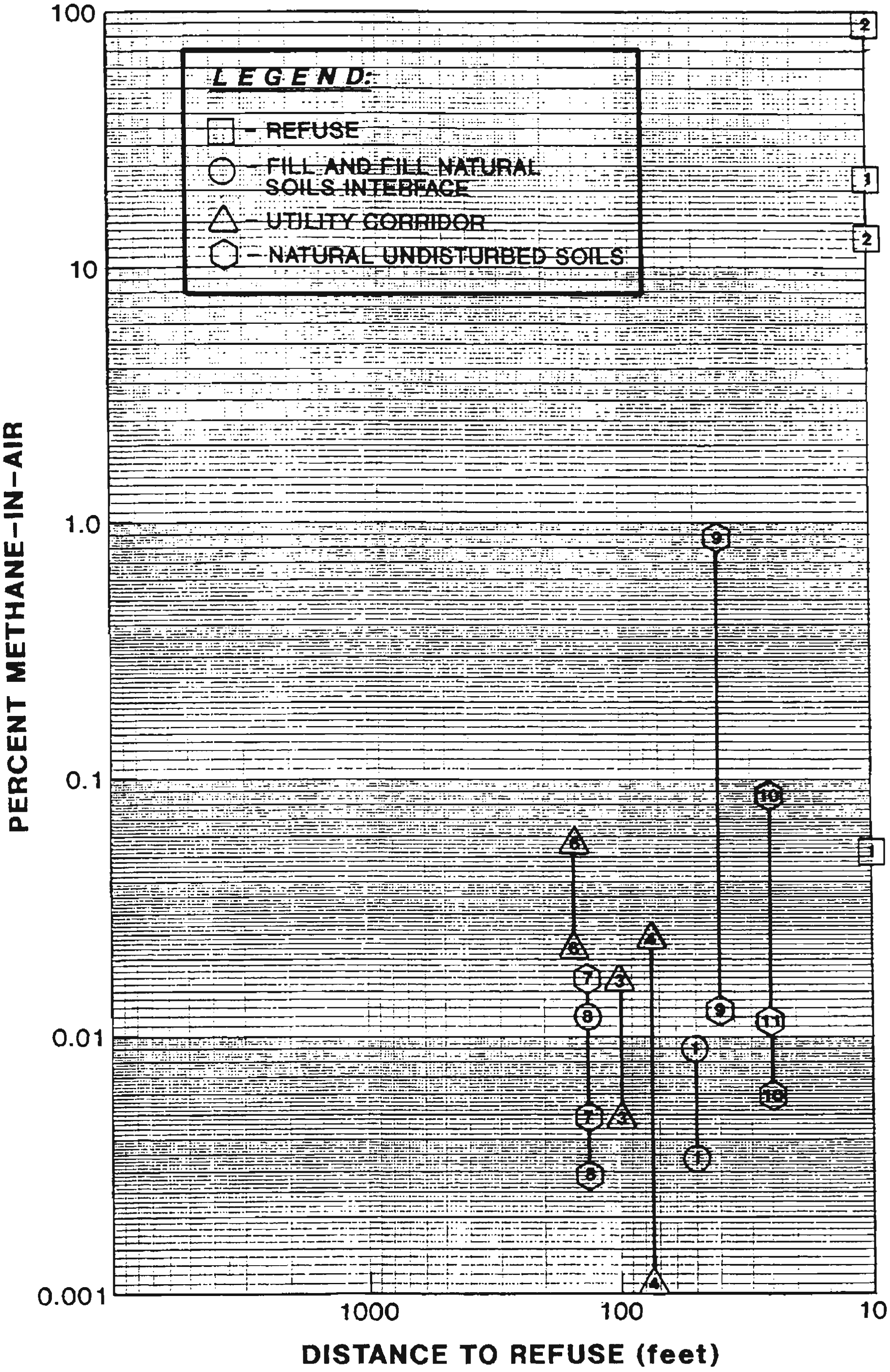


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**FIGURE B-22:**
**KIMBERLY LANDFILL SITE GAS PROBES METHANE CONTENT vs. DISTANCE TO REFUSE**
**(Source: Underwood, McLellan, 1978)**

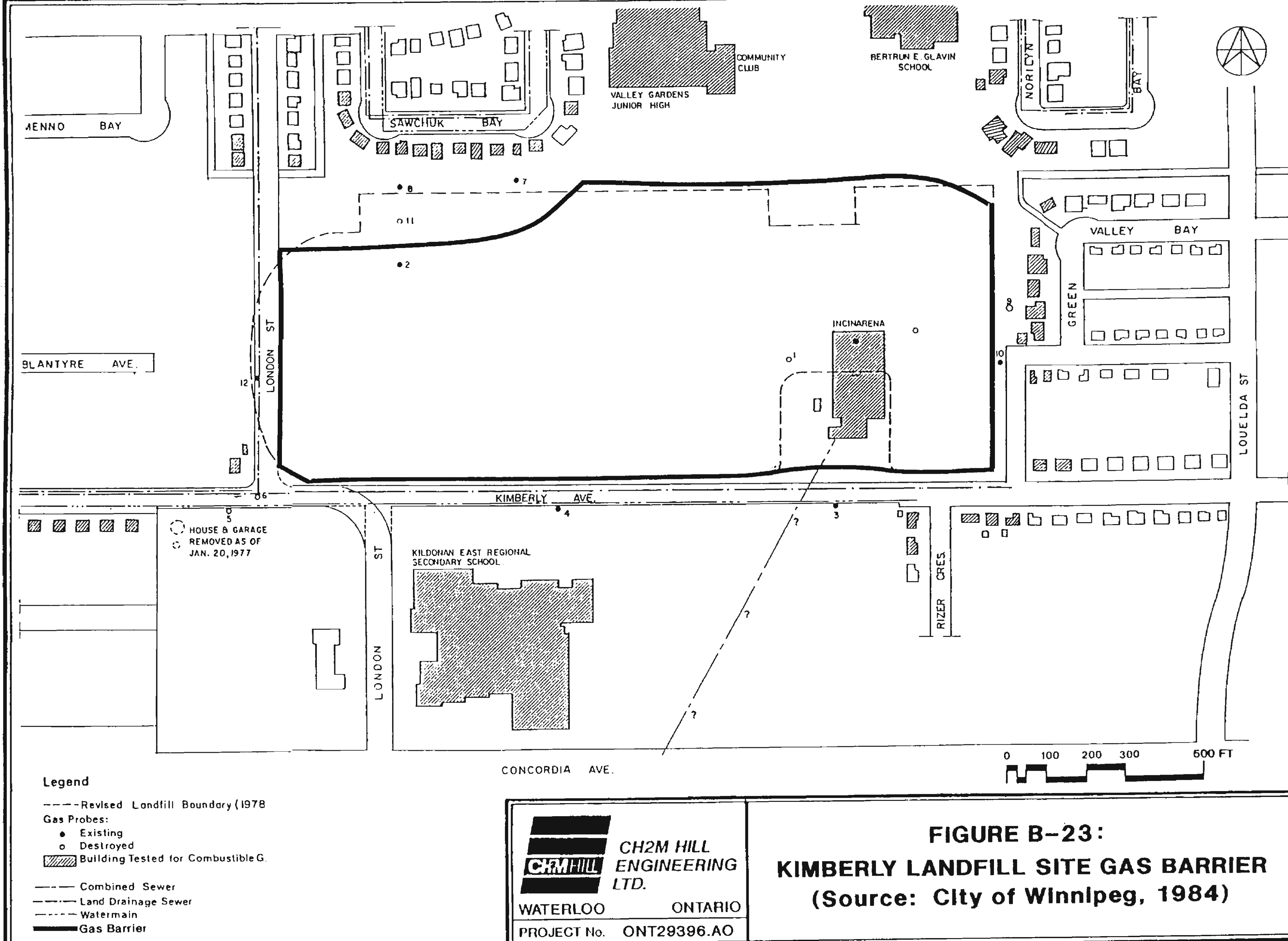


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**FIGURE B-23: KIMBERLY LANDFILL SITE GAS BARRIER (Source: City of Winnipeg, 1984)**

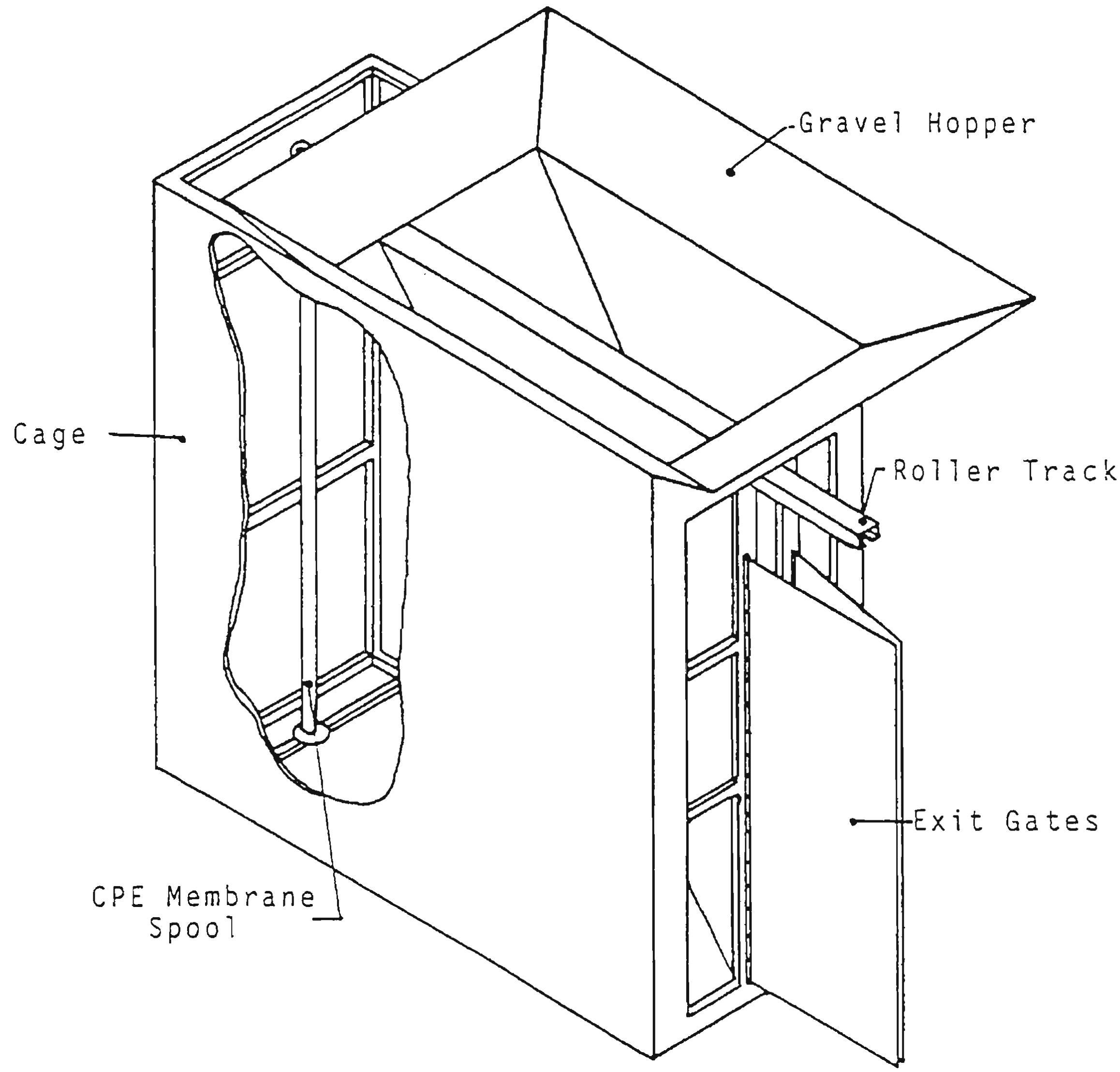


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**FIGURE B-24:**
**SCHEMATIC OF ROLLER AND CAGE ASSEMBLY**
**(Source: E. H. Hanson Associates, 1982)**

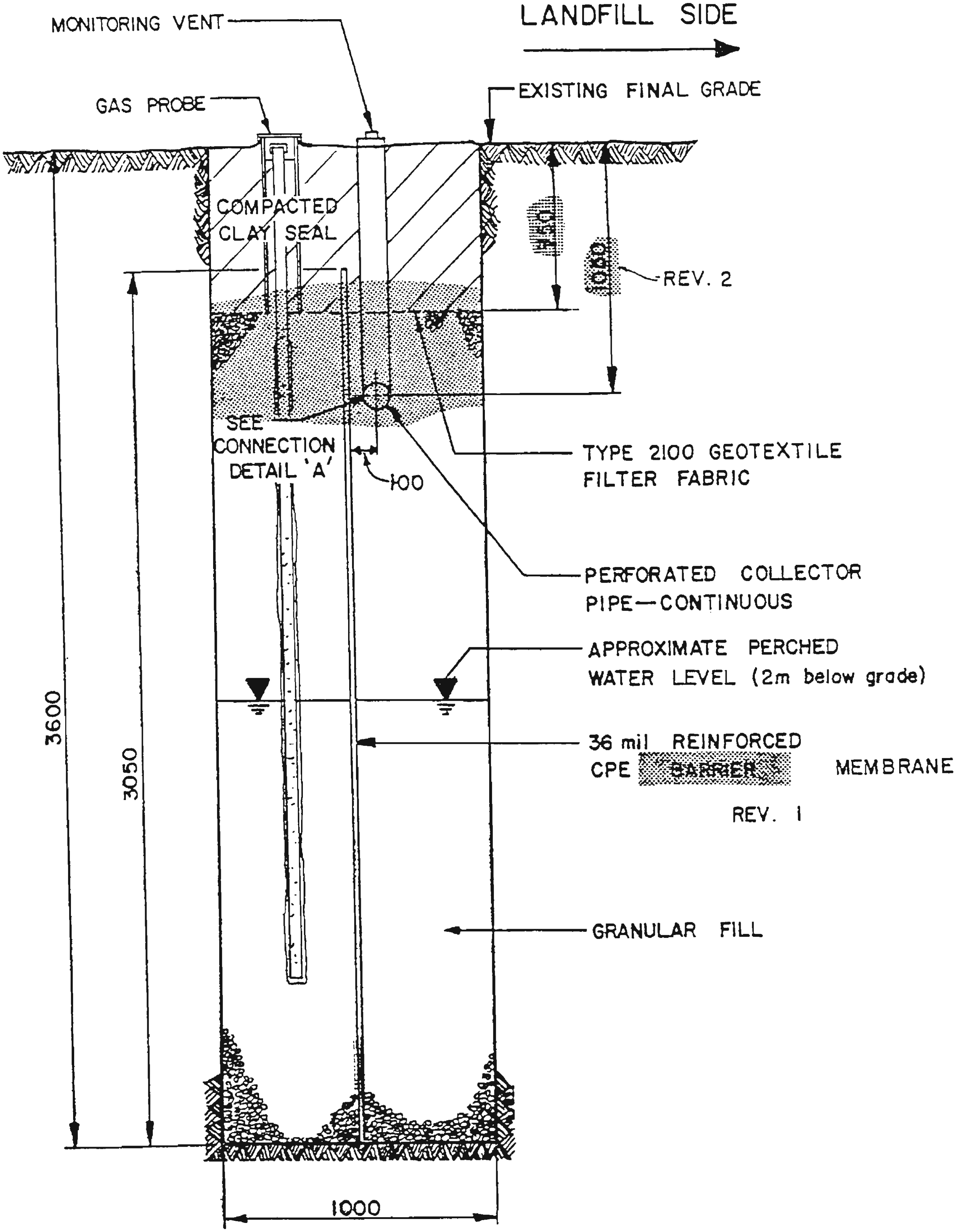


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**FIGURE B-25:**
**SCHEMATIC OF INTERCEPTOR TRENCH**
**(Source: E. H. Handson Associates, 1982)**

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #26**

**BUILDING TYPE AND LOCATION:** Commercial and residential area adjacent to Riverside Drive Landfill Site, Ottawa

**GAS TYPE:** Methane

**SOURCE:** Landfill site

**TYPE OF CONTROL:** Monitoring

**CASE STUDY PRÉCIS:**

**Background**

In order to evaluate the potential of gas migration from existing old landfill sites within the City of Ottawa, the City hired a consultant to investigate the problem. The principal objectives of the investigation were:

- to identify waste disposal areas within the City of Ottawa
- to document site characteristics, the hydrogeologic setting, and identify possible receptors (onsite or offsite structures), and
- provide recommendations for follow-up investigations

The investigators (Gartner Lee Associates Ltd., 1980) identified 19 abandoned waste disposal sites. Four sites were identified as having immediate concerns (in 1980). Twelve other sites had "potential gas concerns". The consultant recommended further study to confirm the nature of gas movement and identification of hazards to public safety at all sites which had "potential gas concerns".

The methodology involved in this investigation included:

1) a search of internal City records, interviews, etc.,
2) a study of aerial photography, and
3) field reconnaissance (Gartner Lee, 1980).

**The Riverside Drive Landfill**

The operational phase of the Riverside Landfill in the Rideau River floodplain spanned from June 1948 to March 1963. The entire site was landfilled during that time frame. The landfill encompasses an area of approximately 97.1 ha extending to a depth of .91 metres at the southern end, 2.4 to 3.7 metres in the central section, and 1.5 to 3.05 metres in the northern section. The refuse landfilled was primarily of a domestic nature with some light industrial and liquid wastes.

Methane was revealed during the initial monitoring program. Monitoring was restricted due to the general nature of the investigation and the area being investigated (97.1 ha). Methane gas was detected from trace amounts to 33 percent, indicating the possibility of higher methane levels. As such, this was regarded as a priority site.

Commercial and residential areas currently border the former landfill, which is presently parkland. Due to the close proximity of these built-up areas, there is some concern regarding the migration of methane gas via fractures in the clay/silt soils, and via the granular/clayey backfill and/or bedding of service trenches.

The site is situated on the former floodplain of the Rideau River. The eastern limit is located at the bank of the floodplain, while the river forms the western limit. The soils are alluvium, consisting of a mixture of sand, silt and clay with organics. Natural soils, which comprise the former floodplain bank, are composed of slowly permeable silts and clays of marine origin. The groundwater table is located within the lower portion of the refuse and slopes towards the river.

Even though the soil is of a slowly permeable material (clay and silts), the potential for a methane gas problem exists. As a result, the installation of gas monitors between the landfill and adjacent buildings was recommended as a precautionary method. Underground service trenches were also recommended for monitoring as possible conduits for gas movement.

A more thorough investigation was initiated following the initial work. Four permanent monitors were installed on and off the landfill site. Although the monitor onsite detected concentrations as high as 79 percent methane-in-air, offsite monitoring results were significantly lower. Methane was detected offsite at only one monitor; only four readings of 1 percent methane-in-air were recorded out of 11 visits. Nearby buildings were also checked; however, no significant readings were detected. Nevertheless, future monitoring was recommended at a nearby school (Gartner Lee Associates, 1982).

**REFERENCES:**

Gartner Lee Associates, 1980. Methane Gas Migration and Impact Study Report Landfill Site Identification Phase, City of Ottawa for the Corporation of the City of Ottawa.

Gartner Lee Associates, 1982. Detailed Methane Gas Migration Study Closed Landfill Sites 1, 3, 5 and 10 for the Corporation of the City of Ottawa.

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #27**

**BUILDING TYPE AND LOCATION:** Church and former school, Ottawa

**GAS TYPE:** Methane

**SOURCE:** Landfill site

**TYPE OF CONTROL:** Monitoring

**CASE STUDY PRÉCIS:**

As part of an overall inventory of all abandoned landfill sites within the City of Ottawa, the landfill on Kilborn Avenue was regarded as a low priority site. (Case Study #26 describes the overall inventory). The landfill on Kilborn Avenue itself, operated for a brief period between May 1947 and October 1947 handling primarily domestic wastes. These wastes were deposited in a depression within a marine clay plain.

The former landfill spans 0.2 ha and extends to a depth of .61 to 1.5 m. The site is situated on a marine clay plain above the valley wall of Mill Creek. The surrounding soil is a slowly permeable clay silt to silty clay with the water table located between 1.5 to 3.05 m below ground surface.

Gartner Lee Associates (1980) conducted monitoring at this site by augering a shallow borehole into the waste. Combustible gas in a concentration of 0.5% was detected in a single auger hole between the waste and a former school.

Based on these findings, the consultant concluded that significant lateral migration was not anticipated from the site. However, the consultant reasoned that migration could occur through fractures towards the former school. Monitoring was suggested.

**REFERENCE:**

Gartner Lee Associates, 1980. Methane Gas Migration and Impact Study Report Landfill Site Identification Phase, City of Ottawa for the Corporation of the City of Ottawa.

## CMHC SOIL GAS RESEARCH STUDY
## CENTRAL CANADA SECTOR
## CASE STUDY #28

**BUILDING TYPE AND LOCATION:** Municipal buildings, Bayview Dump, Ottawa, Ontario

**GAS TYPE:** Methane

**SOURCE:** Landfill site

**TYPE OF CONTROL:** Active venting

**CASE STUDY PRÉCIS:**

As part of an overall inventory of all abandoned landfill sites within the City of Ottawa, the Bayview Dump was chosen as a priority site for methane migration. The Bayview Dump operated between 1933 and 1946 handling primarily domestic wastes. The fill area extended to a depth of 3 to 6.1 m and covered an area of approximately 7.3 ha. The soils in the vicinity were generally alluvial sounds overlying bedrock. About half of the site is developed by buildings and paved parking areas. Two buildings onsite belong to the City of Ottawa. During the initial investigation (refer to Case Study #26 for background), methane gas concentrations of 35 percent were recorded in a shallow borehole. In view of the elevated concentration, the presence of a parking lot (which would limit ventilation), and the present of onsite buildings, a further investigation was recommended.

A further study initiated by the City of Ottawa measured methane gases at various locations around the site. Based on monitoring on some newly installed monitors revealed that concentrations of methane existed below one of the maintenance buildings between 15 and 75 percent. Another monitor not installed in the refuse showed a methane concentration between 1 and 14 percent. Combustible gas concentrations in excess of 5 percent were found in numerous wall cracks and electrical outlets within the building. However, when methane measurements were conducted at a distance of .15 m away from the cracks, negligible readings were observed. Another onsite building, the Spay/Neuter Clinic, had no detectable methane was observed. Since the clinic was situated on ash and possibly building materials, a limited production of methane was believed to be the cause of minimal migration indoors.

In order to remedy this problem, the consultant recommended an active venting system consisting of conceptually of vertical collection pipes buried in the refuse and operating at a negative pressure. Additional renovations such as sealing floor cracks, an alarm system and continued monitoring were also recommended (Gartner Lee Associates, 1982).

The approach used to develop design parameters was as follows:

- Conduct a gas pump test using a gas pumping well and associated monitoring wells
- Calculate the gas transmissivity, storage coefficient and gas conductivity using the Cooper-Jacob approach for groundwater withdrawal
- Predict the cone of influence with the Copper-Jacob approach

Although the consultants (Gartner Lee Associates, 1986) used this approach, the authors did indicate that the model was based on confined fluid flow with no recharge or discharge boundaries. The report indicated that "these assumptions were not completely satisfied. However, the conclusions do provide a reasonable estimate of the above parameters". The report, however, did not make the distinction between compressible vs non-compressible fluid flow (water flow in the subsurface is normally treated as non-compressible flow; vapour is compressible).

The first set of pumping tests in December 1984 showed that a flow rate of 17 L/s from the pumping well produced a drawdown of only 10 Pa at a monitor 6.2 m away. Given the low drawdown, another monitor was installed at a distance 2.5 to 3.5 m away. Larger negative pressures were observed. A third pumping test, of longer duration (73 hours) was also conducted in June 1985. This test indicated that the closest monitor decreased very rapidly; however, at a distance of 12 m (from the pumping well), the data was not entirely consistent. However, based on the pumping test, the consultant indicated that a cone of influence of 25 m was measured. (However, the pressure recorded at 25 m was only -5 Pa).

After conducting the pumping tests, the data was evaluated by the Cooper-Jacob approximation. A predicted cone of influence of 135 m was calculated based on a pumping period of 10 hours. After a pumping rate of 100 hours, an expected cone of influence of 460 metres was predicted. Given the unrealistic nature of these predictions, the consultant disregarded the calculations and advised on a grid spacing of 25 m.

Further recommendations for the gas extraction included two control alternatives: a vertical gas well extraction system or a system of horizontal pipes around the building. Either arrangement would be tied to a header pipe connected to an extraction fan mounted on the top of the building. It is uncertain which remedial method was chosen.

**REFERENCES:**

Gartner Lee Associates, 1982. Detailed Methane Gas Migration Study. Closed Landfill Sites 1, 3, 5 and 10 for the Corporation of the City of Ottawa.

Gartner Lee Associates, 1986. Methane Gas Control Study Bayview Road Works Yard, Main Maintenance Garage, for the Corporation of the City of Ottawa.

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #29**

**BUILDING TYPE AND LOCATION:** Residential, commercial Woodward Dump, Ottawa, Ontario

**GAS TYPE:** Methane

**SOURCE:** Landfill site

**TYPE OF CONTROL:** Monitoring

**CASE STUDY PRÉCIS:**

As part of an overall inventory of all abandoned landfill sites within the City of Ottawa (refer to background of Case Study #26), the Woodward Dump was chosen as a priority site for methane migration. The Woodward Dump was operational from December 1950 to November 1953. The nature of the wastes were determined to be primarily domestic with some industrial wastes. No toxic or liquid wastes were reportedly dumped.

The fill extends to a depth of 1.5 to 2.4 m, and encompasses approximately 4.0 ha. The site is situated at the toe of a topographic high, controlled by bedrock. Soils located at the toe consist of a fine marine sand overlying a sandy glacial till. Bedrock, located 3.0 m from the surface, underlies the soils. The water table is estimated to be located near the original ground surface (2 to 4 m below ground surface).

Due to the thickness of the unsaturated sand layer, the potential for methane gas migration is possible. Combustible gas is being generated at the dump and may present a hazard to the surrounding residential/commercial developments, as well as the parkland to which it has been converted. Although during the initial monitoring program, a methane level of 7.5 was measured in a shallow auger hole in the fill, permanent monitors were still recommended for installation between the fill and key surrounding areas due to the close proximity of neighbourhood houses.

As part of the followup program, Gartner Lee Ass. (1982) installed 6 monitoring probes in and around the landfill. Monitoring of these probes was conducted from December, 1980 to June, 1981 for a total of 12 measurements of methane concentration and depth to groundwater. Of all the readings taken, only one monitor showed a methane content of 1% methane at one occasion. As well, no methane was detected inside any of the buildings or underground services when checked in late September.

The consultant (Gartner Lee Ass. 1982) concluded that significant gas migration through the subsoils does not appear likely from this disposal area." The consultant went further to indicate however, that there was a possibility that methane may migrate towards a sports complex (onsite) in the future. The consultant reasoned that the fills were less than a year old and as such the combustible gases may not yet have fully penetrated the materials to be detected in the monitor installed in this setting.

As a precautionary measure, the six monitors around the site and the onsite building was recommended for testing. Emphasis was placed on testing during frozen conditions.

**REFERENCE:**

Gartner Lee Associates, 1982. Detailed Gas Migration Study. Closed Landfill Sties 1, 3, 5, and 10 for the Corporation of the City of Ottawa.

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #30**

**BUILDING TYPE AND LOCATION:** Apartment building and parking garage, Ottawa, Ontario

**GAS TYPE:** Methane

**SOURCE:** Landfill site

**TYPE OF CONTROL:** Monitoring

**CASE STUDY PRÉCIS:**

As part of an overall inventory of all abandoned landfill sites within the City of Ottawa (refer to Case Study #26 for background), Nunts Farm Landfill was not regarded as a priority site. According to municipal records, the landfill's operational phase spanned from 1954 to 1957. However, it is believed that filling operations commenced in 1955 and ended before 1960. Only two structures are located near the site: an apartment building and a parking garage. Both are located within 30 m of the landfill site.

The landfill site encompasses an area of 6.1 ha, with a fill depth of 2.4 to 3.7 m. Domestic wastes are believed to have been the primary fill, with some industrial and liquid wastes. The site is situated on a marine clay plain composed of clayey silt soils. Prior to filling, the area was flat-lying farmland. The water table is believed to be near the original ground surface, now at the base of the refuse.

Monitoring in shallow auger holes detected methane concentrations of 10 percent to 14 percent in the refuse at two locations. No gas was detected in the sub-soil between the refuse and the apartment building.

A potential for gas migration was deemed possible since the adjacent buildings are located within 30 m of the landfill site. The slow permeability of the soils will prevent any gas migration over long distances (i.e. beyond 30 m). As a result, the installation of gas monitors between the refuse and the apartment building was recommended. Should gas migration become an actuality, a gas venting system was recommended for the apartment building (Gartner Lee Associates, 1980).

**REFERENCE:**

Gartner Lee Associates, 1980. Methane Gas Migration and Impact Study Report Landfill Site Identification Phase, City of Ottawa for the Corporation of the City of Ottawa.

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #31**

**BUILDING TYPE AND LOCATION:** Single family dwelling, Nepean

**GAS TYPE:** Methane

**SOURCE:** Home built on peat bog

**TYPE OF CONTROL:** Passive venting under basement floor

**CASE STUDY PRÉCIS:**

No methane was ever detected in the home. Structural failure occurred in the home as a result of the unstable foundation. Testing revealed that the home had been built on a peat bog and the foundation had to be restructured as a result. A layer of crushed stone was put beneath the home, followed by perforated pipes, to collect the gases and direct the flow of the gases out from beneath the home. A 10 mm plastic sheet was then placed on the pipes and crushed stone. The basement slab was installed and all of the joints were lapped and sealed. All of the gas collection pipes were connected to an exhaust port and a turbine wind-generated fan. This gas management system was installed as a precaution, not as a response to any monitoring of indoor air quality. In fact, no monitoring of indoor air quality has ever occurred. A report was requested from the owner; however, it was not received by the consultant.



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**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #32**

**BUILDING TYPE AND LOCATION:** Office Building, Ottawa

**GAS TYPE:** Gasoline

**SOURCE:** Gasoline

**TYPE OF CONTROL:**
Evacuation of people
Passive vents
Contaminated soil removed
Installation of extraction and monitoring well

**CASE STUDY PRÉCIS:**

Gasoline vapours migrated through the ground to the tile drains in the parking lot, then migrated to the sump hole. It is possible that the gasoline followed the granular base of the storm and/or sanitary sewers. Soil testing was carried out by a consulting firm. Gasoline vapours were detected in the indoor air. Passive vents were installed to alleviate immediate problem. The contaminated soil was removed and an extraction and monitoring well was installed. Analytical tests of the soil were carried out before and after the remediation took place. Government approvals were required with this work. There has been no further migration of the gasoline.



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**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #33**

| | |
|---|---|
| **BUILDING TYPE AND LOCATION:** | Townhouses, Orangeville |
| **GAS TYPE:** | Methane |
| **SOURCE:** | Adjacent Landfill |
| **TYPE OF CONTROL:** | A gas interceptor/ venting system was installed between the townhouses and the landfill |

**CASE STUDY PRÉCIS:**

No monitoring of indoor air quality in the townhouses adjacent to the landfill was ever conducted. A soil assessment determined the need for a gas interceptor/venting system between the landfill and the townhouses. The system was installed with no consideration to indoor air quality. The gas interceptor system consisted of a trench filled with gravel with perforated pipes.



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**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #34**

**BUILDING TYPE AND LOCATION:** Brandy Lane Homes (residential) referred to as the Mandrake Street Area

**GAS TYPE:** Methane

**SOURCE:** Former Swamp and Organic Fills

**TYPE OF CONTROL:** Passive venting system consisting of collector pipes located underneath the floor with a CPE barrier extending up to the exterior foundation walls to ground level to decrease gas concentrations in basements.

**CASE STUDY PRÉCIS:**

Methane gas was detected at explosive levels (74 percent to 100 percent) at the Mandrake Street residential area. At the time of detection, many of the residential units had not yet been built allowing for the design of a methane gas control system to be added to the construction plans. The Ministry of the Environment was not involved since their jurisdiction extends only to former waste disposal sites and not to natural occurring methane gas production (EPA RSO 1980, Chapter 141, Section 45). As such, a consulting firm was contracted to determine the extent of the methane gas problem. Their study was threefold: to confirm the source of methane gas, to establish methane gas concentrations in areas adjacent to the former swamp and the existing houses, and finally, to evaluate if methane gas was migrating into areas where substantial backfill was placed.

The residential area is adjacent to a poorly drained region, a former swamp, which spans over 11 hectares. Organic soft soils now overlie the area defined as the former swamp thus presenting a potential source of methane gas formation. The area in question is covered by 2 to 5 metres of organic fill (wood pieces, roots), followed by a layer of silty clay, a transitional zone made up of loose gravel, sand, silt and clay, underlain by a sandy silt till, and finally terminating over black shale bedrock of the Whitby formation which is bituminous with petroliferous content. Such soils offer the potential for natural methane production. Twenty-three boreholes and gas probes were installed between April 28, 1988 and May 3, 1988 of which only five survived over the year. The locations of the boreholes and gas probes are shown in Figure B-26.

The gas probes were monitored for methane production on a weekly basis during the first month and then on a monthly basis during the remainder of the one year monitoring program. Monitoring was also conducted during frozen ground conditions during the year. A MSA Model 60 dual sensor combustible gas detector (explosimeter) was utilized in determining the concentration of methane gas. The explosimeter was adjusted to detect a concentration of 0.1 percent methane gas. Barometric pressure and other possible controls were not tested. The gas probes were installed at a depth spanning from 3.0 metres to 12.8 metres, the average depth being 5.1 metres. Methane concentrations were discovered to be quite low, spanning from a non-detect reading to a concentration of 18 percent methane per volume of air sampled. The 18 percent reading was recorded on April 4, 1988. The average concentration of methane per volume of air sampled from the start of the monitoring program on April 4, 1988 to the end of the monitoring program on March 29, 1989 was 0.28 percent with non-detect readings being assigned values of zero. Out of a total of 174 numerical readings, 143 readings (or 82.7 percent) were recorded as non-detect. The results of the monitoring program are recorded in Table B.7.

Following the termination of the monitoring program, the consulting firm concluded, firstly, that the methane gas concentrations within the boundary of the former swamp exceeded the lower explosive limit at Gas Probes 6 and 7a, both located at the southern perimeter of the poorly drained area. From this result, it was concluded that methane is slowly being generated from the organic soft soils found in the area defined as the former swamp. Secondly, lateral migration in the subsurface from the soft soils and swamp to the native soils was minimal, resulting in non-detectable methane concentrations outside of the former swamp region. Thirdly, structures located on native soil were determined to remain unaffected by the methane gas. And fourthly, gas probes drilled to bedrock did contain methane at reduced levels (below lower explosive limit) and do not present a concern.

It was recommended that the methane gas problem should continue to be investigated regardless of the low concentrations previously recorded. A passive venting system was proposed for construction in 28 houses affected by methane gas. The passive venting system is shown in Figure B-27. This gas interceptor system consisted of:

a) an inlet for fresh air to collect soil-gas,
b) a sub-floor collection sub-system and a perimeter gas collection sub-system, both placed in a granular envelope with a void ratio to allow the circulation of soil-air,
c) an inlet and outlet pipe,
d) piping for provision of contingency conversion to an active system, and
e) a backup barrier of 20 ml CPE.

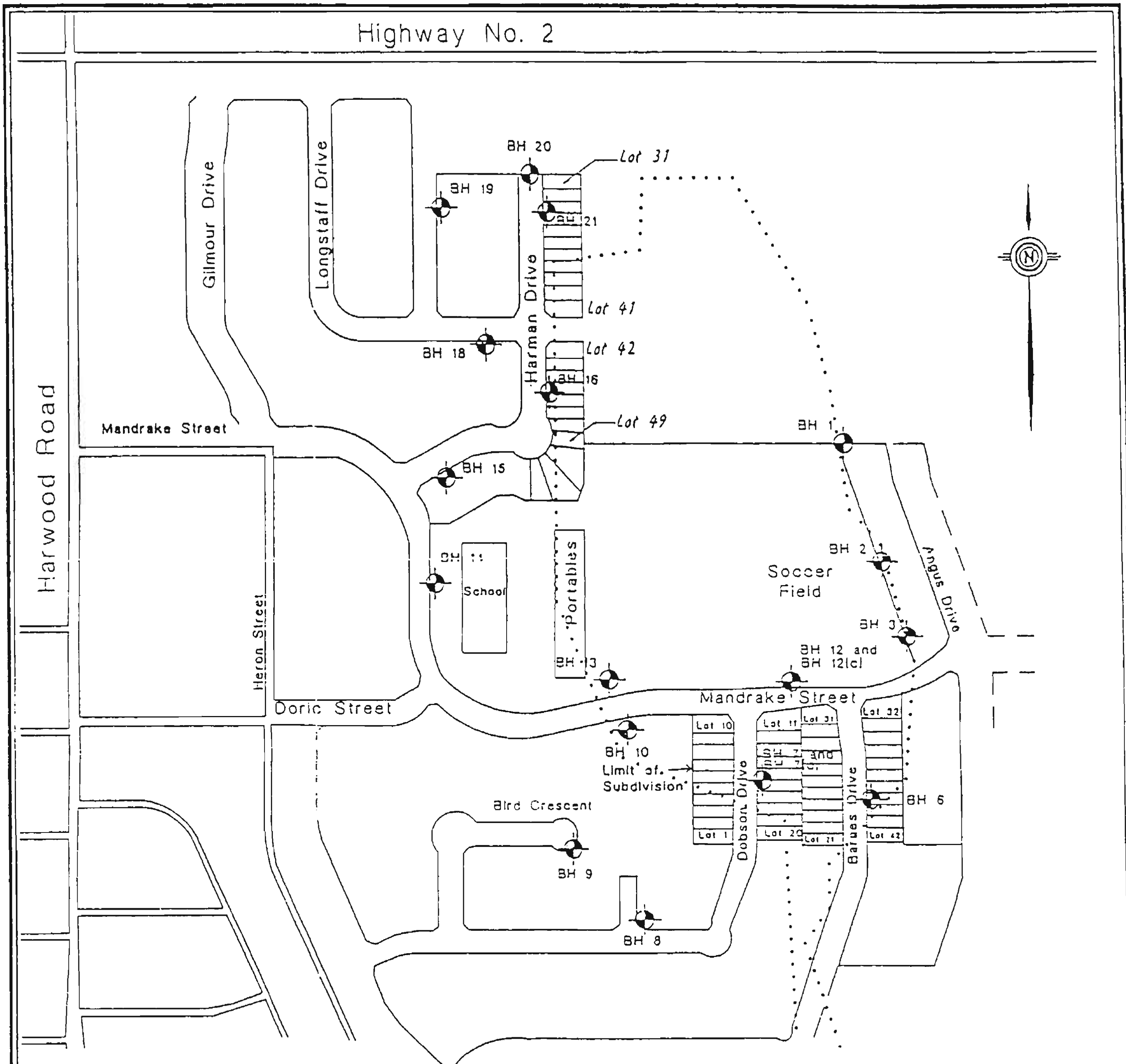
The consultant recommended that subfloor collector pipes be laid underneath the floor with a stack venting to the atmosphere. The exterior stack, responsible for dispersing the accumulated methane gas should extend to a height of approximately 1.5 m along the side of the building. The passive system consists of no moving parts and can be converted to an active system by installing a fan along the exterior riser at the rear corner of the building.

Monitoring subsequent to construction revealed no detectable concentration of methane in any of the gas interceptor systems or the basements. A monitoring program spanning one year revealed no detectable gas in the system or the buildings, but revealed concentrations of up to 66 percent in gas probe No. 1. Despite this reading, monitoring was discontinued at the completion of one monitoring year. No indoor gas monitors were installed and the Ministry of the Environment provided no conditions for safe gas levels. The homeowner is now responsible for determining the presence of a methane gas problem.

**Table B.7**
**Methane Gas Concentrations Mandrake Street Area in Ajax, Ontario**

| Gas Probe | Depth (m) | Date Installed | Initial | April 4, 1988 | April 18, 1988 | May 6, 1988 | June 6, 1988 | July 31, 1988 | August 30, 1988 | September 25, 1988 | October 28, 1988 | November 14, 1988 | December 27, 1988 | January 20, 1988 | February 17, 1989 | March 29, 1989 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.6 | Apr. 28 | ND | * | * | ND | ND | * | * | * | * | * | * | * | * | * |
| 2 | 4.6 | Apr. 28 | ND | * | * | ND | ND | * | * | * | * | * | * | * | * | * |
| 3 | 4.6 | Apr. 28 | ND | * | * | ND | ND | * | * | * | * | * | * | * | * | * |
| 4 | 4.6 | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated |
| 5 | 4.6 | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated |
| 6 | 4.6 | Mar. 28 | ND | 0.2 | ND | ND | ND | 5.0 | 0.6 | ND | ND | ND | 0.1 | ND | 0.1 | ** |
| 7a | 4.3 | Mar. 28 | ND | 18 | ND | 3.5 | ND | 3.5 | ND | 0.1 | 0.6 | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated |
| 8 | 4.6 | Mar. 28 | ND | ND | ND | ND | ND | ND | ND | ND | ND | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated |
| 9 | 4.6 | Mar. 28 | 0.3 | ND | ND | ND | ND | 1.0 | 0.2 | 0.1 | 0.1 | ND | ND | ND | ND | ND |
| 10 | 4.6 | Mar. 28 | ND | ** | ND | ND | ND | ND | ND | ND | ND | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated |
| 11 | 4.6 | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated |
| 12 | 4.6 | Mar. 29 | 1.1 | ND | ND | 0.4 | ND | ND | ND | ND | ND | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated |
| 13 | 3.0 | Mar. 29 | 1.4 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 14 | 4.6 | Mar. 29 | 0.1 | ND | 0.1 | ND | ND | 0.2 | ND | ND | ND | ND | ND | ND | ND | ND |
| 15 | 4.6 | Mar. 29 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 16 | 3.5 | Mar. 29 | 0.2 | ** | ** | ND | ND | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated |
| 17 | 4.6 | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated |
| 18 | 4.6 | Mar. 30 | 0.4 | ND | ** | ND | ND | ND | ND | ND | ND | ** | ND | ND | ND | ND |
| 19 | 4.6 | Mar. 30 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 20 | 4.6 | Mar. 30 | 0.3 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 21 | 4.6 | Mar. 30 | ND | ND | ND | ND | ND | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated |
| 7c | 10.9 | May 3 | ND | ** | ** | 2.4 | 2.0 | *** | 2.5 | 2.0 | 1.4 | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated |
| 12c | 12.8 | May 2 | ND | ** | ** | 0.5 | 0.0 | ND | ND | ND | ND | Eliminated | Eliminated | Eliminated | Eliminated | Eliminated |

Methane concentrations recorded as percent methane per volume air sampled
* Water filled gas probe
** Damaged/Vandalized probe




***LEGEND:***

Borehole and Gas Probe Location

Street Layout Before Development (1974)

Street Layout After Development (1982)

Approximate Limit Of Low Poorly Drained Area 96.8 m Contour

*Lot 34* Houses Built On Engineered Fill

Lot 34 Houses Built With Passive Gas Venting System

***NOTES:***

(1) Base data taken from portion of 1974 topographic map (no identification) supplied to Trow by Totten Sims Hubicki and Associates Ltd.

(2) Data for present street layout were taken from Draft Plan of Subdivision, latest revision November 19th, 1982, supplied by F. J. Reinders and Associates Limited.

(3) Do not scale drawing.

(4) School and Portables dimensions, and locations, are approximate only.

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**FIGURE B-26:**
**METHANE GAS INVESTIGATION**
BOREHOLE AND GAS PROBE LOCATIONS
**MANDRAKE STREET AREA AJAX, ONTARIO**

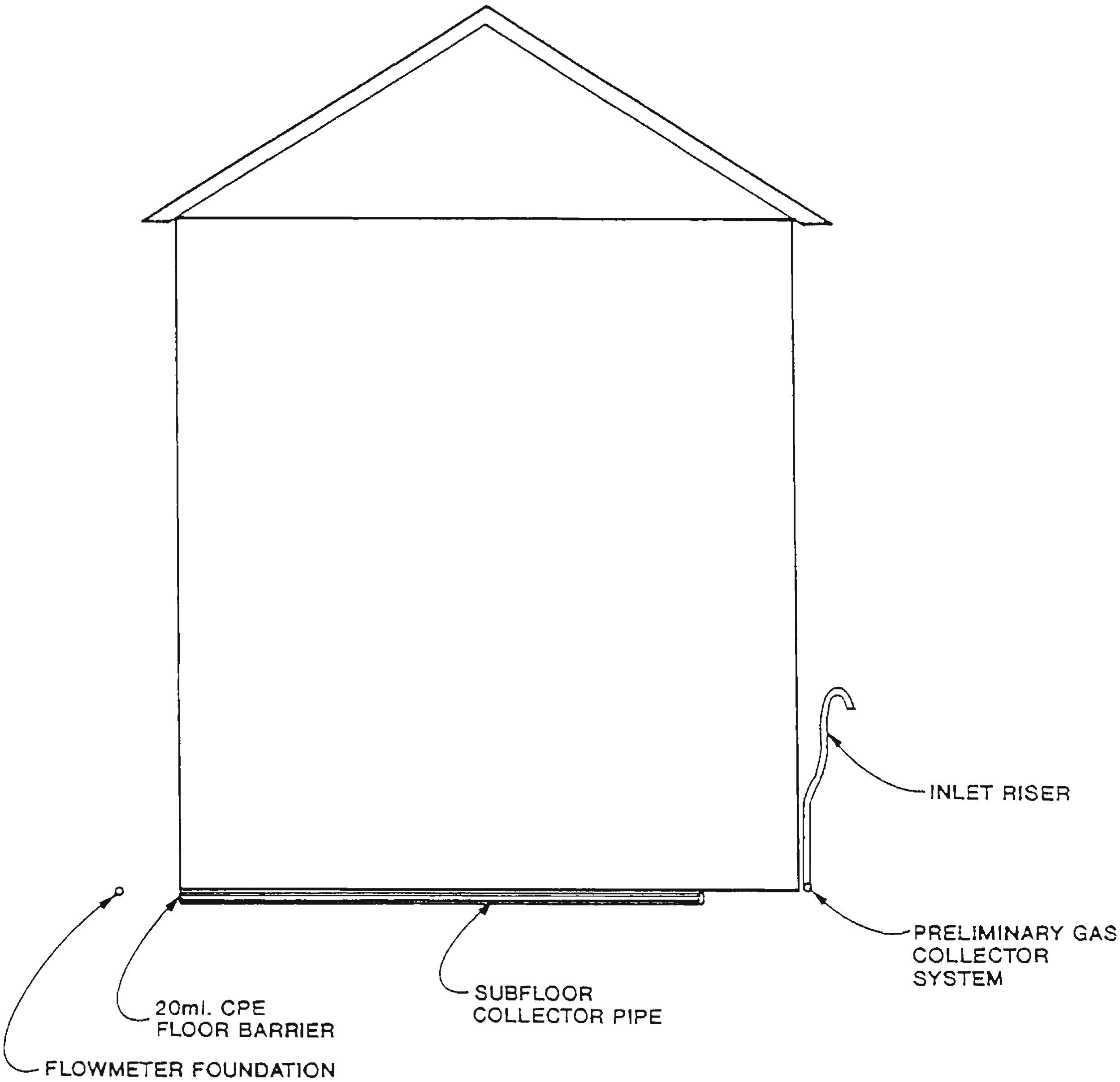


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**FIGURE B–27:
MANDRAKE STREET METHANE INVESTIGATION – PASSIVE VENTING SYSTEM**

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #35**

**BUILDING TYPE AND LOCATION:** Office building and several single family dwellings, Brandon

**GAS TYPE:** Petroleum products

**SOURCE:** Two gasoline and product withdrawals

**TYPE OF CONTROL:** Steam injection and product withdrawal

**CASE STUDY PRÉCIS:**

On December 17, 1974, gasoline fumes were discovered in the basements of two houses in Brandon. As a result of an investigation, it was determined that a privately-owned nearby service station had a leaking underground storage tank. Consequently, on January 6, 1975, three 1,000 gallon tanks were removed from the site. Several cubic metres of contaminated soil and gasoline/water mixture were also removed and disposed of at the city dump.

Coincident with this activity, vapour levels were monitored by the Fire Department in three homes in the vicinity. In early January, occupants were evacuated for safety reasons.

In order to define the problem area, a total of 87 auger holes were drilled between January 25 and February 20, 1975. The extent of gasoline contamination was determined based on olfactory and visual evidence. The stratigraphy of the overburden is relatively simple. Generally, 0.9 to 1.8 m of fill material overlies 0.6 to 1.2 m of sand and gravel on top of a dense clay till. Fluid infiltrating from the surface would move down to the bottom of the sand and gravel layer and move downgradient on top of the relatively impermeable clay till. In order to contain the spill, a trench was excavated in a downgradient location to intercept the flow of gasoline. In this manner, gasoline that reached the trench could be removed before it escaped beyond the affected area.

In addition to the interceptor trench seven other sample holes or trenches of various sizes were constructed after January 25, for removal of gasoline from a home. Two holes were dug in the basements of two houses to remove free product. In an effort to increase the flow of gasoline into the holes and to remove the product from under the building, steam (hot water) was applied at various locations. This was carried out by jetting small diameter pipes into the ground until the ends rested in the granular material.

This scheme appeared to be successful since the amount of gasoline recovered increased significantly and then decreased until eventually, nothing but water was discharging from the ground through the holes in the floor of the house. Neither of the houses have weeping tiles under the floor so steam was applied around the perimeter to drive the gasoline to the collection points inside. There are weeping tiles under the apartment block so steam was used in the tile to drive the gasoline to the outside. The block did not have to be evacuated and holes did not have to be cut in the floor.

Since the program of steaming and pumping worked effectively, it is being continued around the buildings until there is no free gas entering the sumps located in the basements of the respective buildings. The work will then be shifted to the north containment trench where steaming between the containment trench and the collector sump to the south will be carried out. Steaming in other areas should continue if conditions permit.

To confirm the effectiveness of this scheme, groundwater monitors were used to determine quantities of free product in the area of study. Monitoring was conducted indoors by the Fire Department to ensure safe levels had been reached.

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #36**

**BUILDING TYPE AND LOCATIONS:** Single Family Dwellings, Deloro

**GAS TYPE:** Radon

**SOURCE:** Mine Tailings used as backfill around houses

**TYPE OF CONTROL:** Demolition

**CASE STUDY PRÉCIS:**

At the turn of the century, a smelter refining arsenic area was operating in the area. The source of raw ore was of over shore origin and had significant levels of cobalt. As a result of the refining operation, tailing that had high levels of radioactivity were present in the area. Large tailing piles were stored on the refinery property.

As construction in the area proceeded in the early 1970s, some of the tailing material was used as backfill around adjacent houses to the smelter property. In the mid-1970s, a resident living in one of the houses developed cancer and died. Upon investigation, authorities discovered unusually high levels of radioactivity in the victim's home and the adjacent houses. A typical geiger-counter was used to do a relatively small assessment of the problem. All families were instructed to vacant immediately.

The homes were demolished and the backfill material was excavated and returned to the Deloro smelter property. The smelter is no longer operating. The Ministry of the Environment has an ongoing project at the site to treat the contaminated water being generated. The area is fenced to restrict access.



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**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #37**

**BUILDING TYPE AND LOCATIONS:** Fire Hall, North York

**GAS TYPE:** Methane

**SOURCE:** Landfill

**TYPE OF CONTROL:** Geomembrane in conjunction with Active Venting

**CASE STUDY PRÉCIS:**

One of North York Fire Department's fire halls is located on the edge of the Amesburg Park Landfill. The landfill site received ash from an onsite solid waste incinerator during the early 1940s and 1950s. In 1957, the site started to receive domestic refuse.

Boreholes in the area revealed up to 7 metres of refuse near the fire hall. The fire hall abuts the northern edge of the landfill and encrusts one part of the refuse. Gas probes installed around the foundation showed methane levels up to 40 percent GAS in February and March 1981. Staff at the fire hall reported that gases migrating into the building could be ignited.

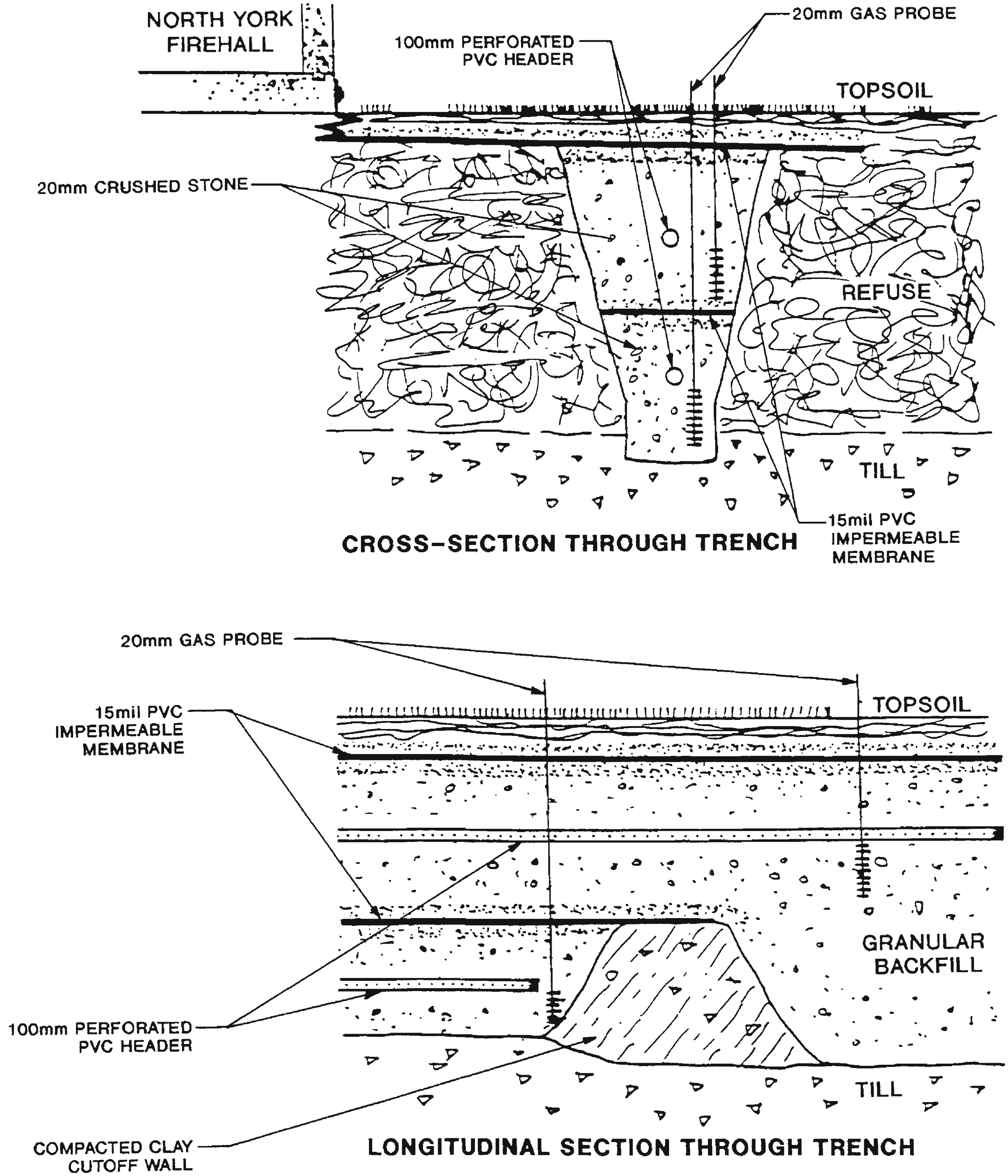
The methane collection system (see Figure B-28) recommended for this site was comprised of tow horizontal collection pipes. The two pipes were placed in a stone-filled trench separated by a 15 mil PVC membrane. The two-tier collection pipes were connected to two low-capacity exhaust fans. The exhaust stack is mounted on the roof of the fire hall.

A 15 mil PVC membrane was also installed just below ground surface over the entire trench. It was attached to the fire hall foundation and extends several metres from the foundation. This membrane acts as a cap reducing the amount of atmospheric air which could short-circuit into the collection system.

According to Clister and Beatty (1984), the system has been in operation since 1981. Routine monitoring shows no methane below the floor slab.

**REFERENCE:**

Clister, Wm. E, B. W. Beatty, 1984. Case Histories of Well, Trench, and Membrane-Type Landfill Gas Control Systems. Workshop Seminar on Design and Construction of Municipal and Industrial Waste Disposal Facilities. June 6-7, 1984. Malton, Ontario.




SOURCE: CLISTER AND BEATTY, 1984

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**FIGURE B-28: METHANE COLLECTION SYSTEM, NORTH YORK FIREHALL**

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #38**

**BUILDING TYPE AND LOCATIONS:** Single family dwellings, Southern Ontario

**GAS TYPE:** Methane

**SOURCE:** Landfill

**TYPE OF CONTROL:** Landfill gas extraction system

**CASE STUDY PRÉCIS:**

As part of a land reclamation project, refuse was used to stabilize an eroding landform. Due to slumping in the landform, refuse was deposited in a 10 metre deep gulley in order to shore up the bluffs. In and around 1965, the bluffs were secured, and landfilling was ceased. Two years later, monitoring in nearby homes and garages showed that methane migration had occurred.

As a result of methane detection, over 30 steel gas vents were installed in the backyard of area residential properties. A site plan of the area is shown in Figure B-29. Following this a monthly monitoring program was initiated. Later in 1977, the monitoring program was expanded to weekly monitoring of 110 points, including one metre deep bar holes, gas vents, garages, and house basements. The need for an overall gas venting system became apparent.

In 1978, a consulting firm initiated a geological study as well as a series of pumping test to evaluate what form of control would be appropriate to handle the gas generation capability of the landfill and provide adequate protection for the nearby homes. The results of the investigation determined that landfill-produced gas was migrating through an upper stratified sand deposit (see Figure B-30). Testing in the landfill revealed that soil gas pressures at times exceeded 500 Pa. This indicated that sufficient methane was being generated such that natural venting of the landfill gas was unable to balance the generation rate.

As part of the monitoring program, the onsite soil gas monitors were sampled and it was concluded that seasonal fluctuations were evident. Independent examination of the data, however, did not produce similar conclusions. The sporadic sampling showed no pattern between summer and winter. This, however, had no impact on the remedial solution.

Several remedial processes were considered including membrane installation, air barrier injection, passive venting, and active venting. Membrane and air injection schemes were discounted due to the possibility of leakage or failure.

Passive venting was eliminated since discharge is typically only a few L/s which is inadequate to account for the methane generation capability of the site. Active venting was the preferred alternative.

Prior to implementation, a series of withdrawal wells were installed into the waste material. Gases were pumped at various rates and monitoring wells were measured for methane and pressure. Based on measurements, the specific capacity (i.e pumping rate/drawdown in the well) was calculated. This number can be used to predict drawdown potential at different pumping rates. Oxygen concentration in the effluent gas was also monitored. Approximately 30 percent of the effluent gases were due to infiltration of atmospheric air. With this number, gas generation capacity was determined. A value of 0.014 $m^3$/kg/yr for methane production was calculated, which is within the range of values quoted in the literature. Testing also revealed that spacing of the wells along the landfill border should be installed at a 30 metre spacing to achieve a 25 Pa of depressurization between the wells.

In total 27 wells were installed in the landfill. Once the system was operational, pressure bulbs extending from the extraction wells was close to 70 metres from the line of extraction wells. The drawdown at 70 metres was approximately 250 Pa. This radius of influence from the pumping wells was well within the range of offsite houses.

By introducing a vacuum to the subsurface, a large amount of oxygen will be introduced. This will cause a reduction in methane generation capability. Oxygen infiltration into the subsurface can be achieved within 3 days with pumping rates greater than 500 L/s.

Venting of landfill gases posed problem odours in the atmosphere. Potential for odours occur primarily due to the presence of sulphur compounds and ethylmercaptans. Controlled tests were conducted after an odour complaint was received. It was concluded that odours were not significantly different before or after the system was turned on or off.

After several years of operation, it was noticed that the flow rates from the gas extraction system were reduced. This fact initiated an investigation to determine the causes for a reduction in venting. Based on the investigation, reduced venting was caused by several factors: plugging of well screens, accumulation of water in the extraction pipes, and settlement of the leader pipe which connected the vertical withdrawal wells.

Many of the problems that were experienced with the extraction system were attributed to the aerobic degradation of the refuse. Aerobic degradation evokes quicker settlement of refuse causing non-uniform settlement of the header pipes which can cause blockages within the vacuum system. The aerobic degradation process also causes higher temperatures to exist within the landfill. Temperatures (~70°C) can cause warping of the PVC pipes which also may reduce flow rates. Aerobic activity was also a contributing factor for slime buildup on the extraction well screens. Several wells were also blocked with water.

As a result of this investigation, header pipes were re-aligned, and several wells were replaced or repaired. Monitoring at the perimeter of the landfill during this entire period showed no signs of methane migration.

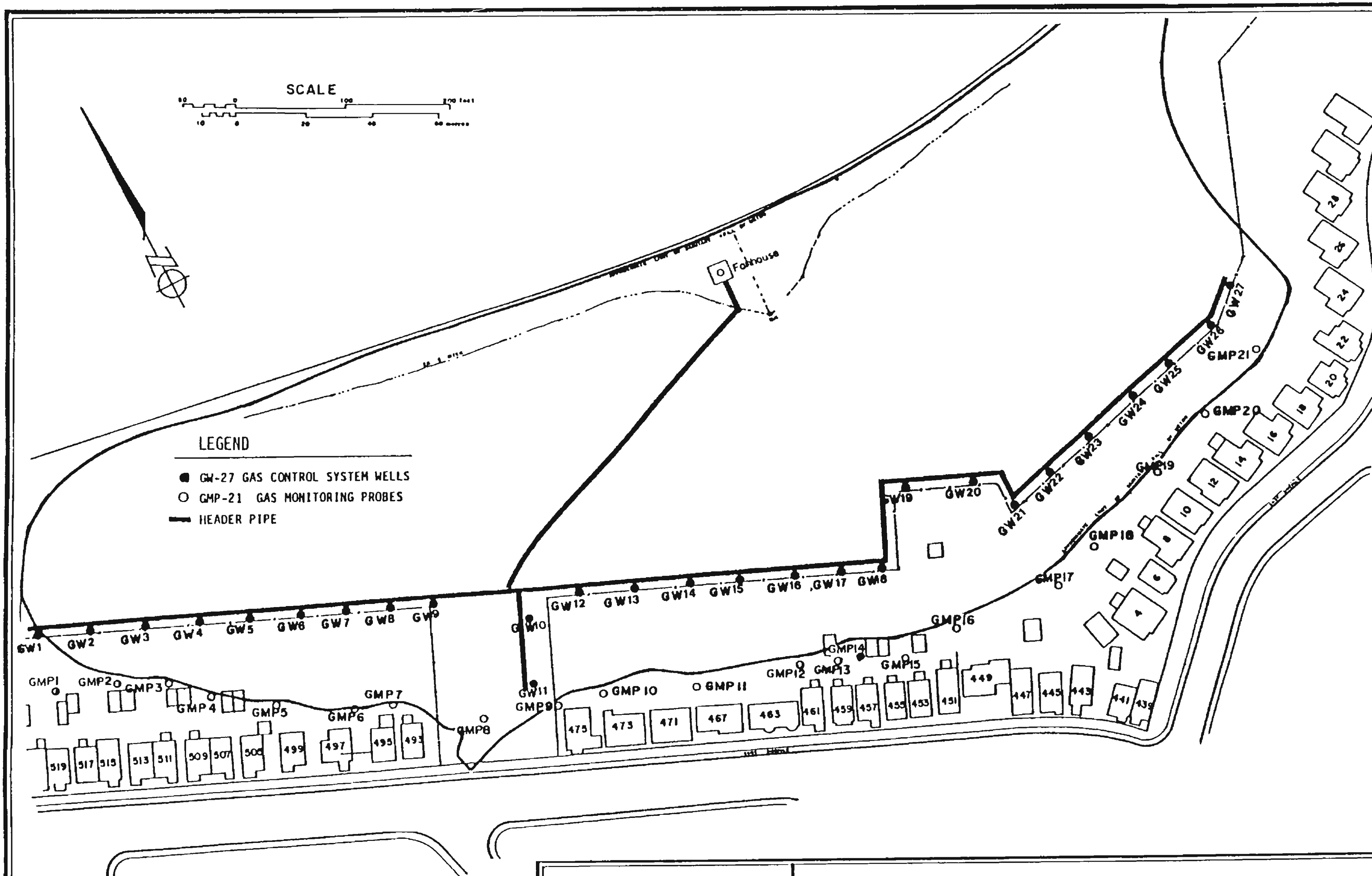


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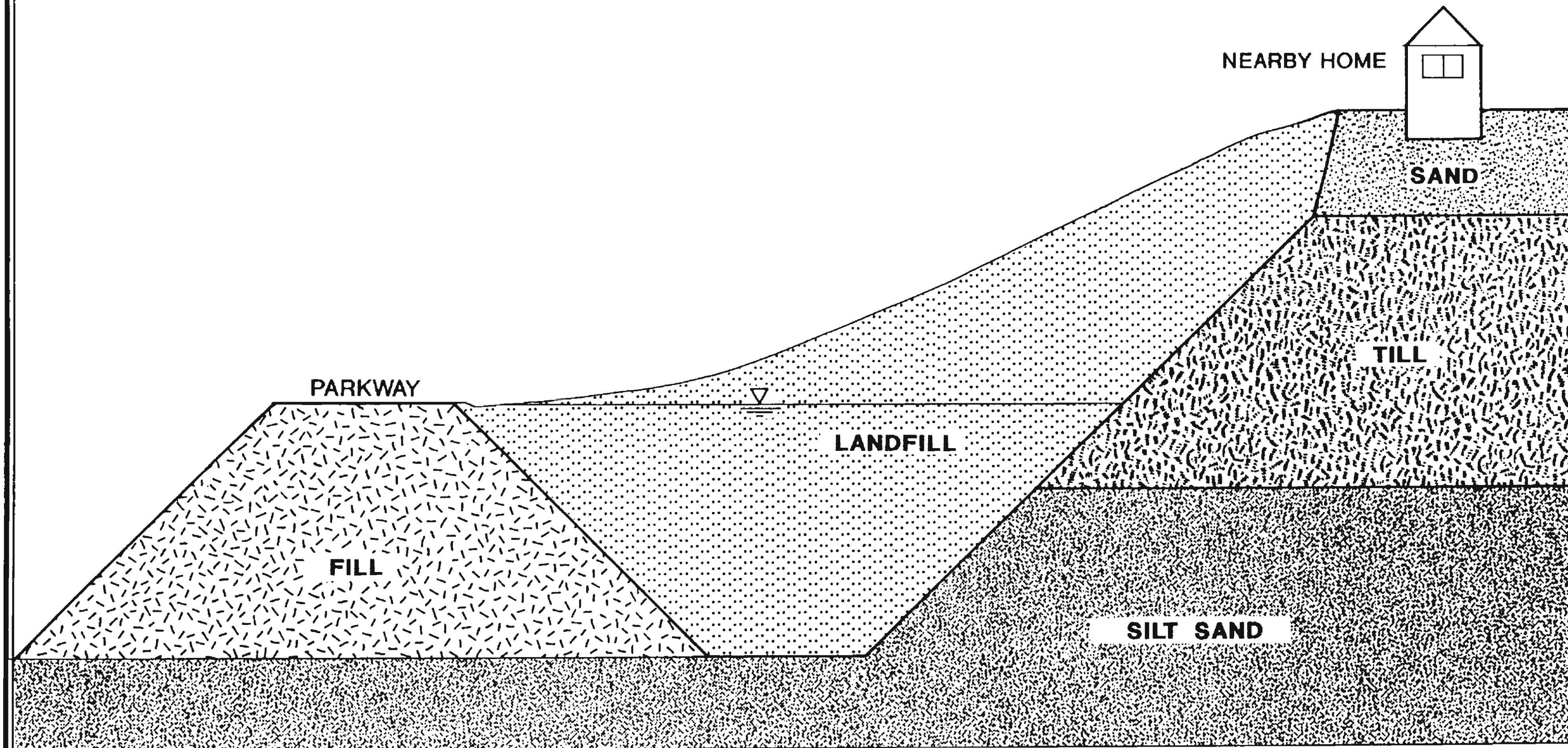
**FIGURE B–29:**

**SITE PLAN**
**LANDFILL SITE**




SOURCE: MORRISON-BEATTLY, 1980

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**FIGURE B–30: SUBSURFACE STRATIGRAPHY SOUTHERN ONTARIO**

## CMHC SOIL GAS RESEARCH STUDY
## CENTRAL CANADA SECTOR
## CASE STUDY #39

**BUILDING TYPE AND LOCATIONS:** Apartment complex, Scarborough

**GAS TYPE:** Methane

**SOURCE:** Landfill

**TYPE OF CONTROL:** Membrane and air injection

**CASE STUDY PRÉCIS:**

In the late 1950s, a valley was reclaimed with landfilling activity. Ten years after landfilling, a number of apartment buildings were constructed on nearby sand pits. One apartment was proposed to be constructed within 50 metres of the landfill. The geology in the area is comprised of a dense fine sand underlain by a clayey silt. The water table exists at a depth of 4 to 5 metres below ground surface and forms the lower boundary of methane movement.

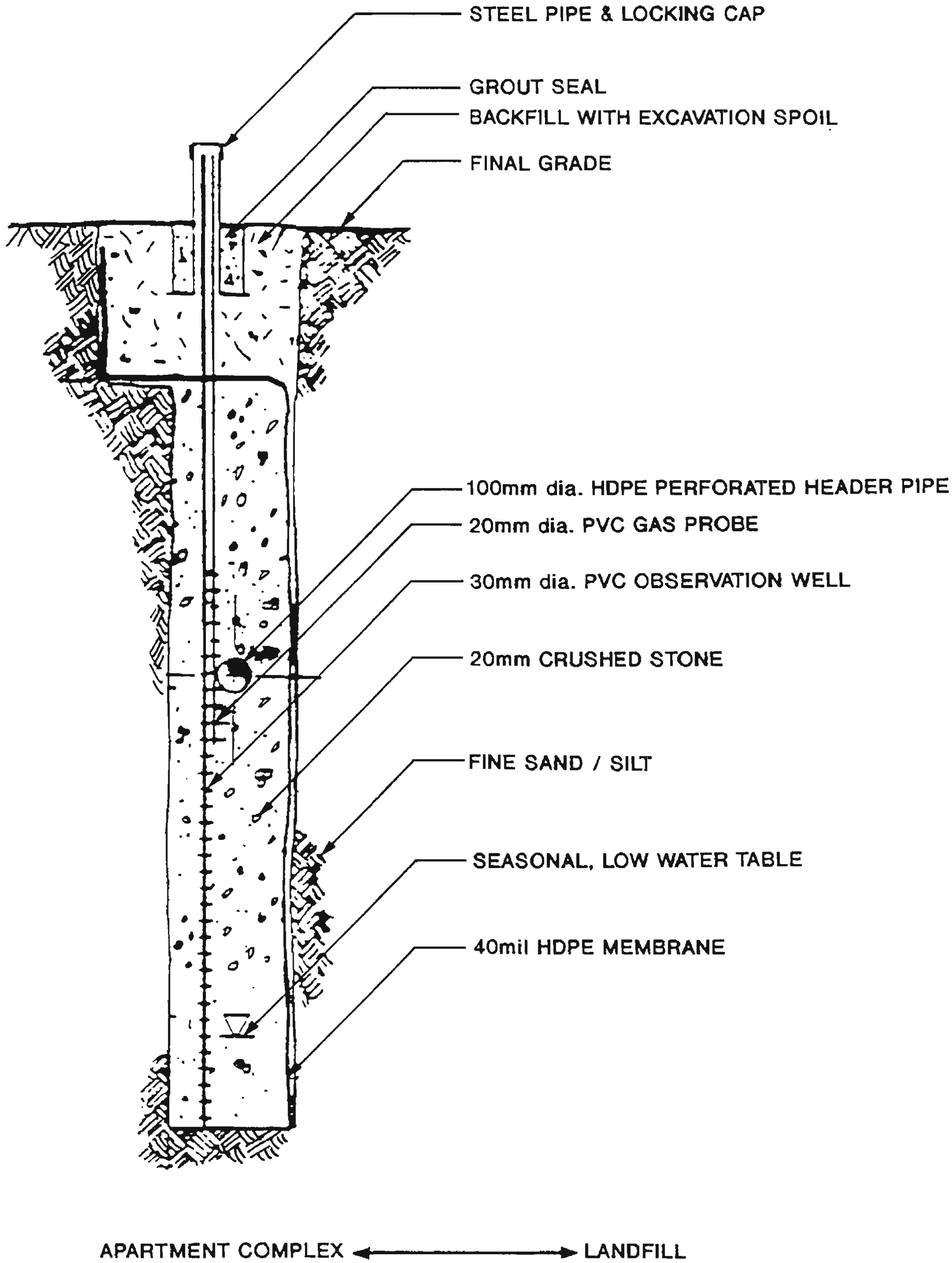
Initial field investigations showed that methane levels were as high as 92 percent by volumes. These abnormally high methane levels were attributed to adsorption of carbon dioxide on specific organics contained within the waste. Gas probes within the sand deposits revealed that methane had travelled up to 45 metres from the landfill limits.

The criteria required for a gas control system were: a reliable and fail safe system, a system of minimal nuisance impacts, and a system which requires minimal maintenance. A system of a plastic membrane in conjunction with a horizontal pressure system was designed and complemented. The membrane was a 40 mil high density polyethylene (HDPE) membrane. Figure B-31 displays installation details.

The header is connected to low-volume fans which pumps air into the trench. The header will distribute positive pressure to counter the pressure which exists within the landfill.

**REFERENCE:**

Clister, Wm. E, B. W. Beatty, 1984. Case Histories of Well, Trench, and Membrane-Type Landfill Gas Control Systems. Workshop Seminar on Design and Construction of Municipal and Industrial Waste Disposal Facilities. June 6-7, 1984. Malton, Ontario.




SOURCE: CLISTER AND BEATTY, 1984

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**FIGURE B-31:**
**GAS BARRIER, APARTMENT COMPLEX, SCARBOROUGH**

## CMHC SOIL GAS RESEARCH STUDY
## CENTRAL CANADA SECTOR
## CASE STUDY #40

**BUILDING TYPE AND LOCATIONS:** Transit/Information centre for transit operations, Ottawa

**GAS TYPE:** Landfill gases

**SOURCE:** Landfill

**TYPE OF CONTROL:** Membrane with positive pressure control

**CASE STUDY PRÉCIS:**

The Riverside Drive landfill is approximately 25 years old. It received both domestic and industrial refuse when operating. Locally, a fill of about 4 metres covers the refuse.

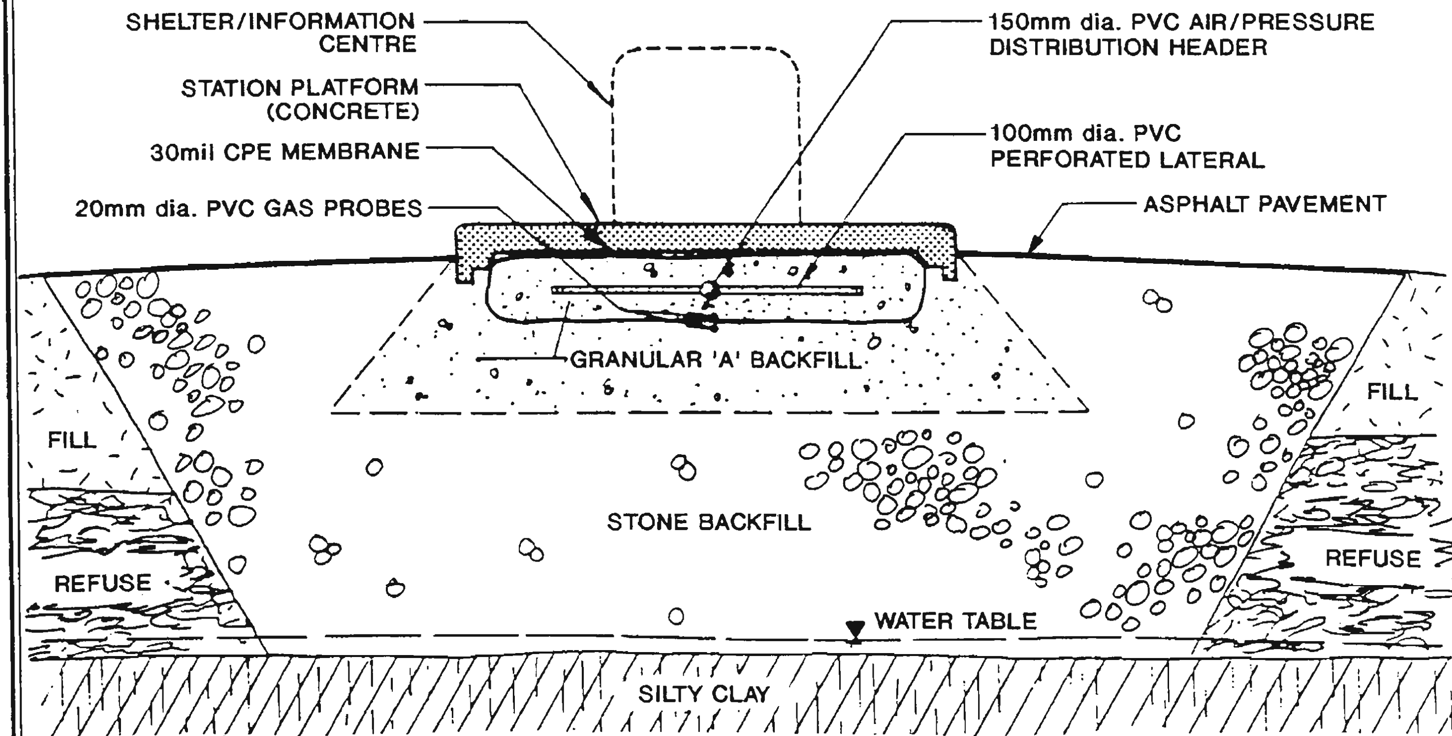
The design of the protection system is shown on Figure B-32. The transit/ information centre is constructed on rock backfill. To protect the building, the foundation, and the utility corridor below the building, a pressurized membrane pillow was designed. A 30 mil CPE membrane resistant to hydrocarbons was installed beneath the floor slab of the information centre. Special attention was made to seal any piping that passed through the pillow.

The header that was installed in the pillow was connected to a moderate-pressure ventilator fan. The pressures in the pillow are pressurized to levels that are greater than in the landfill.

In addition, a methane monitoring system exists. Probes distributed throughout the pillow and around it allow monitoring for both methane levels and gas pressures. Several additional methane detectors are installed within the building. All sensors are monitored remotely on a 24-hour basis.

**REFERENCE:**

Clister, Wm. E, B. W. Beatty, 1984. Case Histories of Well, Trench, and Membrane-Type Landfill Gas Control Systems. Workshop Seminar on Design and Construction of Municipal and Industrial Waste Disposal Facilities. June 6-7, 1984. Malton, Ontario.




SOURCE: CLISTER AND BEATTY, 1984

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**FIGURE B–32:**

**MEMBRANE BARRIER TRANSIT / INFORMATION CENTRE**

# CMHC SOIL GAS RESEARCH STUDY
# CENTRAL CANADA SECTOR
# CASE STUDY #41

**BUILDING TYPE AND LOCATIONS:** Single dwellings, school, Little Grand Falls

**GAS TYPE:** Heating fuel

**SOURCE:** Line failure of heating oil tanks

**TYPE OF CONTROL:** Vapour extraction, groundwater pumping, soil excavation.

**CASE STUDY PRÉCIS:**

As a result of two cracked fuel lines in July and August of 1986, another cracked line in October 1987, and overfilling of storage tanks in 1988 and 1990, approximately 10,000 litres of heating fuel was spilled on the ground in Little Grand Falls. As a result of this spill, soil and groundwater contamination was evident. Strong fuel oil vapours were also reported in adjacent residences and a school.

The geology of the area consists of approximately three metres of glacial till overlying a precambrian granite and granite gneiss. The glacial till in the area is also composed of some outwash sands and silts.

As part of the subsurface investigation, vapour concentrations were monitored in various boreholes drilled around the site. Monitoring was completed primarily with the use of a hydrocarbon surveyor, calibrated to hexane. Vapour concentration in the ground near the affected structures had concentrations as high as 60 ppm. Despite these concentrations, no vapours were detected inside the structures. Vapours were measurable only in the school where some contaminated silt existed directly below the structure. The contaminated soil was excavated and hauled offsite. Vapour problems ceased.

Other air quality sampling completed on the site included sampling by means of drawing a measured volume of air through a charcoal tube. The objective was to determine the total petroleum hydrocarbons in area. Sampling completed in the crawl spaces resulted in non-detects.

**REFERENCE:**

Woolwich, E.A. and Horinig, B. K., 1990. Fuel Oil Recovery by Pumping from a Till Aquifer. A Case History. Little Grand Rapids, Manitoba. Proceedings of Conference on Prevention and Treatment of Soil and Groundwater Contamination in the Petroleum Refining and Distribution Industry, Montreal, Quebec. October 16 - 17, 1990.

## CMHC SOIL GAS RESEARCH STUDY
## CENTRAL CANADA SECTOR
## CASE STUDY #42

**BUILDING TYPE AND LOCATIONS:** Duplexes, Housing Project, Manitoba

**GAS TYPE:** Heating oil

**SOURCE:** Spillage

**TYPE OF CONTROL:** Excavation of soil

**CASE STUDY PRÉCIS:**

An old army base was being renovated for housing purposes. Army barracks were retrofitted to become duplexes. Eighty units were renovated.

The units were previously heated with oil. The oil tanks were buried in the front lawns of many of these units. Over time, several leakages had occurred, contaminating large blocks of soil. Fumes from these spills were detected in many of the units on the base.

Tests were conducted by drawing a measured volume of air through an Arbo 32 charcoal tube for a measurable mass of petroleum components which could be converted to total petroleum distillates in air. All tests were conducted in existing crawl spaces and the main closet inside the front door.

One of the units that was sampled indicated contamination of 0.30 and 0.26 ppm of fuel oil in the closet and crawl space respectively. In order to remediate this problem, the soil vapour extraction system was installed in the soil at the front of the homes. Sealing of closets was also performed. The soil vapour extraction system was to be operated until no further odours were detectable inside and vapour concentrations in the crawl space were reduced to below 0.1 ppm.

Confirmatory sampling indicated that these levels had been reached. Only one sample taken from a closet exceeded that guideline of 0.1 ppm of total petroleum distillates. However, based on the advice of the analyst, the closet sample "was not a good trace and was not a standard pattern for petroleum distillate." In view of the atypical reading, the vapour from representative samples may have emanated from rug which was present in the closet.



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# CMHC SOIL GAS RESEARCH STUDY
# CENTRAL CANADA SECTOR
# CASE STUDY #43

**BUILDING TYPE AND LOCATION:** Two residential areas located southeast of the Oshawa Landfill site but west of Riston Road, and one residential area located east of both the landfill site and Ritson Road

**GAS TYPE:** Methane

**SOURCE:** Landfill gases permeating through sands, gravels, and foreign soils.

**TYPE OF CONTROL:** A temporary passive venting system using a 100 mm perforated pipe extending to the water table and surrounding the landfill was first installed.

An impermeable barrier was then installed between the refuse and the areas of concern to prevent the lateral migration of gases. A permanent gas interceptor system forced ventilation was then designed and constructed followed by routine monitoring of gas using gas sniffers.

**CASE STUDY PRÉCIS:**

Three residential areas bounding the Oshawa Landfill Site to the south and to the east have been subject to unusually high methane gas concentrations of up to 60 percent. As a result, the City of Oshawa contracted a consulting firm to identify the extent of the landfill gas problem and to design an acceptable remediation system. A temporary passive venting system was completed on March 21, 1987. The consultant deemed the system unsuitable for long-term remediation due to wind effects which may prevent the escape of gases, but a time constraint prevented the construction of a more detailed system. A suggestion was made by the consultant to design a permanent gas interception system: forced ventilation or impermeable barrier. A forced ventilation system was selected due to its success in controlling lateral gas migration. A monitoring system was designed consisting of routine measurements of: pressure in the header pipe, exhaust manifold and gas probes, methane and other landfill gas concentrations in selected gas probes and at the exhaust stack, and water table fluctuations. The monitoring system consists of daily to annual checks for a period of up to 10 years due to the possibility of an increase in methane gas production. A contingency plan has also been drafted in the event of a system failure.



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**Background**

The Oshawa Landfill Site is bounded by residential areas to which it may contribute methane gas (see Figure B-33). Most residential areas are located beyond a 45 m range, which has been deemed suitable by the consulting firms, since none of the combustible gases have migrated beyond the 45 m range. However, three residential areas are located in a zone containing dangerous methane concentrations (50 to 60 percent). The procedure by which to remediate this situation has been deemed as Stage I of a two part study.

Methane concentration tests revealed an unusually high level of gas (50 to 60 percent) in the vicinity of the three residential areas and a concentration of $CO_2$ reaching up to 30 percent. Figure B-34 shows methane distribution. Speculation revealed three possibilities for such high gas concentrations. Firstly, the proximity of the townhouses to the landfill is less than 15 m. Secondly, the affected area is underlain by well-sorted sands and gravel and fill as opposed to the poorly sorted soils found elsewhere. And thirdly, imported topsoil, which is fine-grained has a high moisture retention capacity and is impermeable to gas, is found aplenty. The topsoil has been placed around foundations, thus providing a cap for landfill gases and consequently creating a concentration and pressure gradient towards the building.

The Oshawa Landfill site consists of abandoned sand and gravel pits. The pits located west of Ritson Road were filled to ground level and abandoned in 1959. The depth of the cover fill amounted to 250 to 400 mm above grade.

The landfill site is underlain by poorly sorted beach deposits, a remnant of Lake Droguois, that wedge out to the east onto the flank of a drumlin. The drumlin is composed of a sandy silt till. The north and west boundaries of the landfill site are defined by the valleys of Oshawa Creek. The water table if believed to be 250 to 400 mm below the surface and located amidst the sand and gravels.

**The Solution**

Following an initial survey of the site, it was determined that a permanent monitoring system would be required. The reason for this decision stemmed from the fact that the permeable sandy stony mixture on top of the refuse represented a direct route for landfill gas migrations. In the interim, a temporary passive venting systems was installed which consisted of a 100 mm perforated PVC drainage pipe in 300 mm diameter holes augured into the water table (from 2.4 to 2.7 m below ground). The holes were then backfilled with 1.9 cm gravel. Vents were installed on 7.6 m centres, 1.8 m inside the fence line for 61 m north and 61 m east of the extreme southwest corner of the landfill site. A few problems were encountered with wind preventing the escape of gas, but a time constraint prevented the installation of a more sophisticated design.

Following a discussion with the Ministry of the Environment, a permanent gas interception system and a monitoring program were designed. The operation of a gas interception system requires a Certificate of Approval (Air) from the Environmental Approval Branch (Ministry of the Environmental Protection Act 1987). This certificated was obtained in November 1987. The permanent gas interceptors were recommended to be placed no less than 45 m from the nearest property boundary in need of protection.

The perimeter of the affected residential areas were outfitted with inverted stone and weeping tile located 300 mm below ground surface. Any incoming gas would then collect to the stone trench and inverted weeping tile, travel up a pipe located at the side of the house, and be vented to the atmospheres.

A permanent gas interceptor system was then designed to contain gas emissions from the landfill site. The consulting firm considered two methods: forced draft interception and impermeable barriers. Due to its proven ability to control lateral gas migrations, the forced gas interception system was adopted. The system consisted of twin exhaust fans, an automatic fan operation system, various fan-house features a vent silencer, a polyethylene pipe, flow controls and high-efficiency well screens (refer to Table B.8). The exhaust stack, a part of the gas interception system, had to be constructed at a minimum height of two the building height with an exit velocity at least 12 m/s according to Ministry regulations. The components of the forced draft gas interception system are described in Table B.8 and the advantages of each element are also outlined.

A cross section of a gas interceptor is shown in Figure B-35, header assembly details are diagrammed in Figure B-36, and Figure B-37 shows a section of an interceptor well and header assembly.

Two monitoring programs were designed to ensure a fail safe operation of the gas interceptor system and to monitor methane gas levels. The first monitoring program designed in conjunction with the permanent gas interceptor system consisted of five types of monitors: a light outside the building for a visual recorder equipped with a 321 day chart to monitor gas pressure in the outlet manifold; pitot tubes in the header to monitor system pressures; a 3 dimensional network of gas probes (52) around the landfill boundary to monitor gas pressure and gas concentration; and observation wells along the header to monitor water table fluctuations.

The monitoring program was designed to periodically check methane gas concentrations and consists of routine measurements of pressures in the header pipe, exhaust manifold, and gas probes and measurements of water table fluctuations. A list of monitoring equipment may be reviewed in Table B.9. The monitoring program specifies: a daily check of the operating light; a weekly inspection of the equipment and controls in the fan-house; a monthly check (omitting May, July, September and November) to monitor gas pressure, methane concentrations, water level and to replace pressure charts for odourants and toxicants. Copies of the monthly monitoring data were to be submitted to the Ministry of the Environment every three months.

| Table B.8<br>Forced Draft Gas Interception System | | |
|---|---|---|
| **Component** | **Description** | **Advantage** |
| Twin Exhaust Fans | a) Installed in fan house<br>b) Custom designed inlet and outlet manifold allowing single twin fan operation | a) Adjusts for series or parallel operation<br>b) Back-up facility in case of equipment failure |
| Automatic Fan Operation | a) Two fans designed to operate on 24 hour schedule | a) Manual control may override photo-cell circuit |
| Fanhouse Features | a) Electric heaters<br>b) Control panel in enclosed electric room<br>c) Interior light switch activating fan-house ventilation system<br>d) Two horizontal slotted pipes beneath floor | a) Prevents freezing of condensate in exhaust manifold and fans<br>b) Eliminates need for explosion proof controls<br>c) Exhaust air in minutes and maintains slight positive pressure to prevent gas leakage<br>d) Evacuates methane below floor |
| Vent Silencer | a) Installed on exhaust stack | a) Reduces exhaust noise within over 3.0 m of fanhouse |
| Polyethylene Pipe | a) Used for header and well<br>b) High molecular weight, high density | a) Toughness, flexibility, butt-fusea joints and chemical resistance |
| Flow Controls | a) 7.6 cm gate valves on 20 wells | a) Yields of wells maybe adjusted |
| High Efficiency Well Screens | a) Shallow gas migration zone (high water table) required overlapping interference between wells | a) Reduction of friction losses, therefore lower suction pressures required |

| Table B.9<br>Monitoring Equipment | |
|---|---|
| **Parameter** | **Description** |
| A. Gas Pressure | a) Vertical liquid displacement tube manometer for pressure ranges of 0.02 to 4.1 kPa<br>b) Inclined vertical tube manometer for pressure ranges of 0.2 to 800 Pa |
| B. Methane Concentration | a) Bacharach J.W. Model H, combustible gas indicator |
| C. Water Levels | a) Steel chain of electric depth gauge |

A contingency plan in case of system failure was also required and submitted to the Ministry of the Environment. The purpose of the plan was to develop a zone of negative pressure when the fans become activated, ensuring a barrier to landfill gas migration, and to purge the soil and landfill along the header and well system of methane in a period of hours. Three steps to counteract system failure extend beyond a 24 hour period: an adequate generator should be obtained; should one of the two fans fail, the remaining fan should be manually switched into permanent operation; and monitoring of methane concentrations should be carried out at 4 hour intervals in the probes located near the residence.

**Post-Construction Results**

The gas interceptor system was approved by the Ministry of the Environment but was subject to the following conditions:

1. A continuous monitoring system for gas flow and suction pressure required in the fan-house.
2. The contractor be warned of potential problems of methane gas in landfill excavations and drilling.
3. A report be submitted to the Ministry of the Environment on the system installation.
4. The results of gas monitoring before, during and after construction be discussed in the above report.
5. Soil-air monitoring data be submitted to the Ministry of the Environment every three months.
6. A contingency plan (for system failure) be submitted to the Ministry of the Environment.

The exhaust fans were placed in alternating single-fan operation since it was determined that parallel operation would severely over-pump the system.

An examination of the pressure in all probes in the landfill and outside property boundary revealed a negative pressure ranging from -12 to -203 Pa.

Following fan startup, methane was purged from the soil zone outside the landfill boundary and has not been detected in any of the 40 soil probes since. Readings taken in residential areas revealed no methane gas entry in the basements. Based on the post construction test, the gas interception system appears to be operating successfully.

Methane gas concentrations in the exhaust at the fan house averages at about 14 percent by volume, with a minimum of 12 percent and a maximum of 17 percent. At the request of the Ministry of the Environment, stack emissions were also sampled for selected odourants and toxicants (butylamene, benzene, toluene, xylene, styrene, $H_2S$). All of the parameters checked were well below the recommended concentrations for gases and vapours.

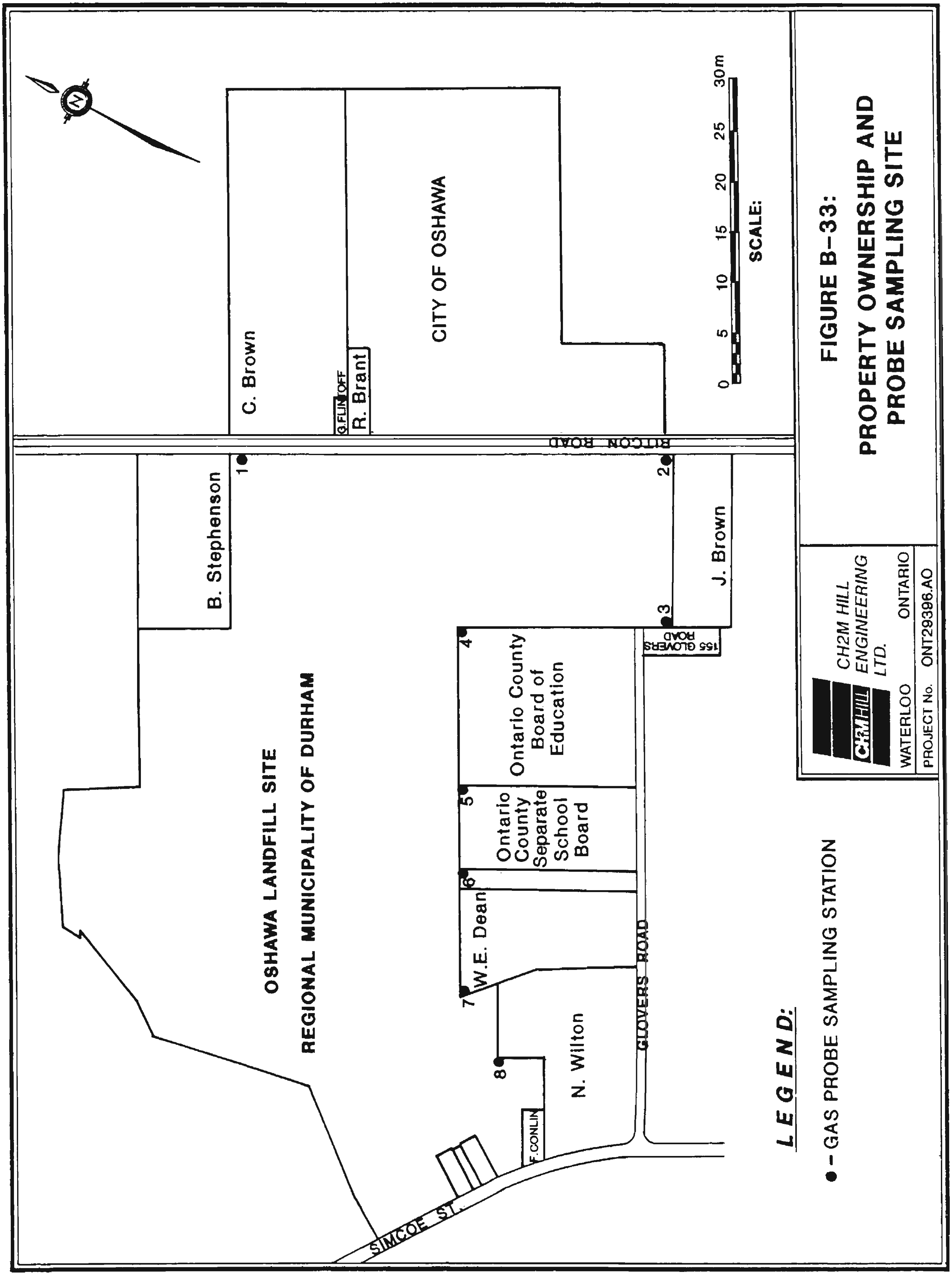


FIGURE B-33:
PROPERTY OWNERSHIP AND PROBE SAMPLING SITE

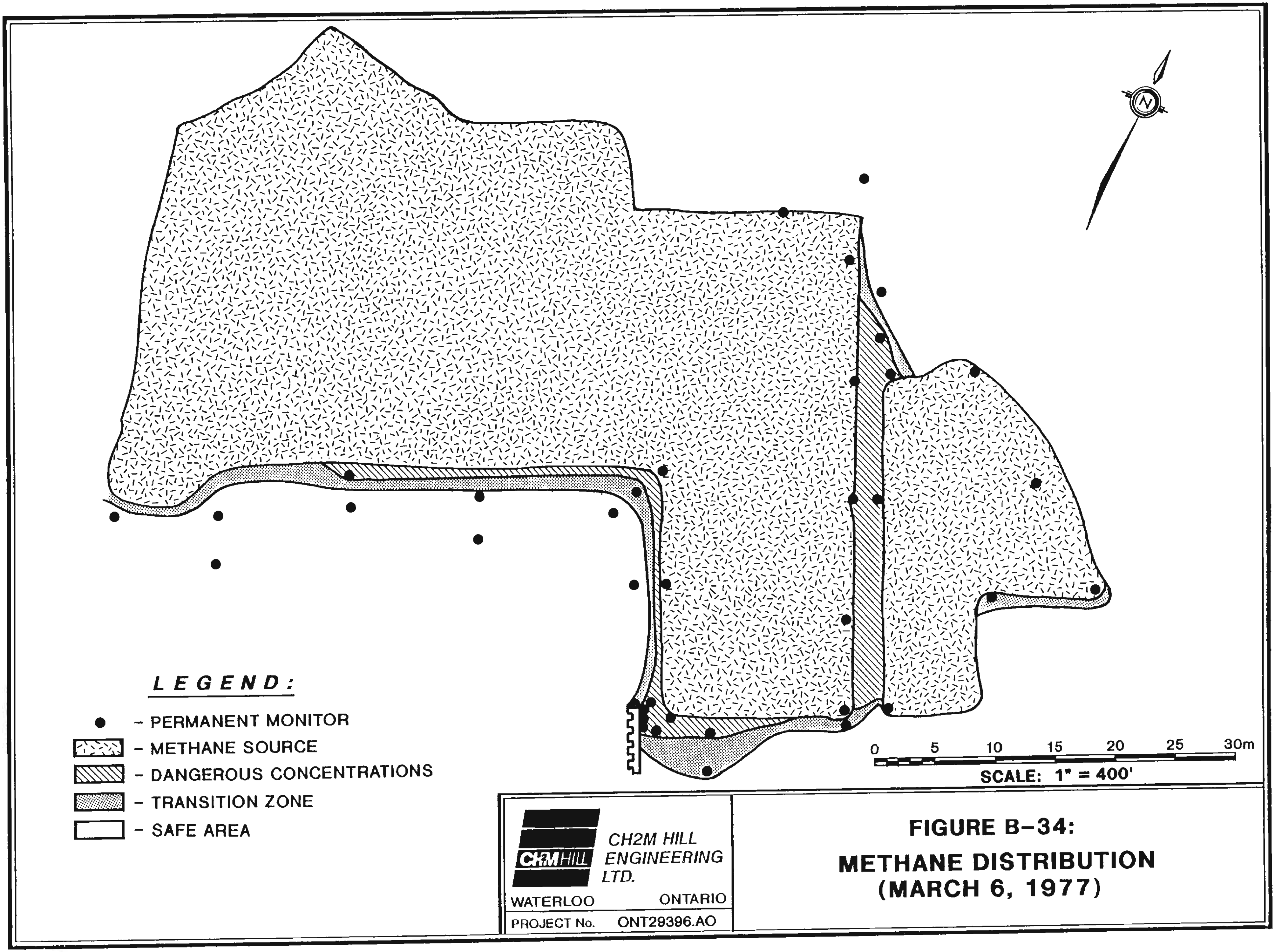


**FIGURE B–34:**
**METHANE DISTRIBUTION**
**(MARCH 6, 1977)**

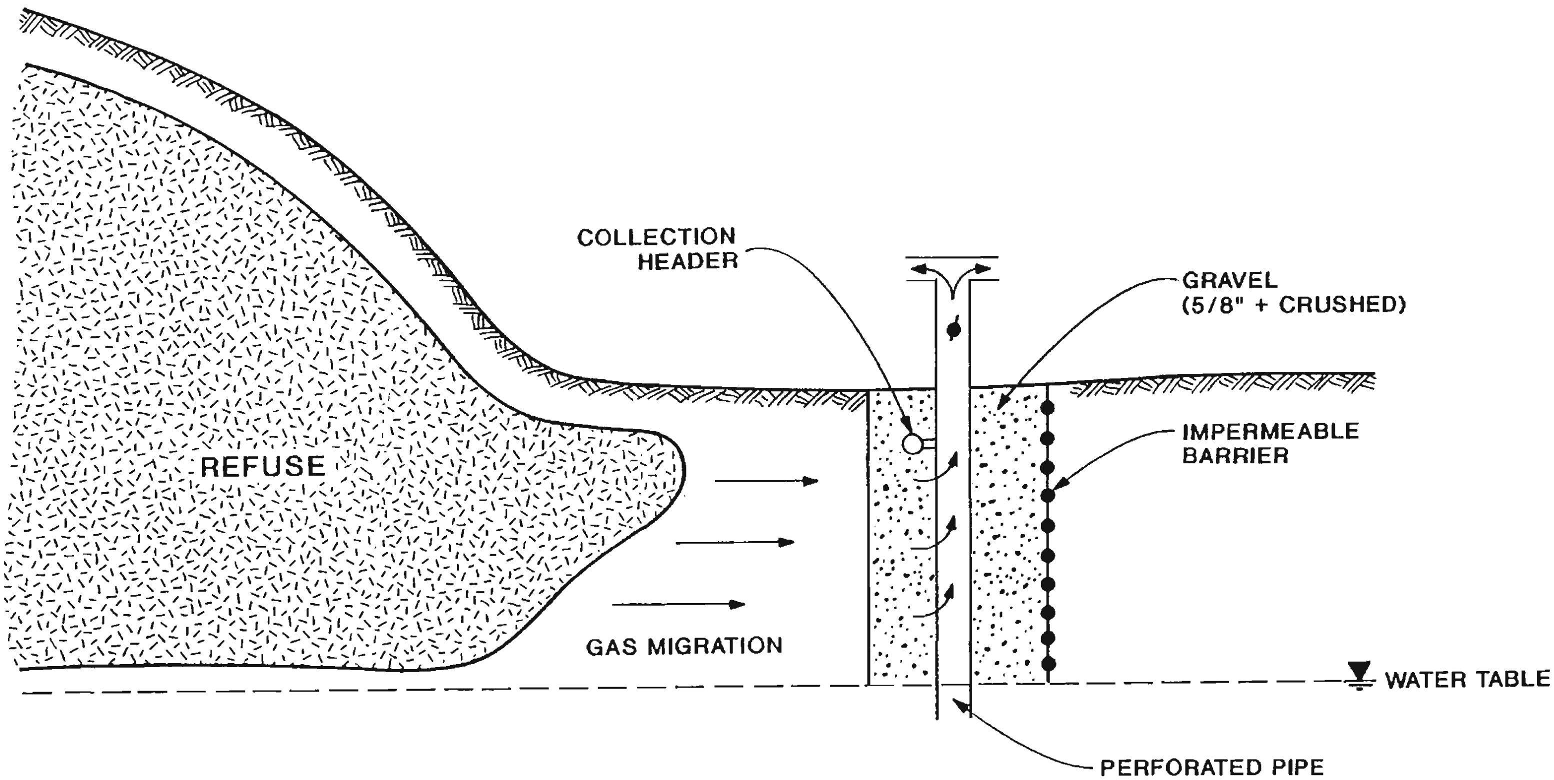


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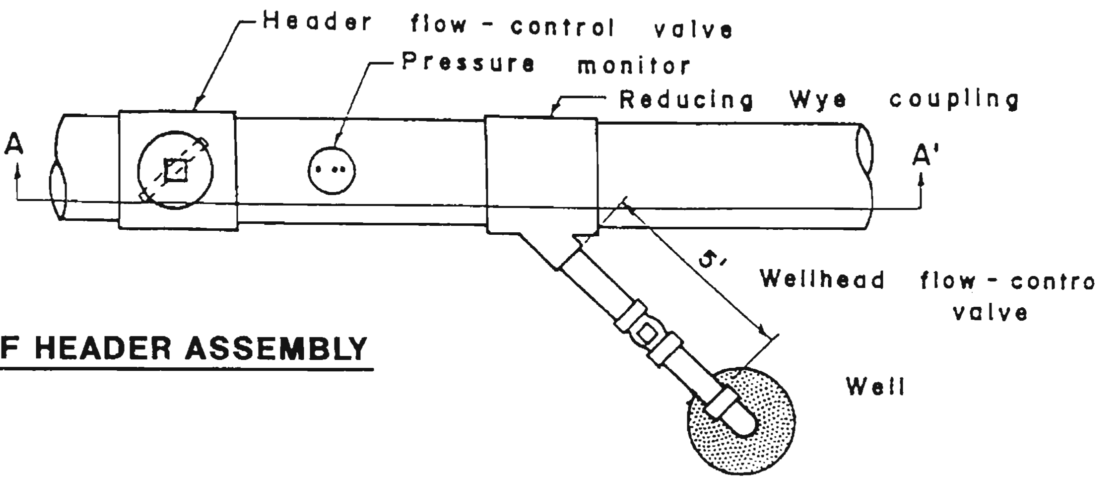
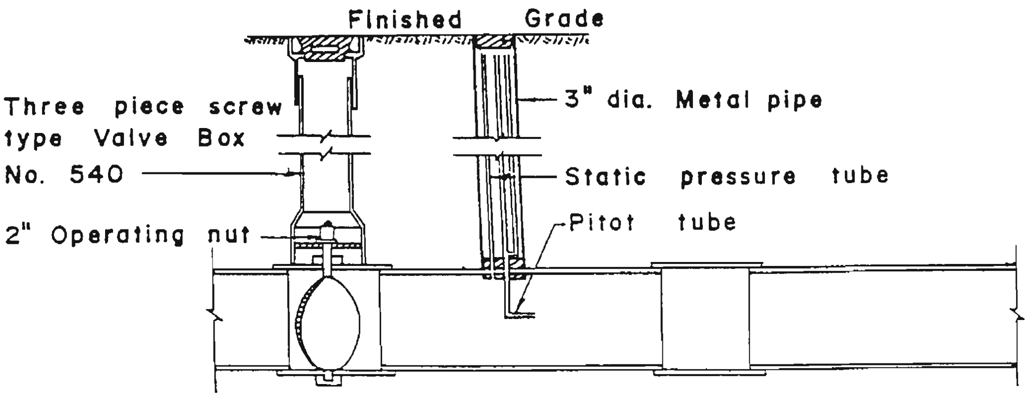
**FIGURE B–35:**

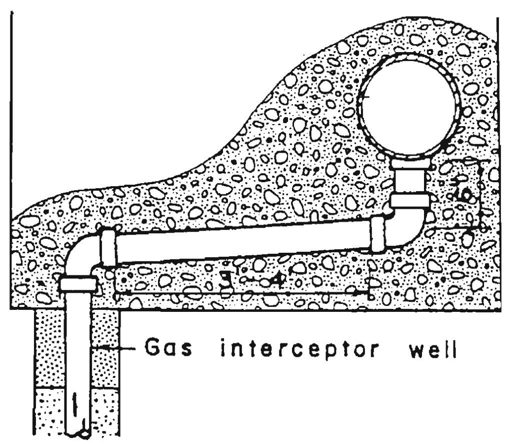
**SCHEMATIC SECTION GAS INTERCEPTOR**



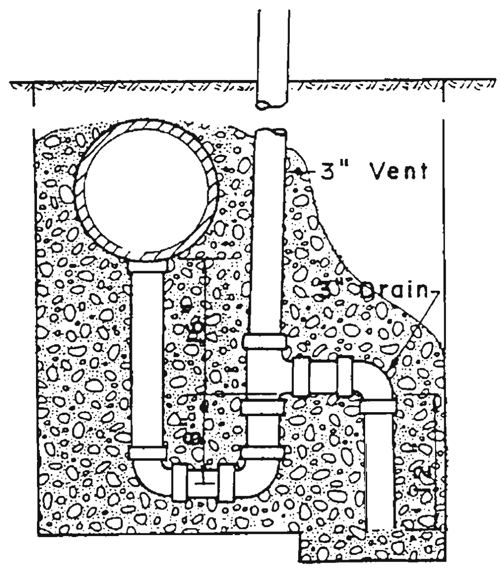

## PLAN OF HEADER ASSEMBLY




## SECTION A - A'




## WELL DRAINAGE UNIT




## HEADER DRAINAGE UNIT

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**FIGURE B-36:**
**HEADER ASSEMBLY DETAILS**

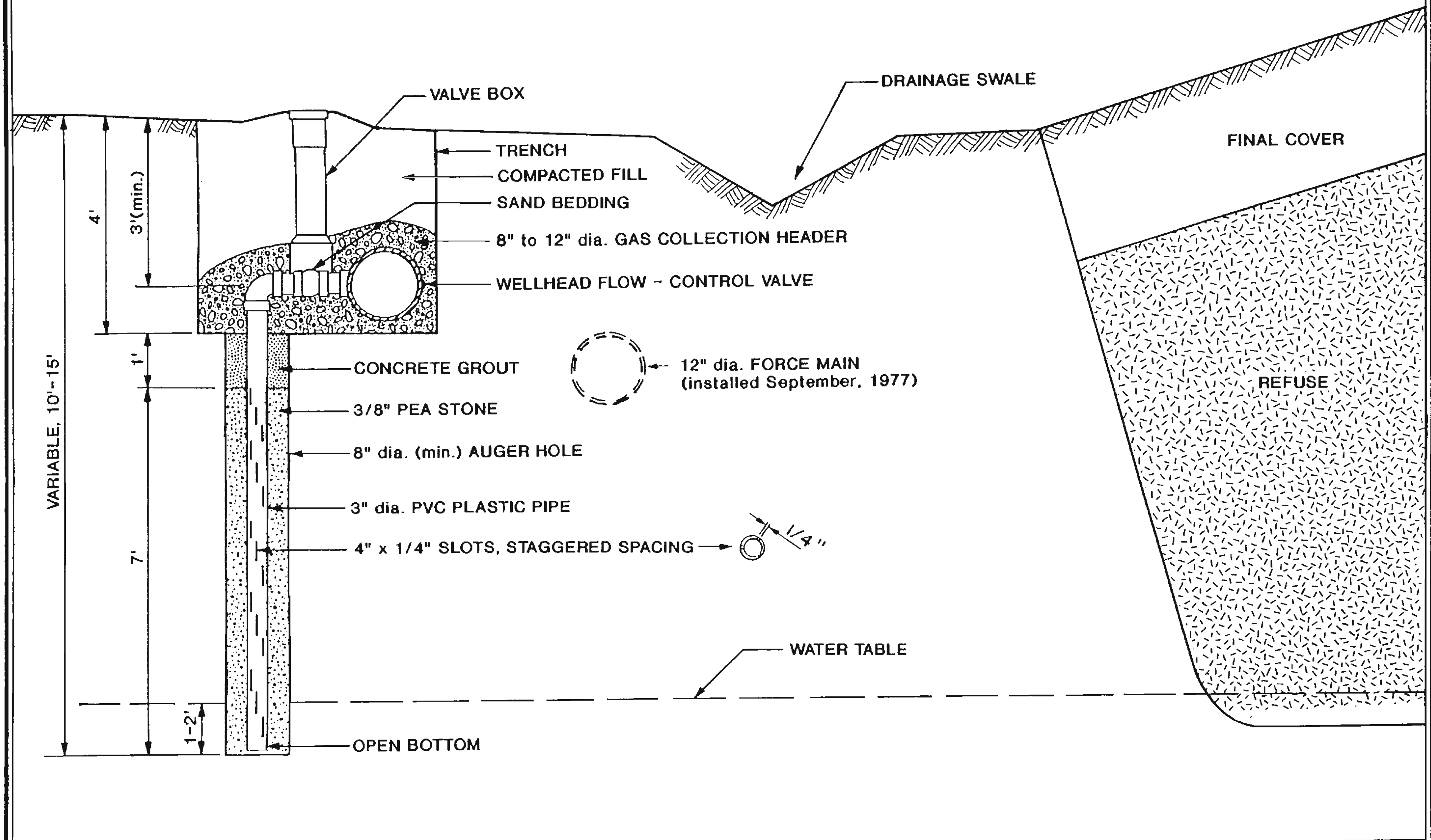


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**FIGURE B–37: SECTION THROUGH TYPICAL INTERCEPTOR WELL AND HEADER ASSEMBLY**

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #44**

**BUILDING TYPE AND LOCATION:** Underground parking garage, McEwen apartments, three residential houses, and parkland, Ottawa

**GAS TYPE:** Methane

**SOURCE:** Landfill Site

**TYPE OF CONTROL USED:** Monitoring

**CASE STUDY PRÉCIS:**

A consulting firm was contracted to determine the extent of a methane gas entry problem associated with selected landfill sites in Ottawa in the spring of 1980. Its method of investigation consisted of three parts. The preliminary site identification consisted of identifying the area of study based on document research. The specific site identification focused on the study of aerial photographs to further narrow the study area. Field confirmation included field reconnaissance and the development of random shallow auger holes around the site in question (refer to Case Study #26).

The McGee Farm landfill was not registered as having a significant methane gas problem. However, due to its proximity to developed areas (15 m from an underground parking garage, 30 m from an apartment building and 18 m from three houses), a consulting firm determined it prudent to install permanent gas monitors for monitoring purposes (Gartner Lee Associates, 1980).

**The Problem**

Combustible methane gas was discovered at a concentration of 10 percent in a hand auger hole. Vegetation killed along the west side of the site indicated the possibility of surface gas venting. Concern has been generated at the possibility of a methane gas problems at the parksite, for which the landfill is currently used, an underground garage located 12 to 15 m to the east of the landfill, the McEwen apartments located over 30 m from the waste, and three residential houses whose back lot bounds the edge of the landfill site.

The landfill site is situated on glacial till associated with a ground moraine. The till soils are believed to be stony and silty in texture, underlain by bedrock and locally veneered with marine sands and silts. The original land was agricultural and sloped from the south to the north. The groundwater levels are believed to coincide with the base of the garbage.

The McGee Farm Landfill spans approximately 3.6 ha and was operational for over two years, beginning in April 1957 and terminating in January 1959. Wastes consisted of some earth or construction rubble and domestic and industrial wastes. The landfill, which is currently being used as parkland, is estimated to have wastes located 1.5 to 3.0 m below surface bounding residential houses to the west.

Since the consulting firm was simply contracted to determine the presence and probability of a methane gas problem, no solutions have yet been installed. However, a set of recommendations to deal with any potential methane problem was drafted. Even though significant gas migration through the subsoils does not appear likely, permanent gas monitors were recommended for placement near developed areas surrounding the landfill (parking garage and residential houses).

**REFERENCE:**

Gartner Lee Associates, 1980. Methane Gas Migration and Impact Study Report Landfill Site Identification Phase, City of Ottawa for the Corporation of the City of Ottawa.

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #45**

**BUILDING TYPE AND LOCATION:** Shopping plaza, residential houses, school and church, Pinecrest Landfill Site, Ottawa, Ontario

**GAS TYPE:** Methane

**SOURCE:** Landfill site

**TYPE OF CONTROL USED:** Active venting

**CASE STUDY PRÉCIS:**

The Pinecrest Landfill Site has been studied for its methane gas problem and its proximity to developed areas in the Ottawa region. The sandy soil type presents the possibility for methane gas migration to developed areas via cracks in foundation walls and/or underground services.

A consulting firm (Gartner Lee Associates, 1980) was contracted to determine the extent of a methane gas entry problem associated with selected landfill sites in Ottawa in the spring of 1980. Its method of investigation consisted of three parts. The preliminary site identification consisted of identifying the area of study based on document research. The specific site identification focused on the study of aerial photographs to further narrow the study area. Field confirmation included field reconnaissance and the development of random shallow auger holes around the site in question.

Methane gas was discovered at a concentration of 10 percent at a water valve and 1 percent in a hand auger hole. Taking into account the soil type (sandy sub-soil), some concern has been expressed about the possibility of lateral gas migration into the developed portions surrounding the landfill site, especially via cracks in foundation walls and/or underground services.

The Pinecrest Landfill Site spans over 4 ha with its northern boundary located behind a church and a few houses on Watson Street and Pinecrest Road and its southern boundary located at the entrance ramp for the Queensway West. The majority of the landfill is presently used as park land, specifically as a soccer field.

The landfill itself is situated on the side of a sandy-soiled valley which extends east and northerly toward the Ottawa River. The garbage was placed on the north slope of the valley wall and over organic fill. Fill depths are estimated at

4.6 to 6.1 m, and groundwater levels are believed to be located at or below the base of the garbage.

The landfill was fully operational for approximately three and a half years beginning in November 1953 and terminating in May 1957. The wastes were primarily solid domestic wastes with reports of commercial and industrial waste disposal. However, no records of liquid or toxic wastes were discovered for this site.

Since the consultant was simply contracted to determine the presence and probability of a methane gas problem, no solutions were implemented in the first phase of work. However, a set of recommendations to deal with any potential methane problem was drafted. Permanent gas monitors were recommended for placement near developed areas surrounding the landfill (shopping plaza, church, residential homes, and the school). Underground services were recommended to be checked for gas. Sub-surface drilling should be undertaken to determine the extent of the wastes at the north end of the site. Future building proposals should be stalled until confirmation of the presence of methane has been received, after which venting systems should be installed.

**Further Investigations**

As part of the followup investigations, eleven permanent monitors were installed between the landfill and locally developed areas. Based on the monitoring results conducted between December, 1980 and June, 1981, methane was detected almost on every visit at four monitors. Three of these four monitors were less than 9 m from adjacent homes. Measured concentrations varied from 1 percent to 35 percent methane-in-air but in most cases exceeded the 5 percent lower explosive limit.

The insides of the homes and other buildings around the site were checked for methane in late September, 1980. No combustible gases were detected. Underground service outlets outside the homes also had combustible gas testing four times from late September, 1980 until late November, 1980. During those surveys, methane in excess of 5 percent was always detected in two water works chambers at a local intersection. No other services had combustible gases (Gartner Lee Associates, 1982).

In view of the presence of methane at the monitoring stations and the permeable nature of the fill, there was a possibility that gas could exist next to the buildings. As a result, it was concluded that methane gas could pose a hazard at the above mentioned buildings.

Two courses of action to deal with methane around the above-noted buildings were considered. One course of action was to continue testing these buildings and the monitor for gas. If methane gas was detected in or around a building at a concentration which is considered dangerous (e.g. more than 4 percent by volume), then remedial measures could be designed and installed. It was recognized that there was an inherent risk with this approach. A problem could develop at a location or at a time not monitored, and thus not be detected. Likewise continuous alarm monitoring systems was not considered effective. (No rationale was given.)

The second alternative, an active venting system, eliminated all risk of methane related problems. Further investigations would be required to provide input for the design of this system. The consultant (Gartner Lee Associates, 1982) recommended the second approach.

**Methodology**

The field work was initiated in December 1984 (Gartner Lee Associates, 1986). A truck-mounted drill rig was employed to bore three holes around the nearby church. Gas monitors were installed and measurements of combustible gas were made. Further drilling was subsequently carried out to assist in the definition of the gasifier properties in the residential and church areas. In the residential area, on pumping well and two monitoring wells were installed. The installations at the church consisted of two pumping wells, and one monitoring well.

The first gas pumping test was carried out at the church. A centrifugal fan capable of removing 142 L/s of air in free air was used for testing. The actual test was conducted for 180 minutes at a flow rate of 20 L/s. The test was repeated at the other pumping well. Poor response was observed in both tests. The same equipment was connected to the pumping well in the residential area. Five monitoring wells were used for this test. The test was conducted for 360 minutes at a flow rate of 17 L/s.

On completion of the field work the test results were evaluated. In view of the small negative pressures recorded in many of the observation wells, there were concerns related to the validity and interpretation of the test results.

In June 1985, two new pumping wells were constructed at the church and in the residential area. The pumping wells were placed in such a manner so as to reduce the distance to the nearest monitoring well. As well, the packing around the well screen was changed form silica sand to 20 mm crushed stone as a means of improving the efficiency of gas flow into the well.

A gas pumping test was carried out at the church and the residential area using the centrifugal fan rated at 142 L/s. The test at the church was conducted for 100 minutes and in the residential area for 210 minutes. The flow rate was 17 L/s for both tests. Samples of the soil were collected before and after testing for analysis of methane concentration.

**Recommendations**

The data was analyzed in a similar fashion as described in Case Study #28 (i.e. the Cooper-Jacob approximation). Although the data were not entirely consistent, certain trends were inferred. Based on the trends, the cone of influence was believed to extend up to 15 m from the pumping well. The negative pressure exerted at a distance of 15 m amounted to approximately 10 Pa.

In recommending a solution for the City of Ottawa, the consultants ultimately suggested a maximum well spacing of 25 m. Within the church area, the wells were to be located in a ring around the outside of the building. Wells within the residential area were to be laid out in a grid. In addition, one line of wells was recommended for placement near the northern edge of the refuse. All wells would be connected to a common header. Subsequent to this investigation, a system was installed.

**REFERENCES:**

Gartner Lee Associates, 1980. Methane Gas Migration and Impact Study Report Landfill Site Identification Phase, City of Ottawa for the Corporation of the City of Ottawa.

Gartner Lee Associates, 1982. Detailed Methane Gas Migration Study Closed Landfill Sites 1,3,5 and 10 for the Corporation of the City of Ottawa.

Gartner Lee Associates, 1986. Methane Gas Control Study Pinecrest/Dr Maurier Landfill Site for the Corporation of the City of Ottawa.

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #46**

**BUILDING TYPE AND LOCATION:** Townhouses, Kitchener

**GAS TYPE:** Landfill gases

**SOURCE:** Buried refuse

**TYPE OF CONTROL:** Sub-slab venting

**CASE STUDY PRÉCIS:**

A group of 81 townhouses was constructed on a site that previously had been used for the purposes of landfilling. The site is relatively level with the exception of a large mound adjacent to this property where the main landfilling activity had occurred. The adjacent landfill was closed in 1975. The group of townhouses is situated on 14 blocks with four to twelve housing units on each block. The attached figures shows the layout of the site. The homes are all two-storey structures with full basements, containing natural gas-fired water heaters and forced air furnaces.

At the time of construction of the units, methane problems were expected to exist because of the presence of buried refuse. Therefore, as part of the building permit, the City of Kitchener Building Department required the developer to install passive venting systems on each housing block as well as remove any onsite refuse from beneath the foundations of the houses. The passive venting systems consisted of a 150 mm perforated plastic big "O" pipe laid next to the building foundations which were connected in 100 mm risers at the end of each housing block. However, despite these mitigative measures, elevated levels of methane were recorded. The elevated readings and localized odours initiated the evacuation of 15 families in 1976 and further evacuations thereafter. Canada Mortgage and Housing Corporation (CMHC) inherited the problem due to defaulting mortgages. No occupants are in the homes at this time.

Further to the mitigative measures at each townhouse block, methane collection systems were also installed on the landfill/townhouse property border. The methane collection systems were intended to control migration of methane from the old landfill site. Two different systems were installed. The first one was installed in the mid-1970s. It proved ineffective due to flooding conditions. Consequently, a second system was installed in 1978. A further addition was also constructed in the playground on the property. This system, known as the "playground system", was connected to the two existing perimeter collection systems. However, despite these systems, the presence of potentially hazardous levels of combustible gas was still found in and around several of the townhouse units.

As a result of these problems, several engineering studies were completed to resolve the issues at the site. Conclusions drawn from these studies indicated methane which plagued the townhouses was primarily migrating from the refuse present on the site.

A relatively low water table, permeable native soils, as well as significant soil gas concentrations made gas migration into basements possible. In order to rectify this problem, a consulting firm recommended the removal of all or part of the refuse and the installation of a perimeter gas collection system. However in arriving at this conclusion, no consideration was given to technologies such as increasing the resistance of the basements to the entry of soil gas or soil ventilation processes. Costs for remediation were estimated at approximately $1 million.

CMHC then initiated its own study to evaluate the feasibility of active sub-slab soil gas venting. The study was conducted in two phases. The first phase conducted in early 1989 evaluated the use of this technology. The second phase of the study in 1990, evaluated the technology for the entire site.

Upon initiation of the first phase, baseline methane concentrations were measured in early spring when frozen ground conditions effectively trap soil gases and increase the concentration in basements. Measurements were conducted with the use of spot and continuous monitoring in a group of townhouses where previously elevated readings were recorded and where the concentration variations were well-known over time. One housing block registered consistently high concentration; another block had medium methane concentration levels; and the third block was used as a control block. The readings obtained in the above units generally compared well with previous historical records with the exception of a few units.

The intention of the study was to apply active soil gas ventilation on the selected group of townhouses. Active soil gas ventilation has proven successful in mitigating radon entry into houses by as much as 99 percent. By pumping the gases out of the already existing passive vent pipes, this technology could be implemented. Testing was first conducted to evaluate the condition of the passive venting system. Unfortunately, testing revealed that major blockages existed in both selected candidate blocks. After several attempts to clear the vents, excavation was deemed necessary. On one block, subsurface conditions revealed generally wet sandy soils which are poor for soil gas transmission. The vent/riser pipes at this block were discovered to the generally poorly fitted; infilling of silt at the connections was common. The system was repaired and the trench was backfilled. At the other block, excavation was also necessary. Trenching exercises revealed wet silty geologic materials, which are poor for gas transmission. It was also discovered that an incomplete venting system existed. By pumping the remainder of the system, poor performance was achieved. As such, an alternative design was required.

A series of shallow soil gas extraction wells were installed in the basements of each unit. Both active soil ventilation systems were then pumped while methane concentrations and pressures across the basement floors were recorded.

Where pumping was initiated on the block where high concentrations were recorded, good depressurization of soil gases, as well as a significant drop in methane concentrations, were observed. Further declines were observed with the installation of additional soil gas extraction wells in one of the units (Unit 71) where previously excessive and explosive concentrations were documented. Figure B-39 shows continuous monitoring results in Unit 71). In general, favourable results were obtained.

In the block where medium concentration levels were previously recorded, a perimeter system was implemented; less favourable results were obtained. With low initial concentrations, only marginal declines in methane concentrations were realized.

Additional testing was also performed on the flue gases emitted from the fan discharges. Gases were sampled and analyzed for volatile organic compounds and carbon monoxide. Of these gases, only one compound exceeded a new permissible point of impingement concentration of vinyl chloride. One stack vent showed a concentration of 2.15 $\mu g/m^3$ which exceeds the provincial criteria of 1.0 $\mu g/m^3$.

As part of the investigation, tracer tests were conducted in order to better understand how the airflow in the units was behaving. Sulphur hexafluoride was injected into the basement air with the sub-slab ventilation system operating. Injections took place in two different units, Units 34 and 36. Figure B-39 shows the concentration of SF6 in the exhaust gas from each of these units. Based on these results, it was apparent that air inside the basement was being drawn down through the floor and out of the exhaust. This would suggest even if methane collected in the building, it would likely be drawn down through the floor. Another high concentration of SF6 was also injected below the sub-floor in Unit 48. The purpose of this injection was to determine if hazardous gases which are present in the subsurface could have an impact on indoor air. The exhaust gases from the sub-floor as well as the indoor air was tested for SF6. Based on the results (as shown on Figure B-39), the SF6 was flushed out from beneath the sub-floor and none appeared in the basement ambient air.

During the 1990 monitoring program, active sub-slab venting was initiated for a period of one month on one third of the units. A typical schematic of the sub-slab soil gas extraction system as implemented at the townhouses is shown on

Figure B-40. Methane spot checks were performed on each unit to evaluate ambient indoor and sub-slab methane concentrations. Permeability testing was performed on each unit. Exhaust gases were sampled and analyzed for volatile organic compounds. Soil probes in the surrounding lawns were also measured for pressure and methane. Energy consumption in the units was monitored.

Essentially three different conditions existed across the site. One area was documented as having consistently high levels of methane intrusion; another area close to the boundary of a closed landfill site had fluctuating methane levels. The majority of houses, however, had low methane readings typical of background levels.

Sub-slab venting was applied as a mitigative measure. Indoor methane levels were maintained close to background levels even when soil gas concentrations around the basements were very high. Analyses from the exhaust gases indicated that contaminants present in the air stream were primarily present due to the piping used for venting. No provincial emission criteria was exceeded in 1990. Analyses from the energy consumption data indicated that sub-slab venting did not noticeably increase heating requirements.

Despite the technical success of this technology, several legal or jurisdictional approvals are still required. Presently, both municipal approval for reoccupation of the homes and Ministry of the Environment Certificate of Approval (Air) have not been given. Negotiations on the extent of necessary monitoring has not been conclusive.

Note: Each graph has a different scale

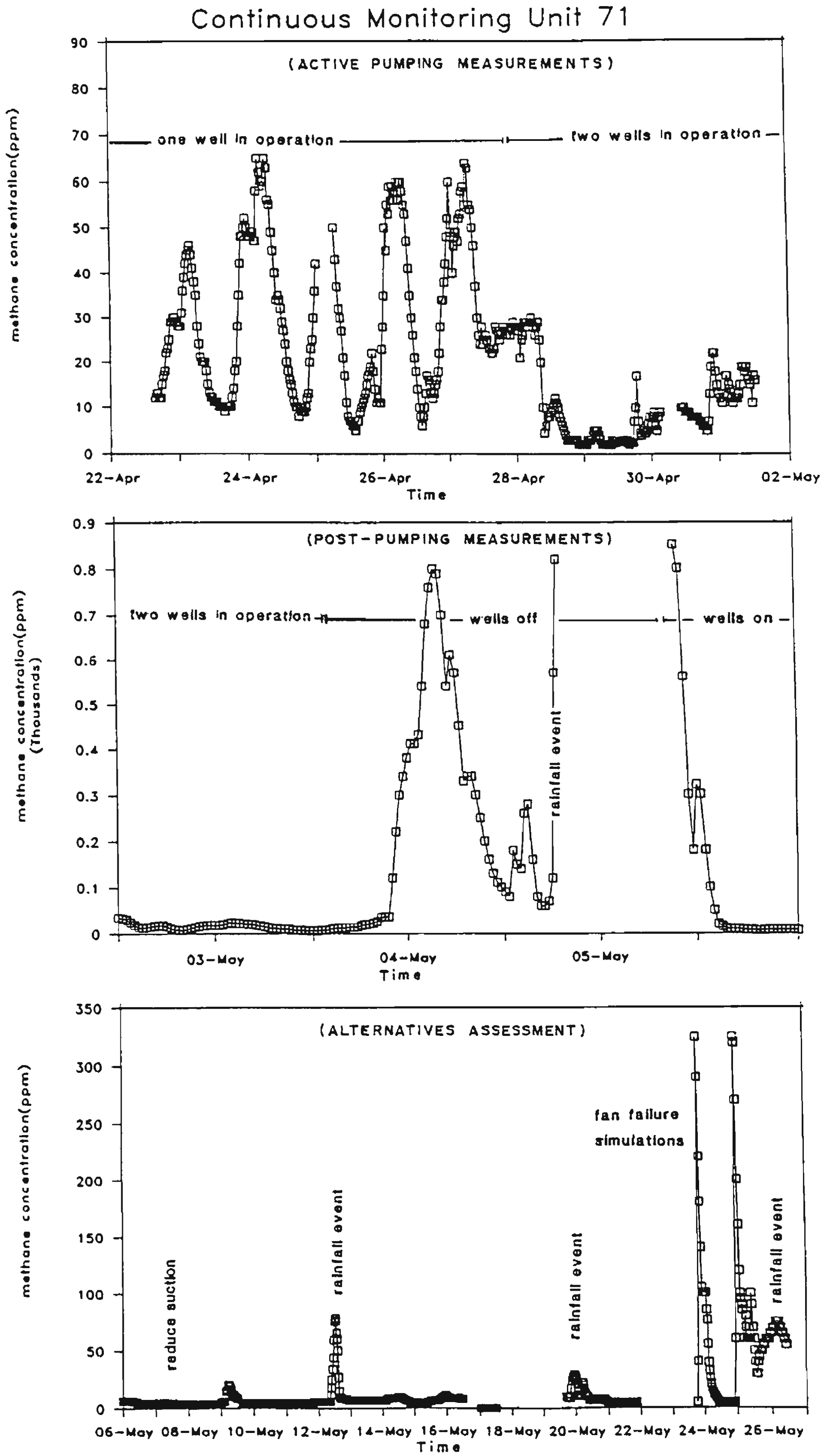


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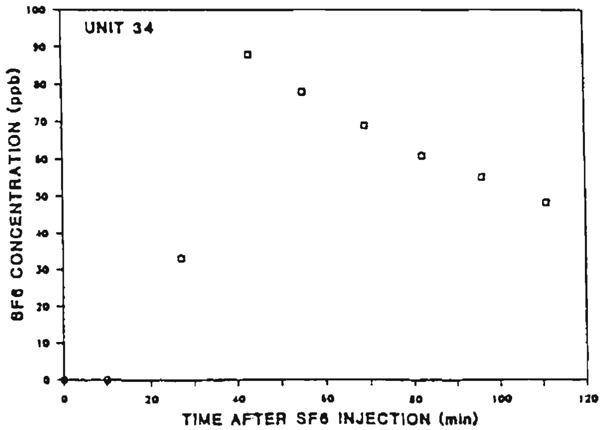
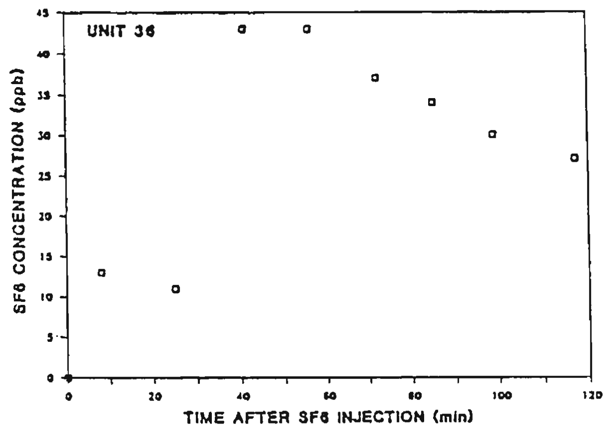
**FIGURE B-38:**

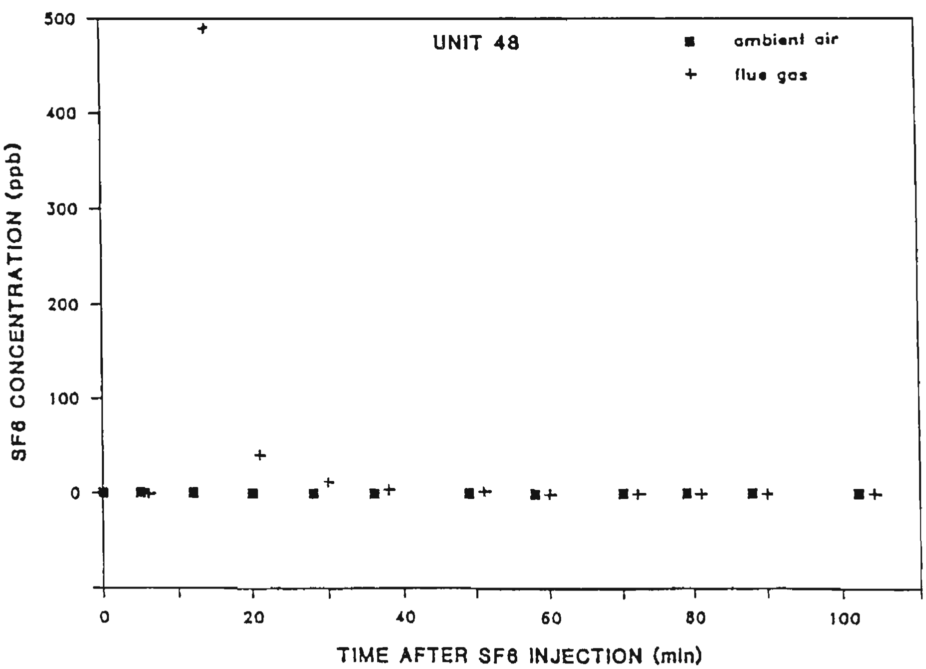
**METHANE CONCENTRATIONS IN UNIT #71 FROM APRIL 22 TO MAY 26**

## SF6 CONCENTRATION SUB-SLAB SPACE AFTER INJECTION




## SF6 CONCENTRATION IN AMBIENT AIR AND FLUE GAS

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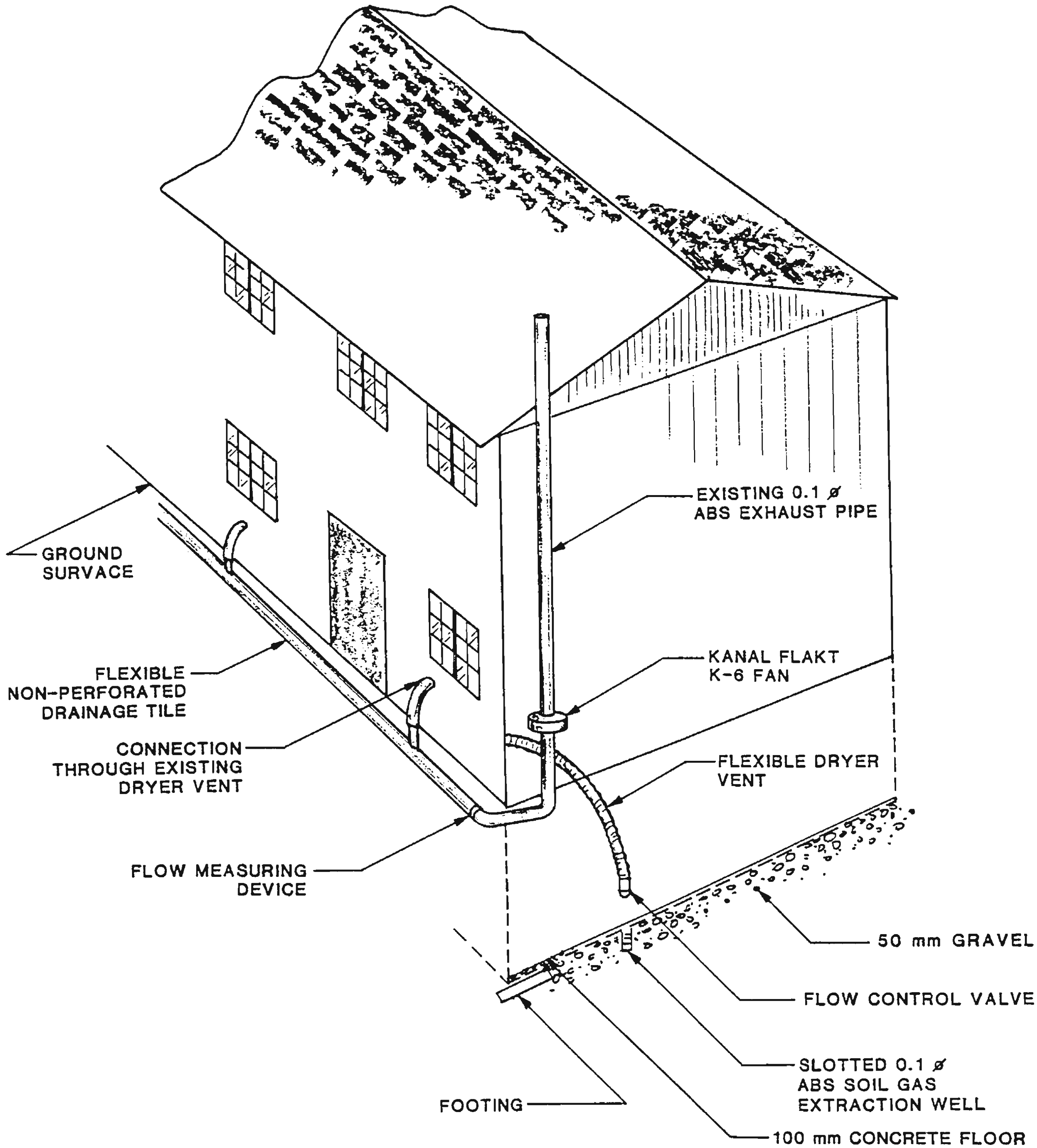
| CH2M HILL ENGINEERING LTD.<br>WATERLOO ONTARIO | **FIGURE B-39: SF6 INJECTIONS** |
| PROJECT No. ONT29396.AO | |

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| CH2M HILL ENGINEERING LTD.<br>WATERLOO ONTARIO<br>PROJECT No. ONT29396.AO | **FIGURE B-40:**<br>**TYPICAL SCHEMATIC OF SUB-SLAB SOIL GAS EXTRACTION SYSTEM AS IMPLEMENTED AT THE STRASBURG ROAD TOWNHOUSES** |

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #47**

**BUILDING TYPE AND LOCATION:** Residential dwellings, St. Catharines

**GAS TYPE:** Sulphur compounds, VOCs

**SOURCE:** Trunk sewer

**TYPE OF CONTROL:** Construct new sewer

**CASE STUDY PRÉCIS:**

The Glenridge Quarry Landfill has had significant problems over an extended period of time. Apart from the many environmental concerns that were experienced at the site, leachate spills into the nearby sewers have caused problems for the indoor air quality of nearby residents. Although a soil gas problem has not been specifically reported, some evidence suggests that soil gas influx may be a problem.

The leachate spills that have affected local residents on many occasions erupt like geysers from nearby manholes. On one occasion, leachate rose through a toilet and a roof stack vent that overflowed onto the roof.

In another spill incident, leachate was found bubbling up in a large flower bed of a home. Following this incident, there was a further back-up of leachate causing leachate to flood the basement of a home.

In July 1987, noxious gases from the dump suffused the area below the escarpment. Methane gas readings in the sewer systems in a resident's front yard were just below the explosive level. This occurred many times during the autumn months. Each time this occurred, the City Engineer's Department flushed the sewers.

In August 1987, leachate gases filled the home of several other residents. The residents were forced to be awake all night while city crews worked on the problem. Because gases still filled the houses and the outside air was saturated in the morning, residents were ill.

Later in December 1987, leachate gases entered and re-entered several homes in an unpredictable fashion. By late December, gases indoors were so concentrated that several residents spent the night in a hotel. Many residents suffered from nausea, vomiting, light-headedness, stinging eyes, and an overwhelming sense of lethargy. The health of several residents has allegedly been severely affected over the past few years.

Based on hydrogeology reports from the area, it is apparent significant quantities of several VOCs appear in the leachate from the landfill site.

**SOURCE:**

City of St. Catharines, Glenridge Quarry Landfill Site, Discussion Document: Issues and Actions, February 1990.

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #48**

| | |
|---|---|
| **BUILDING TYPE AND LOCATION:** | Residential, industrial and commercial region, Cambridge |
| **GAS TYPE:** | Methane |
| **SOURCE:** | Landfill site |
| **TYPE OF CONTROL:** | Passive venting system and short-term monitoring |

## CASE STUDY PRÉCIS:

The Newton Landfill site has been the subject of a number of investigations for both leachate contamination and methane migration. The landfill itself, was operational between 1968 and 1973. Municipal records revealed that the site was landfilled with a myriad of chemical products:

- soluble cleaning and cooling oil
- waste motor oils
- tolylene diisocyanate
- sludge from sewage treatment plant digester
- various unidentified chemicals

As a result of leachate coming from the site, a leachate collection system was installed along the north and west slopes of the landfill in 1977. The leachate collection system consisted of a drainage channel which intersected the groundwater table, thereby diverting any leachate into the local sanitary sewer (refer to Figure B-41).

### Site Characteristics

The landfill site and surrounding areas are located on kame deposits (brown silty fine to coarse sand) in the Waterloo Hills region. The area is a composite of sand deposits and swampy valleys with 15 m to 50 m of overburden. The overburden layer consists of ice contact deposits (silt, sand, gravel) till, outwash deposits, and lake deposits.

The landfill, from top to bottom, is underlain by approximately 6 m of sand, 2 m of gravel, a dense silty sand and gravel till, coarse sand and boulders, and bedrock. A confined aquifer surrounded by low permeability till underlies the landfill site. The aquifer is the source of two municipal water supply wells. Landfill topography displays a 5.5 m decrease from east to west, spanning a total length of 270 m.

The landfill contains approximately 5.5 m of refuse overlain by 0.2 m to 0.6 m of cover material consisting of fine-grained sand.

**Initial Investigations**

The first investigation, completed in 1977, indicated that the site had substantial gas production. Consequently, a further study was commissioned in 1979 by the City of Cambridge. A consultant (Heath, 1979) conducted the study. The objectives of this study included:

- to conduct a shallow probe soil atmosphere test on and around the landfill
- to conduct soil borings to determine the stratigraphy
- to conduct interior investigations of several adjacent enclosed structures
- to assess the site in terms of development

Field activities which were undertaken included the soil atmosphere test, interior building investigations, and the borehole tests. Instruments used in the soil atmosphere test were the standard Health plunger bar and a Davis D-15 gas tester. The plunger bar is a manual impact tool capable of producing a sample hole in the soil up to one metre in depth. The gas tester measured gases in both the % explosive and % gas ranges. Investigations inside buildings used a flame ionization detector (the Heath Detecto-Pak II®). Measurements were taken at floor cracks, wall cracks, floor drains, and other utility conduits. Borehole tests were carried out with a truck-mounted auger drill using a 7.6 cm diameter solid-stem auger. Drilling locations were chosen after soil atmosphere tests were completed.

Soil atmosphere tests revealed that although the site was still very active, there appeared to be little migration to the north and east of the site. Readings on the site ranged to a maximum of 50% GAS; very significant values were also observed offsite to the west up to 75% GAS. Visual and boring evidence indicated that the area west of the site was a former marsh. It was viewed unlikely that gas in the area was a result of the landfill because of the locally high water table.

Methane was also tested during the placement of boreholes. Readings obtained during the drilling program in the former swamp area were as high as 20% GAS. North of the landfill, a reading of 4% LEL was obtained. The consultants indicated that low methane levels may have occurred due to the lack of a frozen soil surface.

The interior building inspection at the time was carried out at six businesses along Highway 24. Four of the buildings were found to have positive readings. The highest reading was 5% LEL at a floor crack.

Recommendations and conclusions were supplied by the consultant. Based on the results, no landfill problems would be encountered in developing the land north and east of the site. It was also recommended that no enclosed structures or hard surfaces be permitted south of the drainage channel and towards Highway 24. If the swamp area north of the site was filled, then appropriate mitigative measures should be included. Recommendations for the area west of the site included a regular weekly monitoring program during the months of December to April when the frost cover was in place. Recommendations for immediate controls on some of the adjacent businesses was also given.

**Subsequent Investigation**

In mid-1988, a monitoring and drilling program was conducted to collect groundwater, surface water, soil, and air samples. Permanent gas monitors consisting of a slotted 2.5 cm diameter PVC pipe were installed at each borehole.

The sampling program for soil gas consisted of recording methane concentrations with a portable TLV sniffer calibrated to hexane. Conversion to methane was accomplished by using a multiplying factor of 1.58. The meter was capable of detecting methane gas up to 31% LEL. A total of forty-seven measurements were taken between July 20, 1988 and July 28, 1988.

Methane was detected from 0.9 percent to hazardous levels exceeding 30 percent of the lower explosive limit. High methane concentrations were particularly evident south of the landfill in the residential area. A summary of the methane gas readings is summarized on Figure B-42. As a result, the situation has been recognized as a potential health hazard.

**Post Construction Test Results**

A passive venting system was installed between the southern boundary of the landfill and the houses affected by methane infiltration. Monitoring conducted during the winter revealed that methane migration decreased in severity in the north, south, and western boundaries. As such, it was determined that methane does not represent a problem to existing structures in these areas.

Recommendations proposed by the consulting firm (M.M. Dillon, 1989) suggested future monitoring to focus on the southern boundary of the landfill to determine the efficiency of the passive venting system. Methane alarms were also recommended for installation in the basements of homes adjacent to the landfill. As well, the west edge was identified to necessitate an engineered system to mitigate offsite migration of leachate in the shallow groundwater.

**REFERENCES:**

Heath Consultants, 1979. Investigation of Dunbar Road Industrial Site for the Corporation of the City of Cambridge.

M.M. Dillon, 1989. Investigation and Monitoring, Newton Landfill Site, Cambridge. Report prepared for MOE Waste Management Branch.

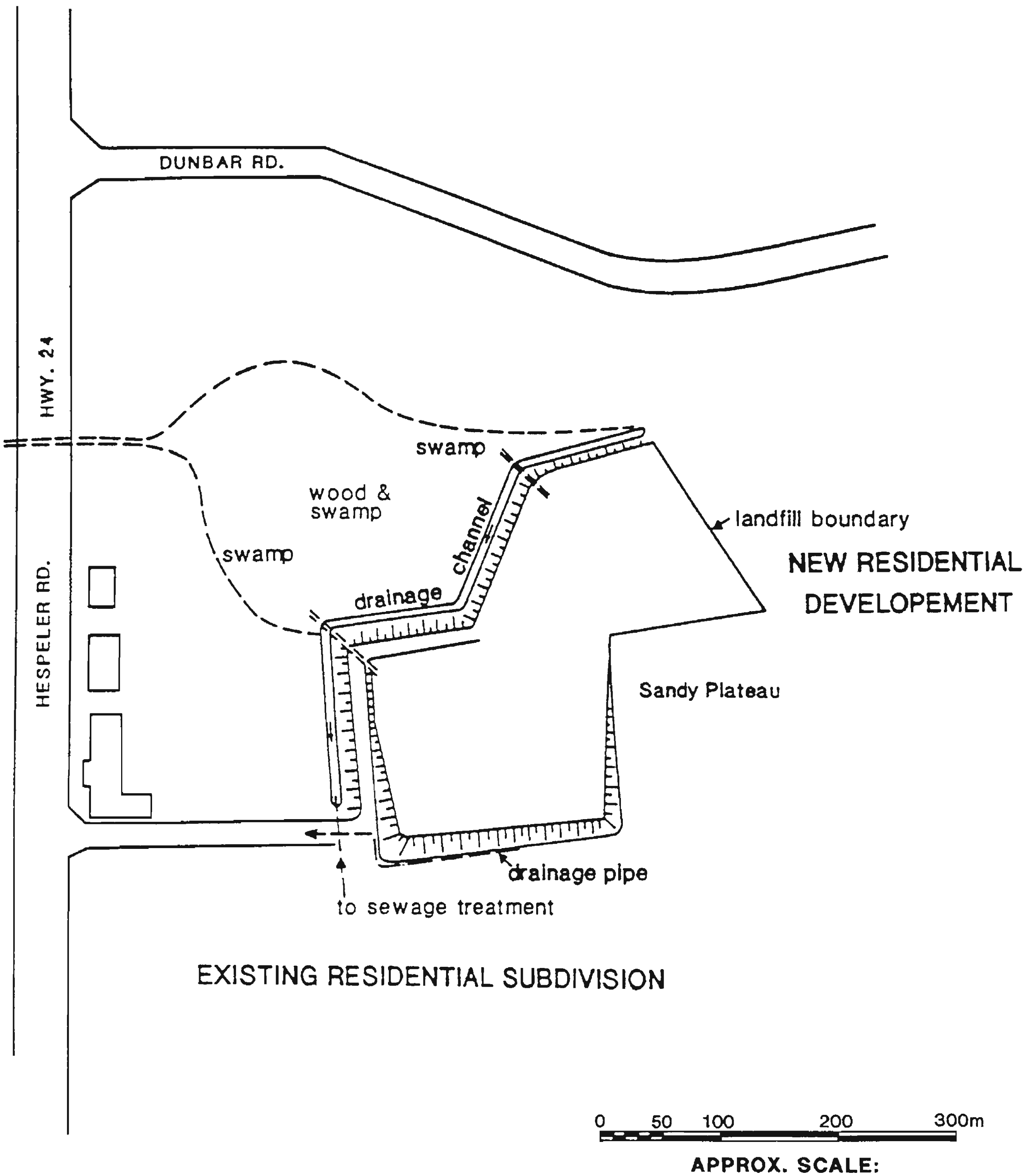


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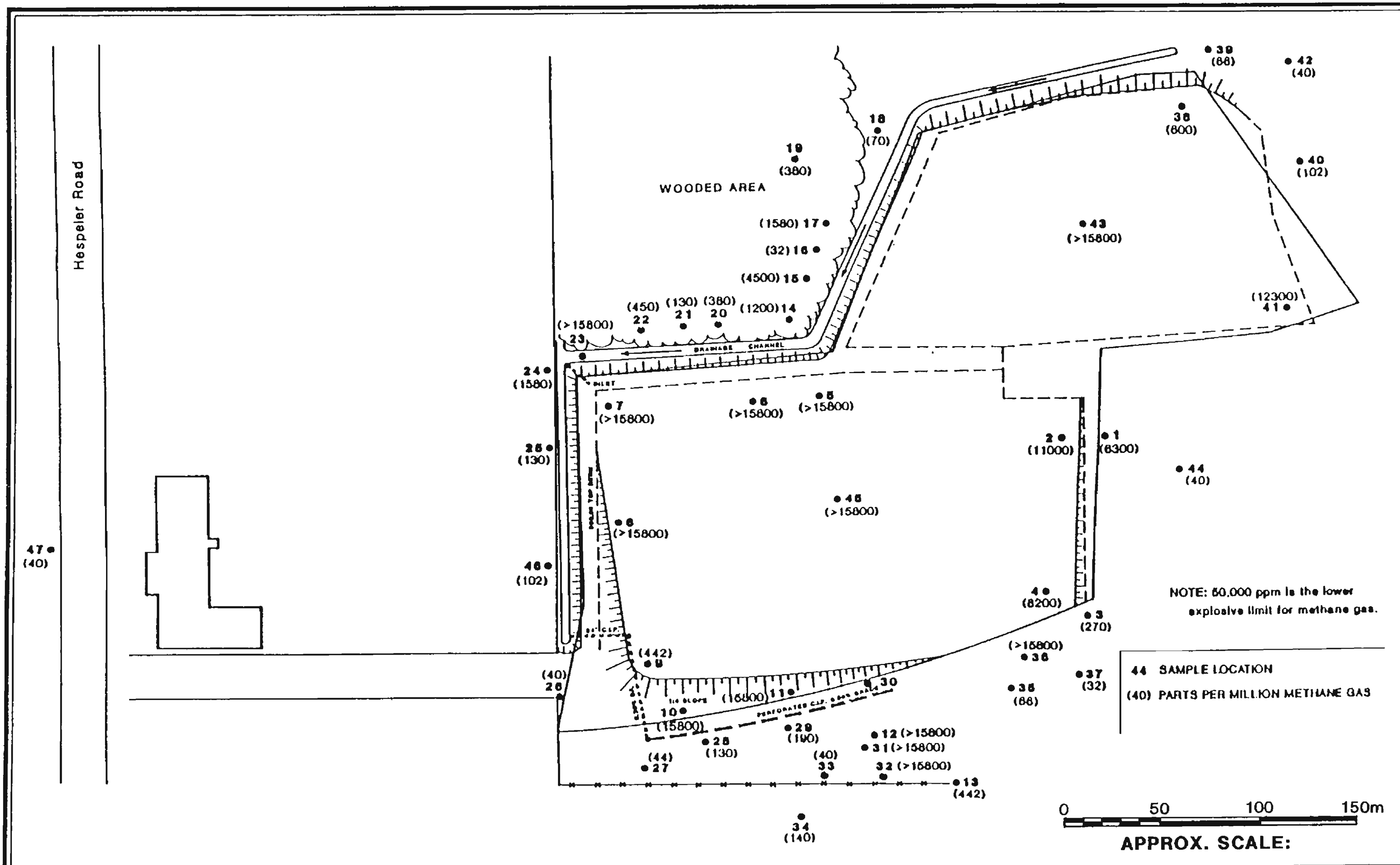
**FIGURE B–41: NEWTON LANDFILL SITE**

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## FIGURE B-42: NEWTON LANDFILL SITE

## METHANE GAS READING LOCATIONS

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #49**

| | |
|---|---|
| **BUILDING AND TYPE LOCATION:** | Single family dwellings and an apartment building, Winnipeg |
| **GAS TYPE:** | Gasoline vapours |
| **SOURCE:** | Gasoline spill |
| **TYPE OF CONTROL:** | Soil vapour extraction |

**CASE STUDY PRÉCIS:**

Following the subsurface release of gasoline from a Winnipeg gasoline station, residents in a nearby apartment building complained of hydrocarbon vapours in their apartments. Manitoba Environment investigated the problem. Residents in suites 4, 6, 12, and 18 of 84 Regal Avenue were evacuated on November 26, 1986. Following the evacuation, an environmental consultant (O'Connor Associates) was contacted to further investigate the problem.

According to information provided by Manitoba Environment personnel, gasoline seeped from the underground storage tanks located on the Shell Service Station property to the east of the apartment building. The tanks were removed on December 2, 1986.

The St. Anne's Shell Service Station is located on the southern corner of Regal Street and St. Anne's Road. A three storey apartment building is situated on the southwest corner of the intersection separated by a lane behind the service station. Several single family homes are located on the north side of Regal Avenue. The ground surface is generally flat, but regionally the ground surface slopes west toward the Red River (approximately 0.5 km from the service station). The site plan is shown on Figure B-43.

Initially, the environmental consultant monitored vapours in the apartment building and in the subsurface, and estimated the pure product that was present. Based on those results, four boreholes were drilled on the Shell property, five boreholes were drilled on the apartment property, and eight boreholes were drilled in the laneway between the properties. Standpipe piezometers were installed in each borehole for the purpose of groundwater monitoring and determining vapour concentrations.

According to the borehole information, the natural soil profile in the vicinity of the site generally consisted of a black silty clay overlying a layer of light brown silt deposited on a laminated silty clay. The silt stratum appeared to be laterally discontinuous under the site and often contained perched groundwater. White gypsum veins occurred randomly throughout the upper portion of the olive brown, laminated clay. The silt layer between the clays was absent in the boreholes in the northern portion of the Shell site. During the excavation of a collector trench along the back lane, a siltier clay was noted. The site was entirely overlain by asphaltic pavement. Surface fill material ranging from sand to gravel were encountered below the asphalt in many of the boreholes. The attached cross section A-A (Figure B-44) illustrates the position of the silt layer in relation to the tank backfill area from which the contamination is believed to have originated. It was speculated that the product found in the boreholes and the petroleum vapours detected in the apartment building may have migrated through the more porous silt layers.

Based on the vapour measurements, which were taken outside the apartment building, vapour concentrations exceeding (100 percent LEL) were originally detected near the storage tanks on the Shell property. On one occasion, vapour concentrations exceeding 10 percent LEL were also detected east of the apartment building.

In order to alleviate the vapours in the building, several vapour control systems were implemented. Several different fan and vacuum units were connected to subsurface wells and inside the apartment building. The attached Figure B-45 displays the location of the vapour management systems. O'Connors Associates (1987) reported that when the remedial measures had been in operation for several weeks (as of January 26, 1987), vapour concentrations did into exceed 10 ppm in any of the sites.

Concurrent with the consultant's activity outside of the buildings, Manitoba Environment also measured indoor air concentrations in several of the suites. Monitoring indoors was primarily completed with the use of a photoionization detector (an HNu). However, it was not known whether calibration of the equipment was routinely completed. Additional air quality measurements were made using charcoal adsorption tubes. The adsorption tubes were then submitted to a laboratory for analysis by gas chromatography/mass spectrometry (GC/MS).

Indoor air monitoring was initiated by Manitoba Environment when complaints were received on November 26, 1986. The accompanying Table B.10 partially summarizes the concentrations that were recorded indoors by Manitoba Environment. Sampling was completed in various locations in each suite including: living rooms, bedrooms, closets, and crawl spaces. Of all the locations monitored, crawl spaces and linen closets had the highest readings. Based on the initial readings on November 26, 1986, residents of Suites 4, 6, 12, and 18 were excavated. However, by January 8, 1987, indoor vapours had declined sufficiently to allow re-entry of the occupants. Correspondence between the Ministry of Heath and Manitoba Environment confirmed that re-entry was possible.

Low vapour levels, however, were short-lived. On January 19, 1987, the apartment caretaker called to report (at 9:00 p.m.) that "bad gas odours" were coming up through the crawl space. On January 20, Manitoba Environment recommended caulking of some baseboards in Suite 6. A local contractor, "Con-Pro", was requested to complete the work. Door jams were also caulked in Suites 12, 1,8 and 4. A chart recorder was installed in Unit 6 to record variations.

By January 22, 1987, high vapour concentrations were still evident in the apartment building. By January 22, several plumbing access panels were discovered. It was felt that such panels could be a pathway for vapour migration. "Con-Pro" was contracted to seal off vapour pathways.

On January 26, 1987, some indoor measurements were still observed. Additional sampling with the use of Gastec 101L tubes (gasoline low range) was completed. Readings both inside and outside Unit 6 repeated gasoline concentrations of 0 ppm in all locations. The chart recorder was removed from 84 Regal because all suites were deemed habitable.

As part of the monitoring program, vapour concentrations were also measured using charcoal tubes. Several samples were obtained in the apartment building between February 3 and 8, 1987. The test results from Suites 6, 12, and 18 indicated that benzene, toluene, and xylene were not detected on any of the dates sampled. Further sampling by activated carbon tubes was completed by O'Connor on November 22, 1988. The sample was drawn from the crawl space. The results by GC/MS revealed the following:

| | |
|---|---|
| Benzene | $<17.2\ \mu g/m^3$ |
| Toluene | $<17.2\ \mu g/m^3$ |
| Ethylbenzene | $<17.2\ \mu g/m^3$ |
| Xylenes | $<179.3\ \mu g/m^3$ |
| Total Hydrocarbons | $2,493\ \mu g/m^3$ |

The above values were compared to the ambient air quality criteria from Regulation 308 (Ontario Environmental Protection Act). Ambient air quality criteria (Benzene = 3,000 $\mu g/m^3$, toluene = 2,000 $\mu g/m^3$, Ethylbenzene = 4,000 $\mu g/m^3$, xylene = 2,300 $\mu g/m^3$) from Ontario was used since Manitoba had not yet established ambient quality.

It should be noted, that sampling was not conducted according to barometric pressure patterns, and soil gas pressures were not monitored.

**REFERENCES:**

O'Connor Associates Environmental Inc., 1987. Investigation of Subsurface Hydrocarbon Contaminants at St. Anne's Shell submitted to Shell Canada Ltd.

Manitoba Environment, 1987. Letter summarizing gas vapour readings from 84 Regal. Addressed to O'Connor Associates.

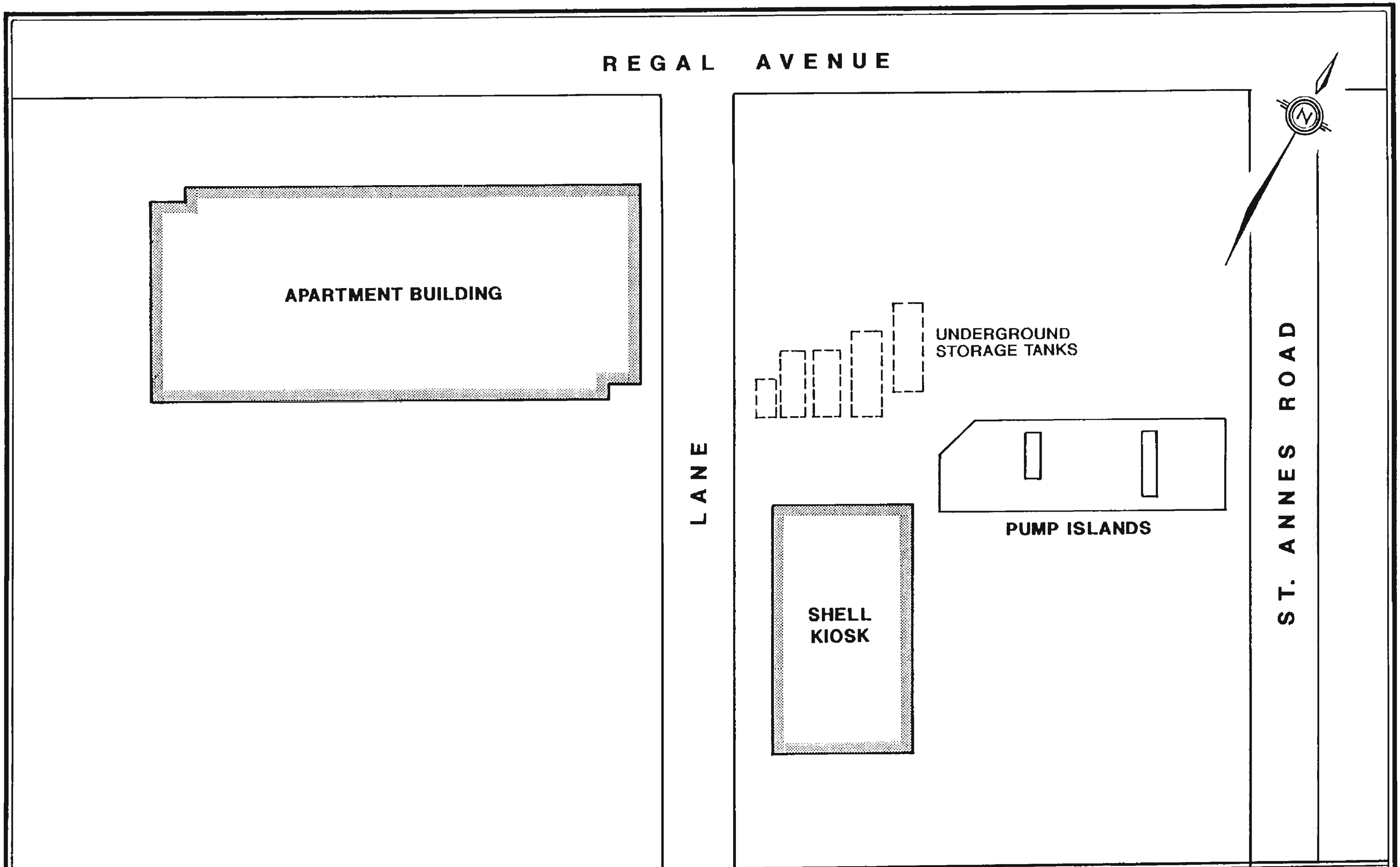


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**FIGURE B–43:**
**SITE PLAN**
**(Source: O'Connor Associates, 1987)**

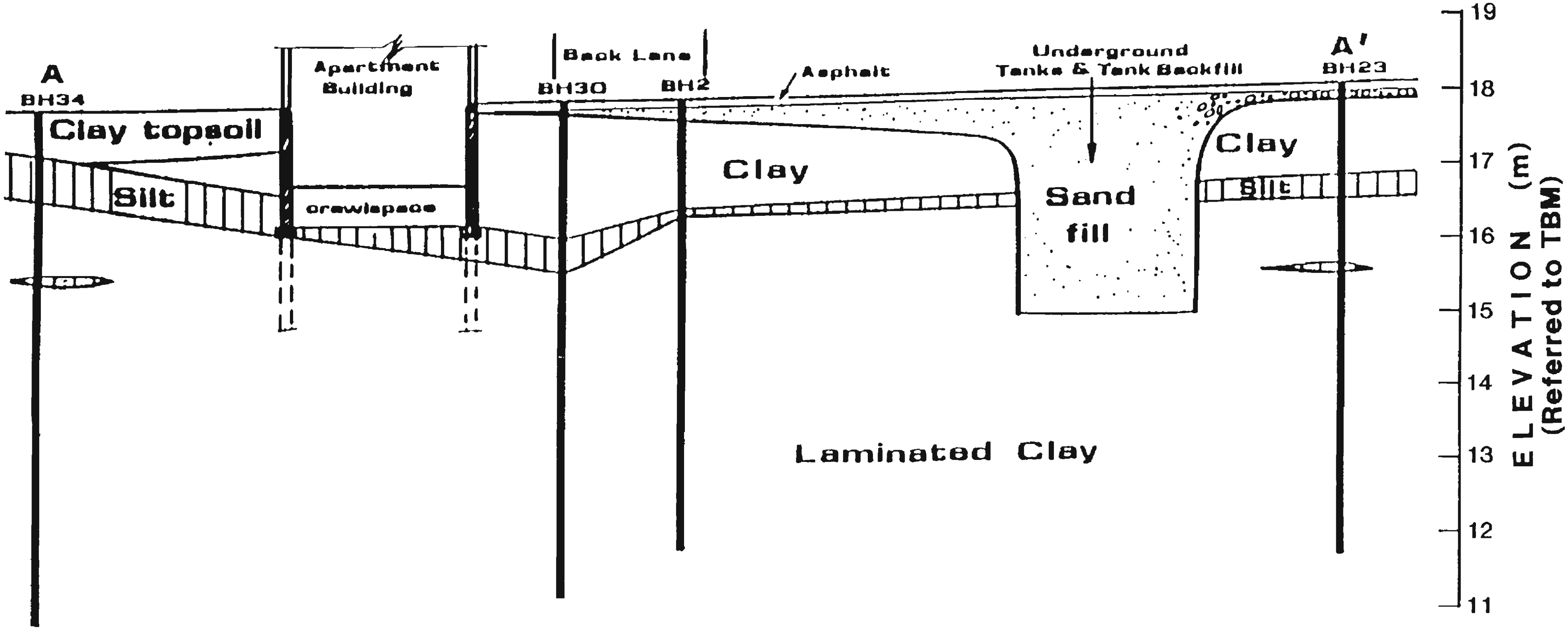


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**FIGURE B-44: CROSS-SECTION A-A' SHOWING SUBSURFACE GEOLOGY**

**(after O'Connor Associates, 1987)**

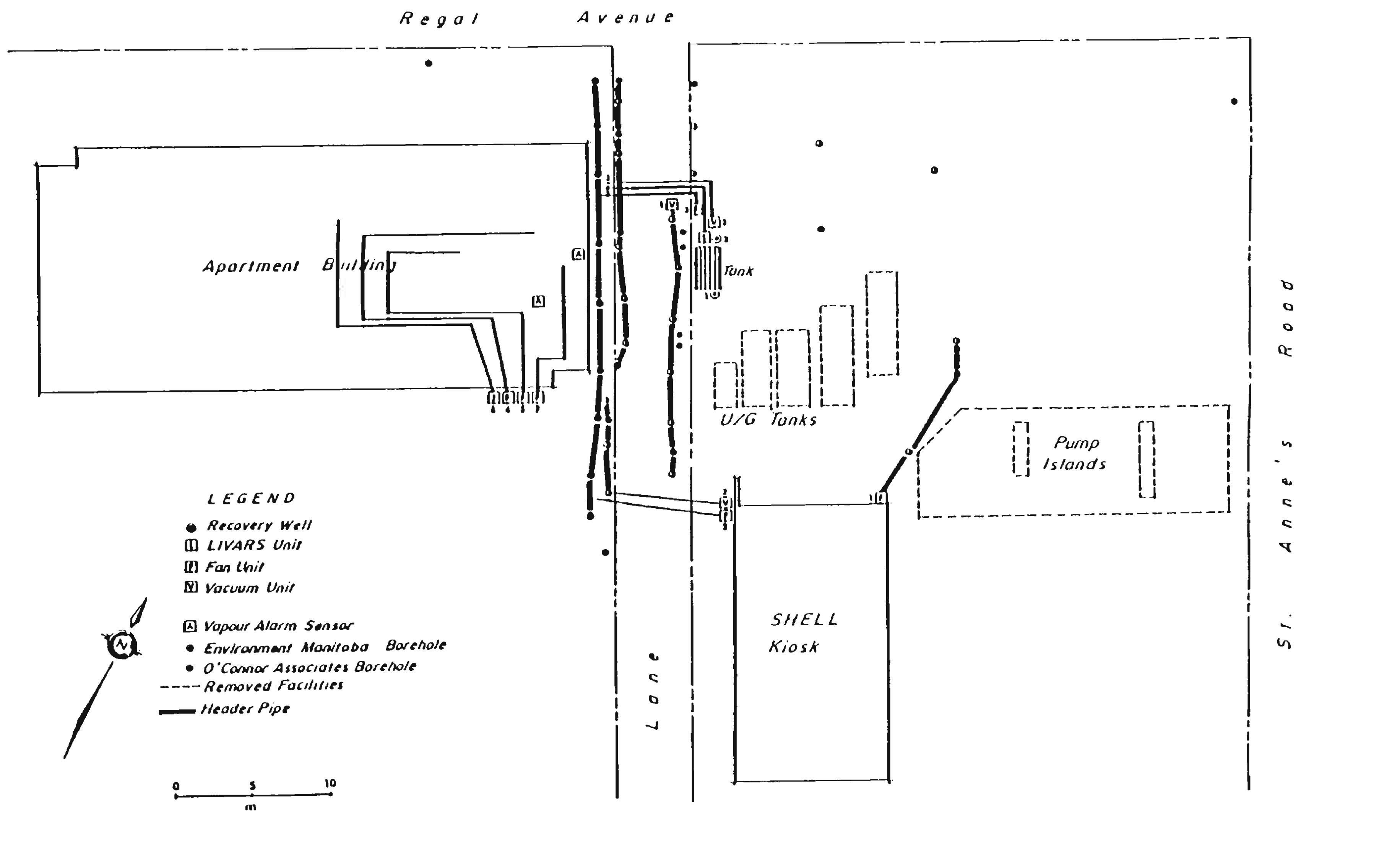


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**FIGURE B-45: LOCATION OF VAPOUR MANAGEMENT SYSTEMS (after O'Connor Associates, 1987)**

**Table B.10**
**Partial summary of Indoor Contamination as Measured by Manitoba Environment** **Page 1 of 2**

| Date | Suite #2 ppm | Suite #4 ppm | Suite #6 ppm | Suite #12 ppm | Suite #18 ppm | Locker #1 ppm |
|---|---|---|---|---|---|---|
| 86/11/26 | | 30 | 50-60 | | | 30 |
| 86/12/04 | 115 | | 7-80 | | | 140 |
| 86/12/04 | 30-500 | | 50-100 | | | |
| 86/12/05 | 5-400 | | 60-400 | | 60 | 250-400 |
| 86/12/08 | | | 22-40 | | | 170-195 |
| 86/12/08 | | | 7-60 | | | 200-700 |
| 86/12/10 | 5-100 | | 38-60 | | 45-50 | 70 |
| 86/12/11 | 15 | 14-35 | 35-80 | | 30-50 | 75 |
| 86/12/12 | 4-30 | | 35-50 | | 35-48 | 20-40 |
| 86/12/12 | 4-170 | | 25-30 | 17-20 | 35-40 | 18 |
| 86/12/15 | 4 | | 30-50 | | 38-40 | 2.5 |
| 86/12/15 | 40 | 7-20 | 15-75 | | 8.5-19 | 3.0 |
| 86/12/16 | 7 | 2 | 2.5-50 | 2.5 | 1.5-7.0 | |
| 86/12/18 | 2.2-60 | 1.0 | 4.6-46 | 2.0-3.0 | 5-15 | 1.6 |
| 86/12/22 | 2.0-3.8 | | 4.8-48 | 1.2-1.6 | 2.0-6.0 | 1.3 |
| 86/12/23 | 4.0-15.0 | | 12-118 | 6.0-16 | 10.5-38.0 | 2.2 |
| 86/12/24 | 1.8-7.0 | 7.2-10 | 2.8-38 | 2.9-2.6 | 4.2-5.6 | 7.0 |
| 86/12/25 | 1.5-2.0 | | 1.6-44 | 0.9-1.0 | 1.6-2.5 | 1.4 |
| 86/12/29 | 1.8-2.4 | | 1.5-11.4 | 0.9-1.2 | 1.3-1.4 | 1.4 |
| 86/12/30 | 1.5-14 | | 1.0-9.4 | 0.5 | 1.0-2.2 | 1.0 |
| 86/12/31 | 1.2-2.2 | | 1.9-6.8 | 0.7 | 0.8 | 1.3 |
| 87/01/04 | 2.2-45.0 | | 1.2-5.6 | 0.7-1.0 | 1.0-1.3 | 2.0 |
| 87/01/06 | 0.5-0.6 | | 0.3-1.3 | 0.2 | 0.3 | 0.4 |
| 87/01/06 | 1.1-1.2 | | | | | |
| 87/01/07 | 0.5 | 0.4-0.6 | 0-0.5 | 0.40 | 0.3-0.4 | 0.01? |
| 87/01/08 | 0-10 | 0-5 | 0-20 | 0 | 0 | 0 |
| 87/01/09 | | | 0.5-1.8 | 0.04 | .04-.06 | |

**Table B.10**
**Partial summary of Indoor Contamination as Measured by Manitoba Environment**



| Date | Suite #2 ppm | Suite #4 ppm | Suite #6 ppm | Suite #12 ppm | Suite #18 ppm | Locker #1 ppm |
|---|---|---|---|---|---|---|
| 87/01/19 | | | 3.5-17.5 | 4.9-5.3 | 1.2-3.0 | |
| 87/01/19 | | | 3.3-40 | 3.3-10 | 7.6-16.0 | |
| 87/01/19 | | | | 3.8-6.0 | | |
| 87/01/20 | | 5.0-10.0 | 6.5-35.0 | 3.5-3.9 | 4.5-15 | |
| 87/01/21 | | | 6.2-9.0 | 3.5-3.9 | 4.5-15 | |
| 87/01/22 | | | 2.2-2.8 | 2.5-3.0 | | |
| 87/01/22 | | | 1.8-22 | 0.9-1.1 | 1.0-1.4 | |
| 87/01/23 | | | 2.5-3.2 | 1.6-2.3 | 2.0-2.6 | |
| 87/01/23 | | | 1.2-1.9 | 1.1-1.2 | 1.7-2.4 | |
| 87/01/24 | | | 1.1-1.2 | 1.7-1.9 | 1.8-2.1 | |
| 87/01/24 | .7-.8 | | 1.0-1.7 | 2.1-2.2 | 1.6-1.8 | |
| 87/01/25 | | | 1.0-1.9 | 1.0-2.6 | 1.8-1.9 | |
| 87/01/25 | | | 1.3-7.5 | | 2.5 | |
| 87/01/26 | | | 0.9-8.7 | 2.9-2.8 | 2.2 | **2.5** |

Notes:
- Whenever a date is repeated, the first reading was taken in the a.m., whereas the second reading was taken in the p.m.
- reference - Manitoba Environment, 1987

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #50**

**BUILDING TYPE AND LOCATION:** Commercial buildings, Winnipeg, Manitoba

**GAS TYPE:** Gasoline vapours

**SOURCE:** Gasoline spill

**TYPE OF CONTROL:** Sub-slab ventilation

**CASE STUDY PRÉCIS:**

In February 1988, combustible gas concentrations were identified in a store occupied by the Yahama music school. The music store/school was located adjacent to a gasoline station. The attached Figure B-46 shows the location of the school relative to the gasoline station. When gasoline vapours were detected, the concentrations were measured. Gas concentrations along the east wall in the school office ranged from 10 percent LEL to 100 percent LEL. In one of the classrooms in the school, concentrations along the baseboards ranged between 50 and 450 ppm.

As part of the investigative program at the site, the consultant (O'Connor Associates) drilled a total of 21 boreholes in the vicinity of the spill and installed piezometers. The team also drilled an additional 31 probe holes in various businesses of the Kona building and the Husky store. Soil samples were recovered for the purpose of analysis, and soil vapour measurements were obtained. The location of the boreholes and probe holes are shown on Figures B-47 and B-48.

The maximum depth of sampling on the site was 6.1 m below ground surface. The soil profile encountered at the site consisted primarily of clay and some fill materials. Fill materials were encountered in some boreholes to depths of approximately 4 m below grade. Some sand backfill was encountered in the vicinity of the underground storage tanks (at BH10). Sewer line backfill was encountered at BH13, BH14, BH16, and BH17.

In view of the excessive vapours recorded in the probe holes and the indoor ambient air, two vapour extraction systems (VES) were installed beneath the floor slabs of the music store and the adjacent bar. Each VES consisted of pipe work connected to granular material beneath the floor slab and an exterior venting fan. Connection with the granular material beneath the floor slab was achieved by coring through the grade beam on the east side of the building.



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A portion of the sidewalk was removed to provide access for the installation. The configuration of the vapour extraction systems is shown on accompanying Figure B-49.

An attached table provides a record of the combustible gas concentrations in the music school before an after the activation of the VES. As seen on the table, significant decreases in the gas concentrations were evident at 7:30 p.m. on February 25, 1988 when the VES was activated. By 7:28 a.m. on February 26, 1988, combustible gas concentrations were no longer detected by the monitoring equipment in the school.

**Table B.11**
**Combustible Gas Concentrations in the Music Store**

| Date | Time | Baseboard (% LEL) | Office (ppm) | Watermeter (% LEL) | Classroom (ppm) |
|---|---|---|---|---|---|
| 88/02/25 | 4:06 p.m. | 22 | 10-15 | 8 | 13 |
| | 5:02 p.m. | 7 | 15 | 7 | 15 |
| | 6:00 p.m. | 6 | 10 | 7 | 6.5 |
| | 7:00 p.m. | 7 | 10 | 8 | 7 |
| | 7:30 p.m. | 45 | 20 | 8 | 6 |
| | 7:47 p.m. | 0 | NR | 3 | 6.5 |
| | 8:17 p.m. | 0 | NR | 0 | 5 |
| | 8:57 p.m. | 0 | 10 | 0 | 3 |
| 88/02/26 | 7:28 a.m. | 0 | 0 | 0 | 0 |
| | 8:30 a.m. | 0 | 0 | 0 | 0 |

NR = no reading

Another VES was installed to remove vapours from beneath Dirty Harry's Restaurant and Bar. The VES was activated on March 1, 1988 at 3:11 p.m. Immediately on startup, vapour concentrations below the slab decreased considerably. Table B.12 summarizes the performance of the VES at Dirty Harry's Restaurant and Bar.

Also as part of the monitoring program, vapour samples were obtained from several boreholes and analyzed by means of gas chromatography. The results of the analysis concluded that significant amounts of methane and other $C_3^+$ constituents were presented in the sub-slab vapour. At some well and probe locations, significant levels of methane were identified; at other locations however, larger concentrations of $C_3^+$ compounds were prevalent. The $C_3^+$ hydrocarbons are indicative of gasoline-derived compounds.

| Table B.12 Subfloor Combustible Gas Concentrations Dirty Harry's Restaurant and Bar | | | | | |
|---|---|---|---|---|---|
| **Probe Hole** | **88/02/27** | **88/02/28** | **88/03/01[1]** | **88/03/1[2]** | **88/03/03** |
| PB1 | 14 % LEL | | 270 ppm | 0 ppm | 0 ppm |
| PB2 | >100% LEL | 30 ppm | 0 ppm | 0 ppm | 0 ppm |
| PB3 | >100% LEL | >100% LEL | 89% LEL | 0 ppm | 75 ppm |
| PB4 | 75 ppm | | | | |
| PB5 | 175 ppm | | | | |
| PB6 | 175 ppm | | | | |
| PB7 | 100 ppm | | | | |
| PB8 | 130 ppm | | | | |
| PB9 | 55 ppm | | | | |
| PB10 | 40 ppm | | | | |
| PB11 | NR | | | | |
| PB12 | 50 ppm | | | | |
| PB13 | | NR | | | |
| PB14 | | 45 ppm | | | |
| PB15 | | 15% LEL | 150 ppm | 20 ppm | 10 ppm |
| PB16 | | NR | | | |
| PB17 | | 125 ppm | | | |
| PB18 | | 100 ppm | | | |
| PB19 | | 175 ppm | | | |
| PB20 | | >100% LEL | 5% LEL | 15 ppm | 105 ppm |
| PB21 | | NR | | | |
| PB22 | | 640 ppm | | | |
| PB23 | | 25 ppm | | | |
| PB24 | | 5% LEL | | | |

Notes: (1) prior to VES activation
(2) 15 minutes after VES activation

Following the initial monitoring at the time of the VES activation, further follow-up monitoring was conducted. Monitoring of the exhaust streams from the vapour extraction systems showed steady declines. Sub-slab monitoring at Dirty Harry's Restaurant and Bar showed continued low concentration levels. Table B.13 displays the longer term monitoring results at Dirty Harry's Restaurant and Bar. No sub-slab concentration data was available for the music school at the time of writing this report.

Three types of portable equipment were used during this investigation including: an HNu, an MSA explosimeter, and Gastec tubes.

**REFERENCE:**

O'Connor Associates Environmental Inc., 1988. Preliminary Site Investigation, Husky Service Station, Winnipeg, Manitoba.

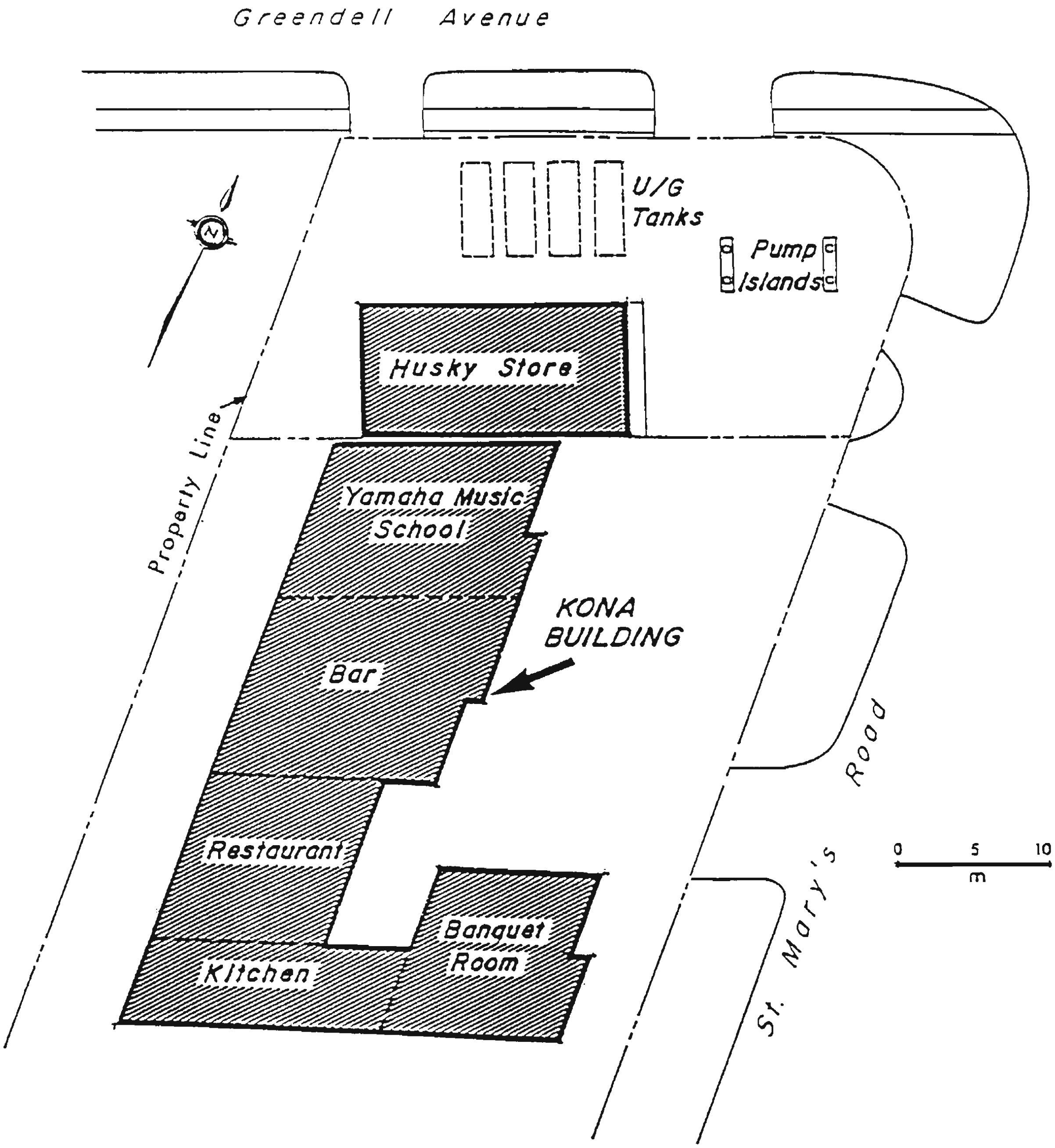


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**FIGURE B-46: LOCATION OF SCHOOL RELATIVE TO GASOLINE STATION (after O'Connor Associates, 1988)**

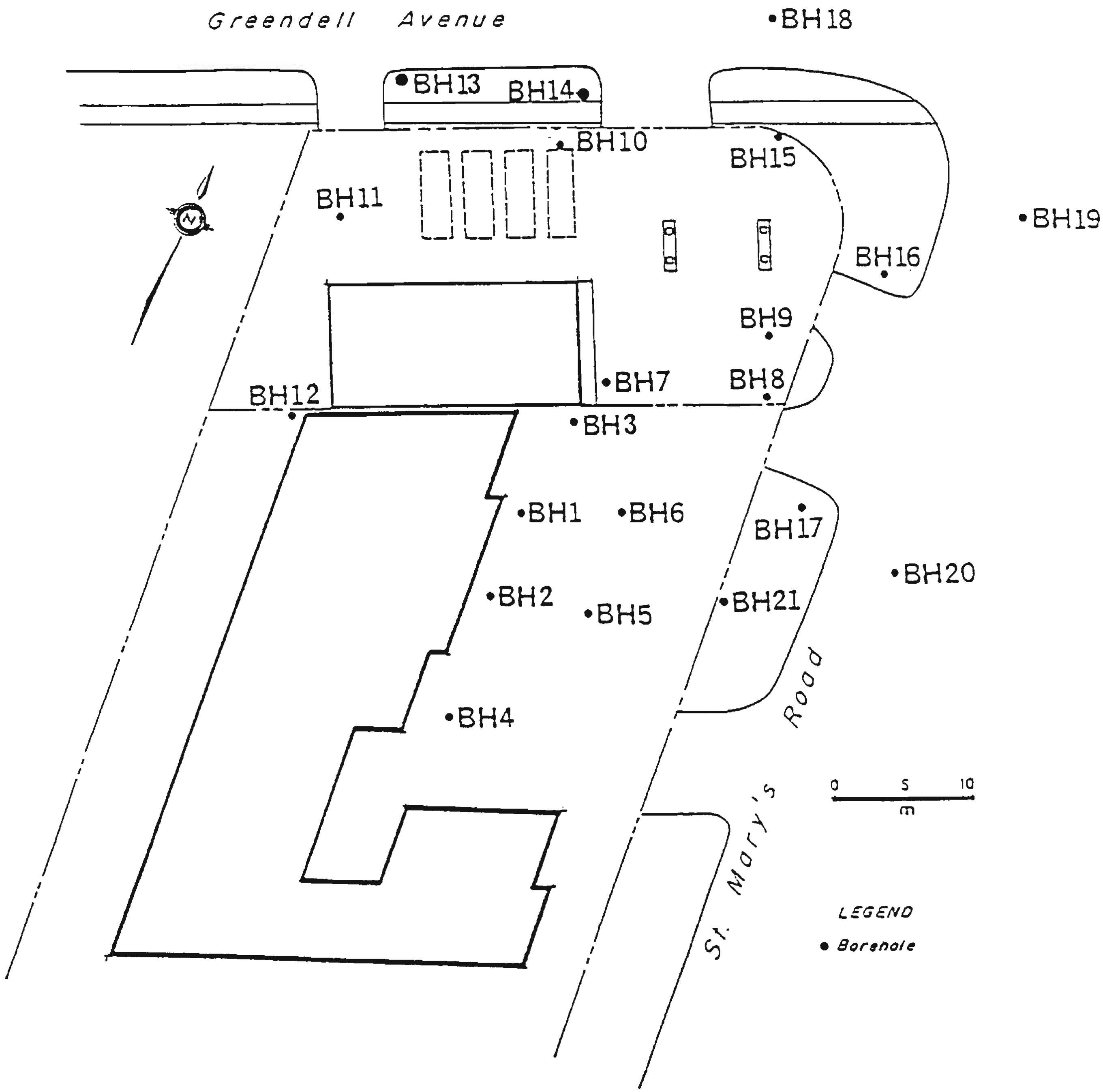


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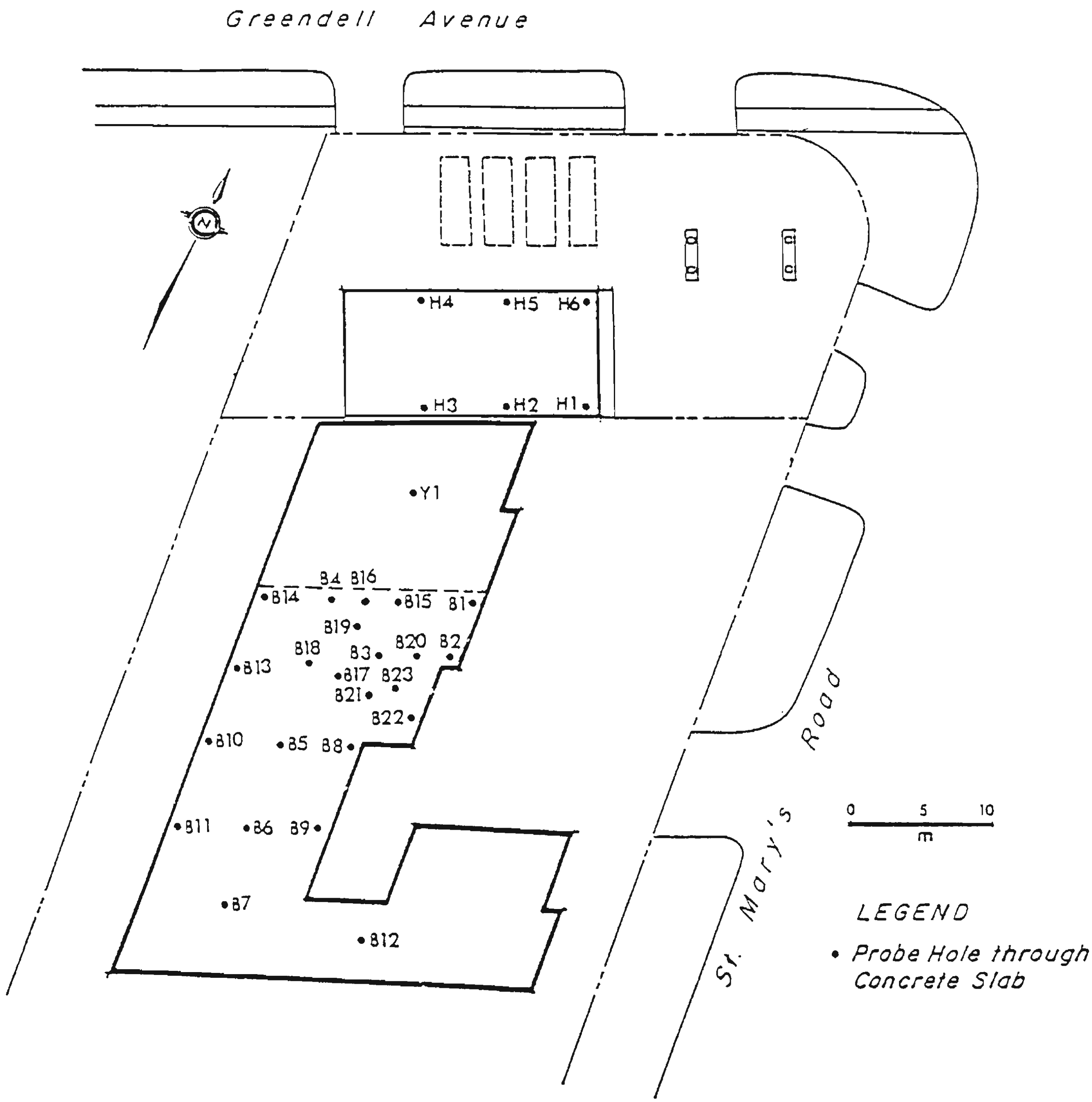
**FIGURE B-47: LOCATION OF BOREHOLES (after O'Connor Associates, 1988)**

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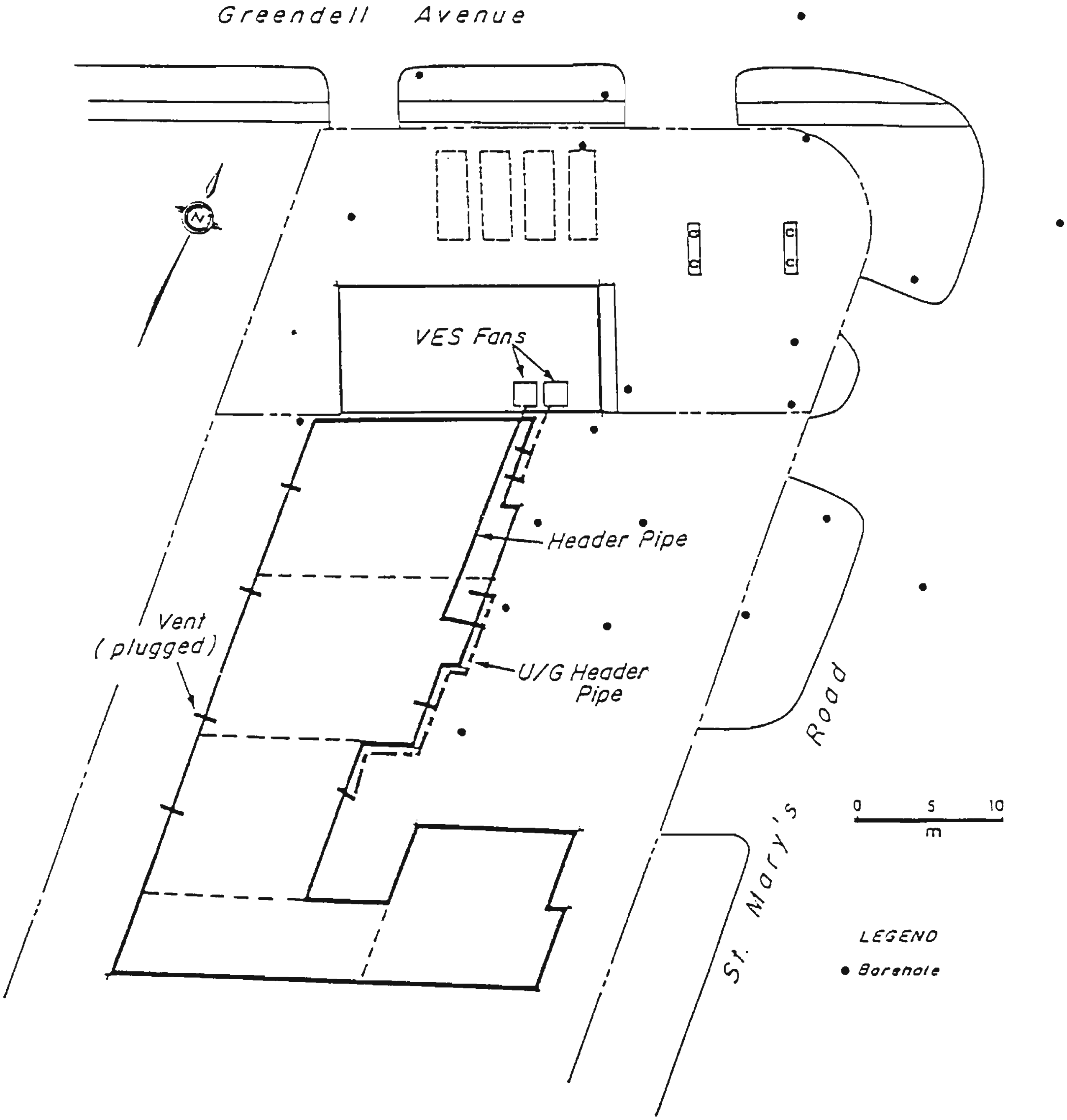
PROJECT No. ONT29396.A0

**FIGURE B–48:**
**LOCATION OF PROBE HOLES**
**(after O'Connor Associates, 1988)**

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PROJECT No. ONT29396.AO

**FIGURE B-49: CONFIGURATION OF VAPOUR EXTRACTION SYSTEM (after O'Connor Associates, 1988)**

**Table B.13**
**Longer Term Monitoring at Dirty Harry's Restaurant and Bar**

| Location | Date | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 88/02/07 | 88/02/28 | 88/03/01[1] | 88/03/01[2] | 88/03/03 | 88/03/16 | 88/04/14 | 88/04/14[3] | 88/05/27 | 88/05/27 | 88/06/21 |
| PH1 | 14% LEL | | 270 ppm | ND | ND | ND | ND | ND | ND | ND | ND |
| PH2 | >100% LEL | 30 ppm | ND | ND | ND | 5 ppm | ND | ND | 5 ppm | ND | ND |
| PH3 | >100% LEL | >100% LEL | 89% LEL | ND | 75 ppm | 15 ppm | ND | 5 ppm | ND | ND | ND |
| PH15 | | 15% LEL | 150 ppm | 20 ppm | 10 ppm | 10 ppm | ND | 5 ppm | ND | ND | ND |
| PH20 | | >100% LEL | 5% LEL | 15 ppm | 105 ppm | 15 ppm | 5 ppm | 15 ppm | ND | 15 ppm | ND |

Notes:
1 gas concentrations prior to initial VES activation
2 gas concentrations approximately 15 minutes after initial VES activation
3 VES fans shutdown for approximately 1 hour before monitoring
ND combustible gas concentration not detected

**CMHC SOIL GAS RESEARCH STUDY**
**CENTRAL CANADA SECTOR**
**CASE STUDY #51**

**BUILDING TYPE AND LOCATIONS:** Apartment building

**GAS TYPE:** Gasoline Vapours

**SOURCE:** Leaking underground storage tank

**TYPE OF CONTROL:** Soil Vapour Extraction

**CASE STUDY PRÉCIS:**

Gasoline fumes were first noted in the basement and main floor of an apartment building located near a service station with a leaking underground storage tank. The geology of the area consisted of various alluvial sand deposits.

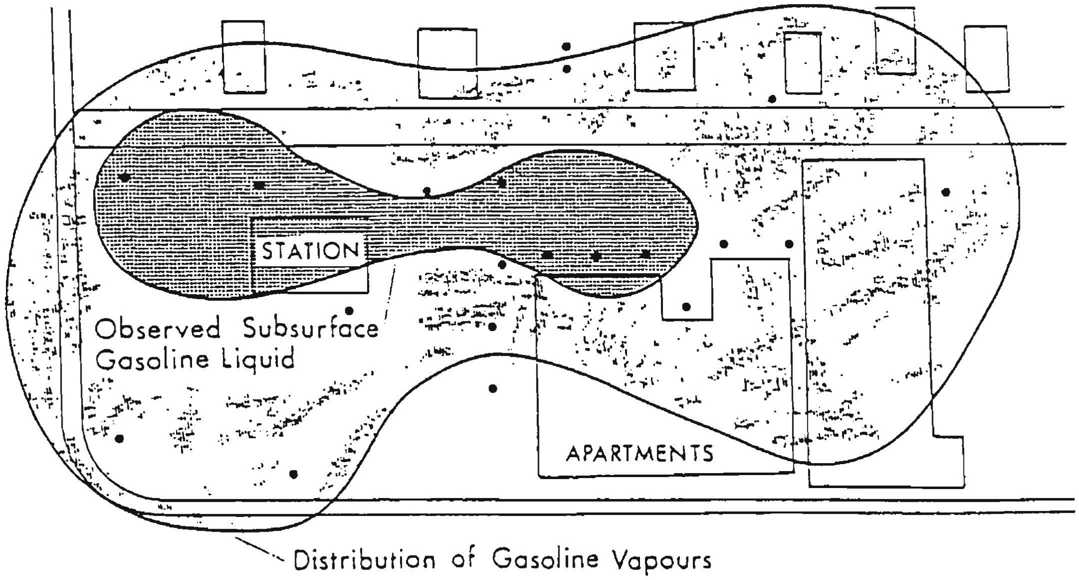
In order to release the vapour problem in the apartment building, an inspection was first initiated. The basement floor was in poor repair. Nevertheless, sealing of the basement floor was attempted. In addition, a positive pressure system was applied to the inside of the basement. Within a few hours, all the business operations within the building were restored to normal.

Subsequent investigations revealed that gasoline had pooled proximate to and beneath the building (refer to the attached Figure B-50). An external vapour management system was therefore installed. Once the external system was operating, the internal positive pressure system was disconnected.

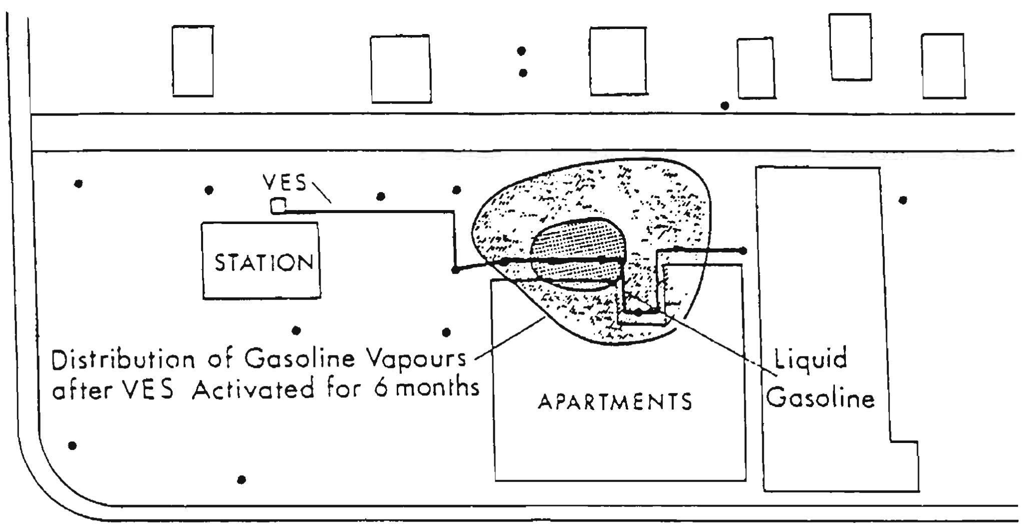
The system operated for one year at which time no liquid product was observed in any of the monitoring wells. After 3 more months, the system was shut down. Following late spring and early summer rainfall, vapours were again reported in the basement of the apartment building. An external vacuum was applied at the location of contamination. No further problems were reported in the building.

**REFERENCES:**

O'Connor, M.J., Agar, J.G. and King, R.D., 1984. Practical Experience in the Management of Hydrocarbon Vapours in the Subsurface. Presented at the NWWA/ API Conference on Petroleum Hydrocarbons, Houston, Texas, November, 1984.




**ORIGINAL SUBSURFACE DISTRIBUTION OF CONTAMINANTS**




**DISTRIBUTION OF CONTAMINANTS AFTER 6 MONTHS**

| | |
|---|---|
| CH2M HILL ENGINEERING LTD.<br>WATERLOO ONTARIO<br>PROJECT No. ONT29396.AO | **FIGURE B-50:<br>GASOLINE VAPOURS INTO APARTMENT BULDINGS<br>(Source: O'Connor et al., 1984)** |

## Appendix C

# WESTERN CANADA CASE STUDIES

**CMHC SOIL GAS RESEARCH PROJECT**
**WESTERN CANADA SECTOR**
**CASE STUDY #1**

**BUILDING TYPE AND LOCATION:** Single family residences, Richmond, British Columbia

**GAS TYPE:** Methane

**SOURCE:** Natural peat and organic fills

**TYPE OF CONTROL USED:** Passive barriers using 30 mil chlorinated polyethylene geomembranes. Utility Pipes were installed in a gas free sand layer between the membrane and floating slab.

**CASE STUDY PRÉCIS:**

New residential subdivisions in eastern areas of Richmond, B.C. have been subject to difficult soils conditions. Problems are associated with deep organic silts as well as surficial peat. The peat and organic sediments were determined to be producing methane. As well, there is a potential for special light weight organic fills to produce methane. Protective foundation geomembranes were designed and installed under close engineering observation. Methods were revised and techniques adopted to ensure the safety of the barrier. Post construction tests showed that there were undetectable levels of methane passing through the barrier.

**The problem**

The Corporation of the Municipality of Richmond lies within the Fraser river delta. The community has developed rapidly over the past 20 years from a primarily agricultural based economy to a urban residential community and now is evolving as a commercial centre. It has a population of approximately 150,000 people.

The readily accessible western land masses have been built upon the more difficult and less stable portions lie in the Eastern areas of the community. This case study concerns a residential development of 11 ha containing single family units as well as other structures on these unstable lands.

The surficial soils profile is shown on the accompanying figures. The peat and the organic silts in the region have been known to produce methane; at times the concentrations become a safety concern. An additional potential for methane creation arose when light weight organic fills were used to raise land elevations above flood levels.

Preliminary assessments and field studies determined that existing soils were decaying anaerobically and producing trace levels of methane in all locations. At some points concentrations in excess of 40% were found. Foundation simulation tests were conducted on land where the highest concentrations of methane were encountered. Mixed results were obtained. At one location negligible methane was captured during the simulation. On the other opposite extreme of the four simulation tests and within 50 metres of the first location, sufficient methane was extracted to sustain a burning flare for 2 hours. Test results such as these are not uncommon; peat lands can be bacteriologically stable or active and contain pockets of varying activity within zones. As a result of previous experiences it is surmised that stable peat lands (or pockets within it) can turn active. This increased microbe activity can be associated with surface disturbances, changes in water table or the introduction of destabilizing chemicals. It was determined that protective measures were warranted for the proposed commercial and residential structures. A source of standard protection methodologies was not known.

**The solution**

Experience was gained from results at other locations in the use of geomembranes to control gas migration (see North Vancouver, Premier Street). The economics of that solution (which used double layers of CPE) were prohibitive, therefore based on close construction supervision it was recommended that a single layer carefully sealed membrane be used. The membrane would be buried below foundation level and placed at slopes to allow continuous release of gas to atmosphere. The barrier material would be made up of continuous sheets of 30 mil black chlorinated polyethylene, which was selected for strength, chemical resistance, its impermeability to methane and its weldability using heat or solvents. An essential requirement of the installation was the certification of the inspected installation and ratified test results of the effective barrier by a qualified engineer before final permits for occupation were issued.

The barrier design required the installation of continuous factory welded sheets of the geomembrane to cover the entire foundation. Where a single sheet was not feasible in terms physical manipulation, field welded seams were allowed, and were visually inspected by the Engineer before backfilling. A minimum sand bedding of 150mm was required below the membrane; sand backfill was also specified between the floating slab and the geomembrane.

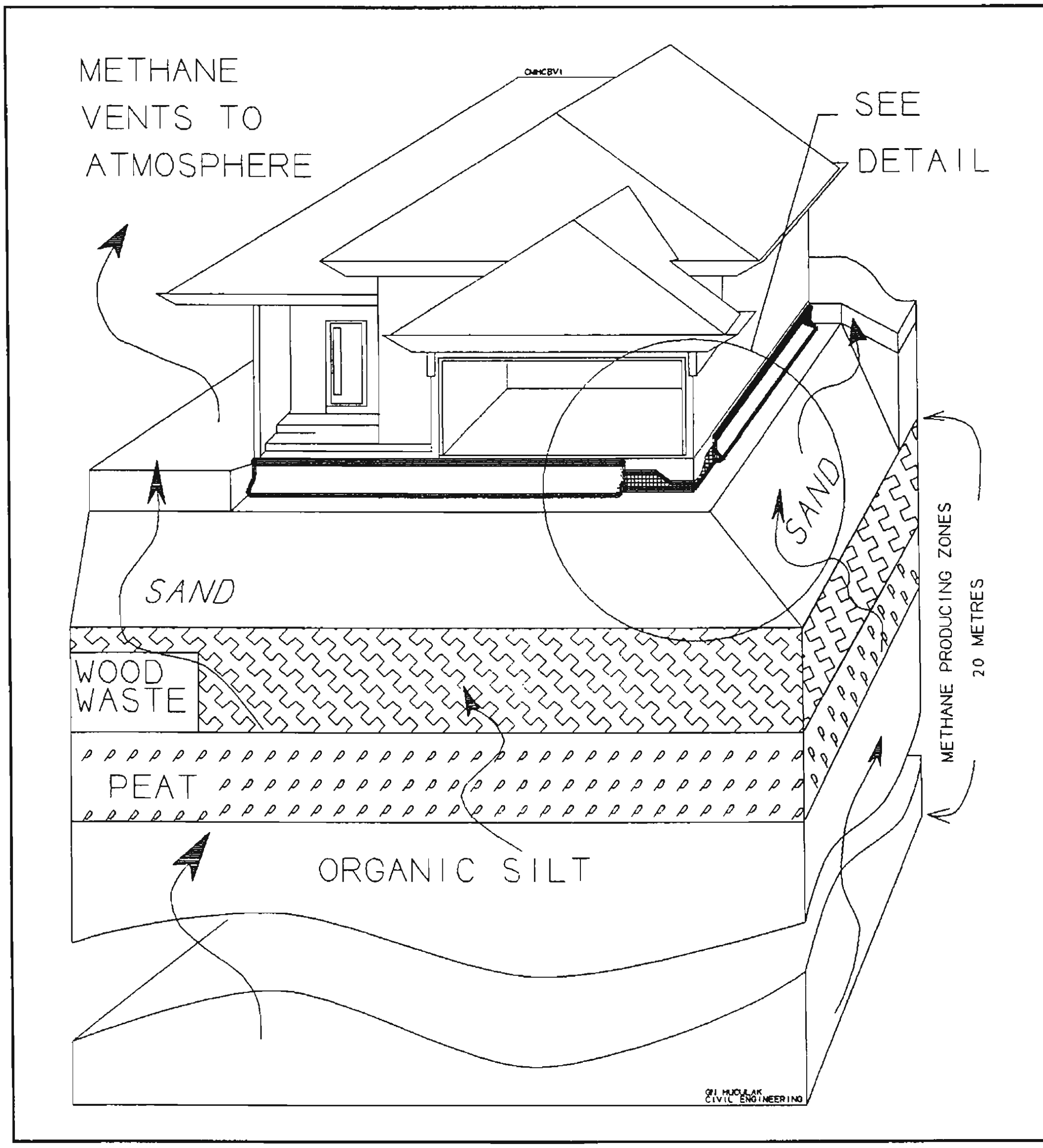



**Figure C-1**
**East Richmond Methane Barrier Foundation Conditions**

During the initial test installation on the first homes, the membrane was raised with the footing excavation and placed inside the concrete forms and attached thereto. After the concrete was set, the membrane was flush to the concrete finish. It was judged however, that this method exposed the membrane to the danger of perforation by trades people, thereafter, the membrane for each residential unit was sized to extend 1.2m beyond the slab perimeter. When the construction of the dwelling was virtually complete, the edges of the membrane were carefully re-excavated by people specifically trained for the task. The membrane was then folded upward and raised 0.3m above the footing soffit and pinned to the concrete slab using a treated 2x4 nailer as shown in the Figure C-2.

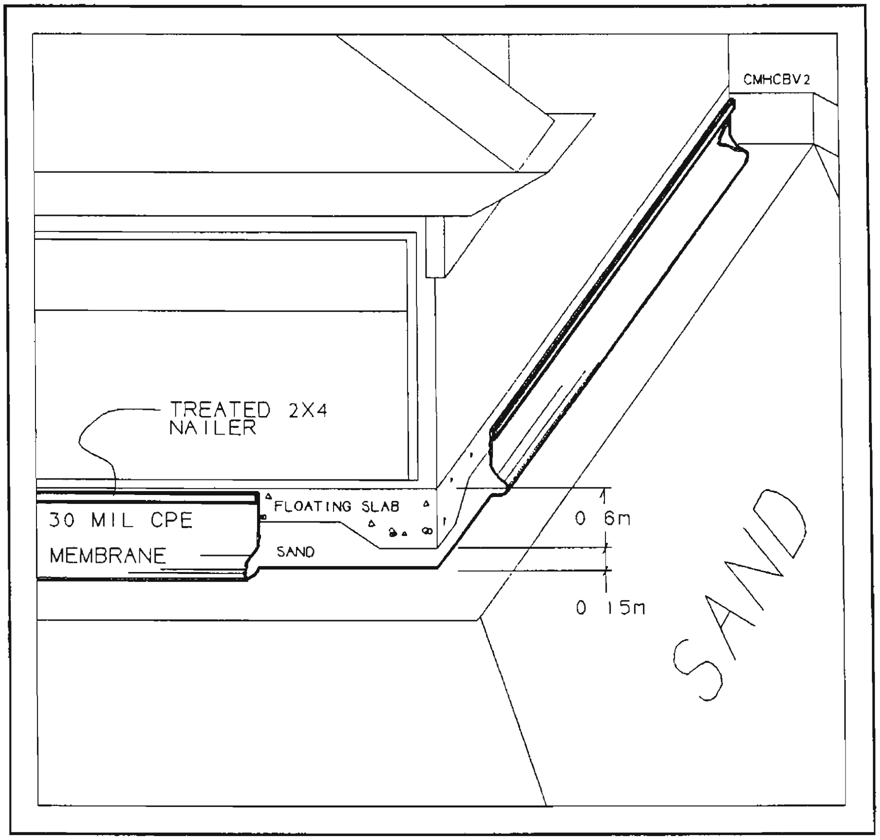



**Figure C-2**
**Detail of Membrane Installation**

Services entering the underside of the floor slab were installed within the gas free zone between the slab and membrane. Where the water and sanitary pipes penetrate the membrane, a soil bentonite seal was liberally applied to prevent gas intrusion at that point (refer to Figure C-3). Electrical service conduits were installed outside the foundation wall to the meter base.

## Post Construction Test Results

Under agreement with the Municipal Building Inspections division, the supervising engineer agreed to provide inspection certificates to verify the correct installation of the membrane during construction and to issue a separate test report to verify the integrity of the barrier at the end of house construction. Final tests involved drilling through the slab, extraction of gas for a sufficient length of time to test the integrity of the membrane and to test a representative sample for combustible gases using field instruments. A certificate, sealed by the inspecting engineer was issued for each test.

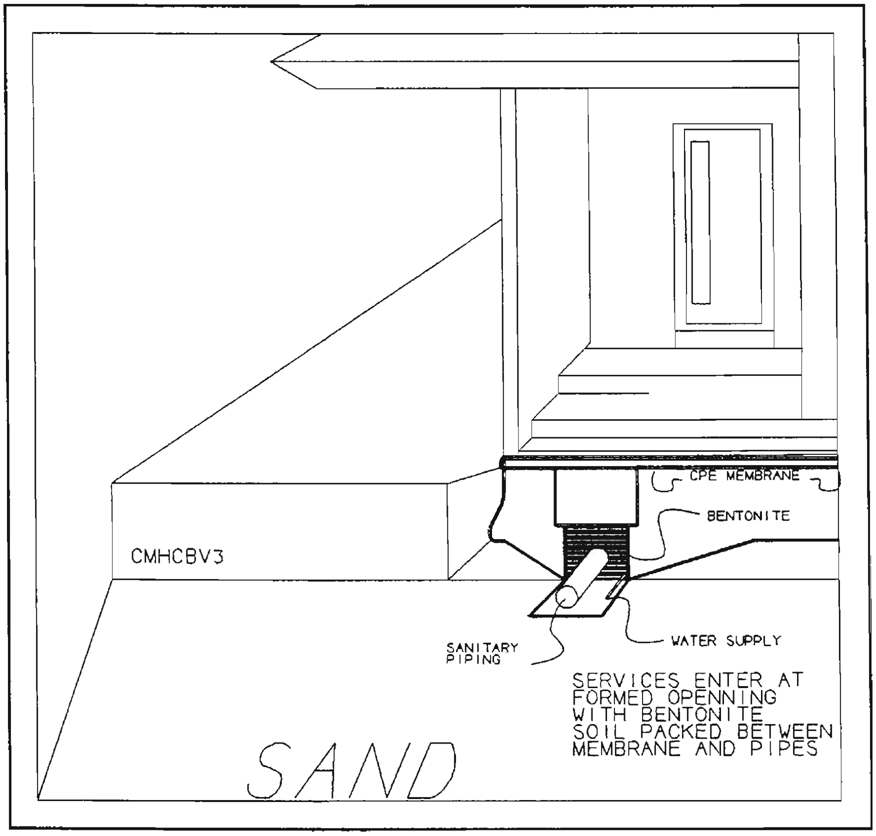



**Figure C-3**
**Detail Showing Installation of Sanitary and Water Services**

To date 16 houses and 16 townhouses have been tested; all units tested showed non-detectable levels of methane intrusion. One unit showed methane levels in the 50 PPM range but was determined to be the result of methane generated by lightly contaminated wood waste inside the membrane.

At the time of original design approvals involving the municipal building department it was suggested that some form of long term testing program be initiated for the residential and commercial properties. As yet, such a program has not been established.

**CMHC SOIL GAS RESEARCH PROJECT**
**WESTERN CANADA SECTOR**
**CASE STUDY #2**

| | |
|---|---|
| **BUILDING TYPE AND LOCATION:** | Townhouse residences, Richmond, British Columbia |
| **GAS TYPE:** | Methane |
| **SOURCE:** | Natural, peat |
| **TYPE OF CONTROL USED:** | Passive barrier using 30 mil chlorinated polyethylene membrane |

## CASE STUDY PRÉCIS:

During the soils investigations for footing design, the soils engineering consultant identified the potential for methane generation from underlying peat. Subsequent investigations determined the presence of explosive gases. Control membranes were designed to be laid inside the piled footing beams. Thirty mil CPE membranes were attached to the inside walls and sealed using caulking. Services were installed in prefabricated boots, clamped and then sealed. Passive foundation vents were installed below the membrane. Post construction tests showed no detectable presence of combustible gases in the protected crawl space. Construction inspection was carried out by the supervising engineer in cooperation with the buildings permits division. Figures C-4 and C-5 illustrate the installation concept. No long term testing mechanisms have been established.

### The Problem

The extent of problems with organic soils and wood waste throughout building sites in the Lower Mainland has not been quantified or mapped. As a consequence, architects and builders are sometimes unaware that testing needs to be conducted or that measures may be required for methane control. The following case study illustrates the method used to protect foundations after foundation construction had begun; simpler methods could have been used if the problem had been identified earlier.

During the construction phase of the Blundell Road townhouses in Richmond, the architect learned too late that the soils on the site had potential for methane generation due to underlying peat. With sufficient advance warning it would have been possible to excavate the peat in this area, avoiding any need for methane control systems as part of the building construction. Nearby subdivisions have opted for complete removal of the peat, and this approach is thought to offer sufficient protection. Due to the high water tables in this area, soil gas is vented vertically in most situations, and therefore, as long as the part directly below the site is removed, the problem can be solved.

Tests undertaken showed that methane concentration of up two 2% were present and traces of the gas were evident at many points. Protection was warranted. To avoid major changes in the construction schedule of the Blundell Road townhouses, excavation was ruled out, and a passive methane control system was designed and installed.

**The Solution**

The control system for the Blundell Road townhouses consisted of a passive 30 mil CPE membrane laid inside the piled footing beams and caulked to the inside foundation walls. This system is presented schematically in Figures C-4 and C-5. For simplicity and convenience the CPE barrier has been placed inside the footings. Unfortunately, this approach leaves open the possibility for the membrane system to be penetrated at some later date due to renovations or repairs.

The overlapped sections of membrane were welded together on site by the installation crew. Acoustical sealant was used to bind the membrane to the footings and conduits. In addition the membrane was mechanically attached to the perimeter foundation wall with 2x4 treated nailers. The consultant for the project opted not to employ prefabricated boots, and instead assembled custom boots for each penetration on site. Copper vents were installed through foundation walls to release methane which may accumulate under the membrane.

Although the system appears straightforward on paper, the consultant found the actual installation to be very tricky. Lots of picky details to consider.

**Post Construction Test Results**

The Blundell Road townhouses were completed in 1989. Post construction test results showed no detectable presence of combustible gases in the protected crawl space. No long term monitoring was implemented and none is planned. Spot tests and inspections were attempted as part of this case study, but no easy means was found to access the crawl space area.

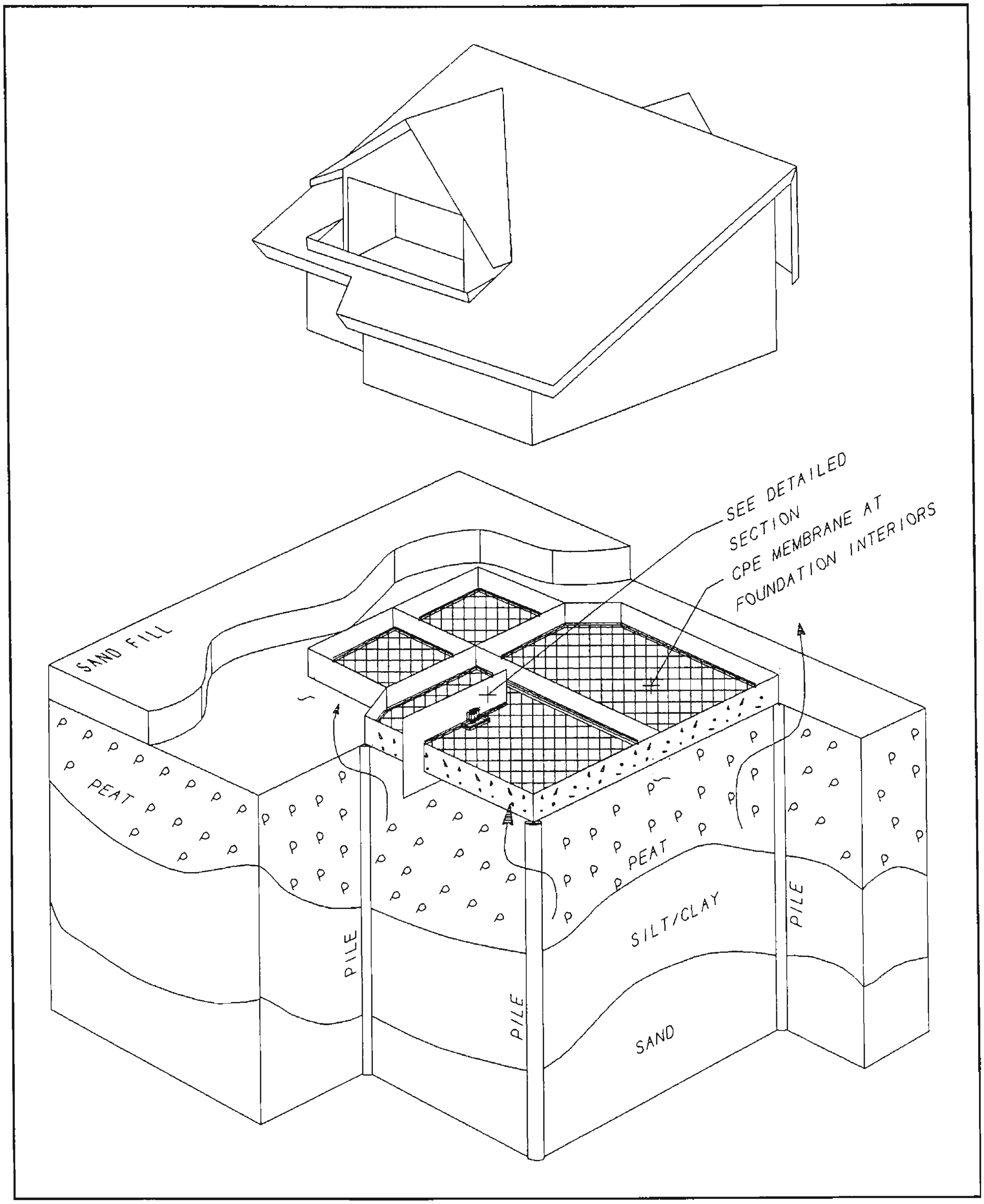



**Figure C-4**
**Site and Foundation Schematic at Richmond Townhouses**

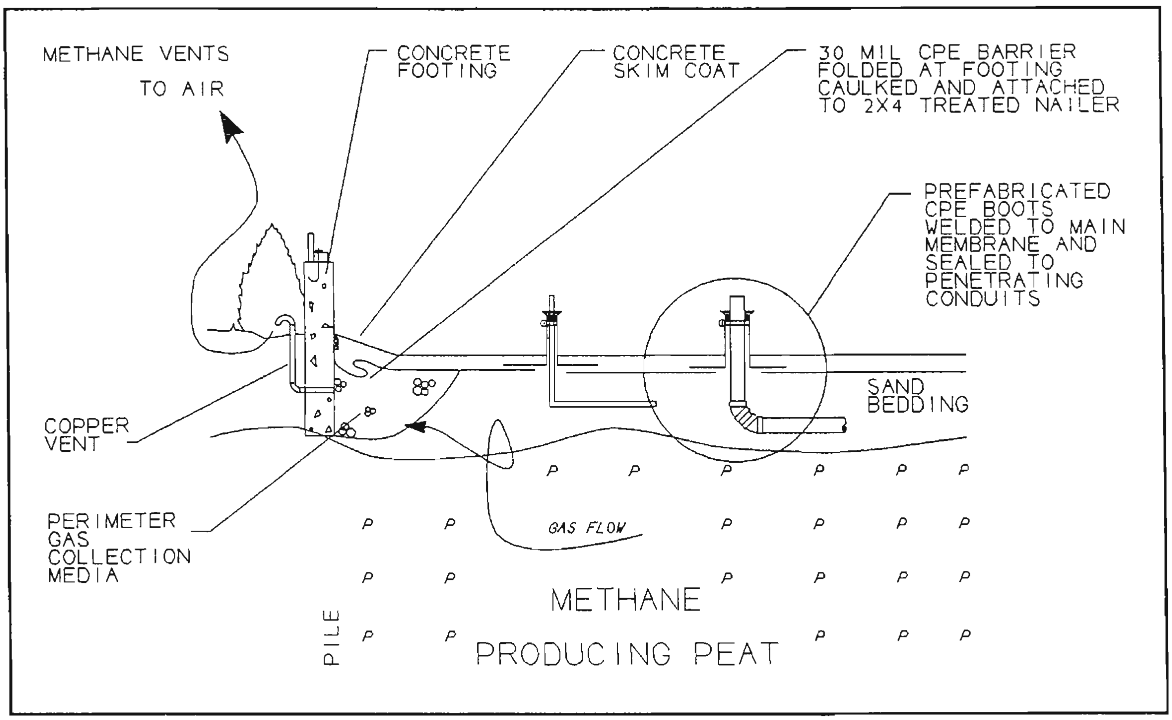



**Figure C-5**
**Richmond Townhouses**
**Detail Showing Membrane Placement**
**and Sealing at Pipes**

**CMHC SOIL GAS RESEARCH PROJECT**
**WESTERN CANADA SECTOR**
**CASE STUDY #3**

| | |
|---|---|
| **BUILDING TYPE AND LOCATION:** | New construction of commercial sales/warehouse, Coquitlam, British Columbia |
| **GAS TYPE:** | Methane |
| **SOURCE:** | Natural peat and wood waste |
| **TYPE OF CONTROL USED:** | Passive collection and venting |

**CASE STUDY PRÉCIS:**

The Mayfair Industrial Park lies within the Fraser River lowlands. Its alluvial soils contain organics in silts and sands as well as peat. Wood waste fills were also present. Other structures in this area have been subject to gas intrusion and fires due to gas migration from putrescible fills. Tests at this site detected methane in trace quantities. Adjacent properties contained significant methane levels below asphalt parking surfaces. The contractor elected to install a passive venting system which could, optionally, be upgraded to an active process in future. Figures C-6 and C-7 show the site arrangement and vent piping concepts. This type of arrangement is considered to be a nominal treatment of the problem. No municipal authorities were involved. Building permits had been issued before systems were implemented.

**The Problem**

Testing by B.C. Gas along roads and gas mains had identified trace elements of methane in the area of the Mayfair Industrial Park. Land owners in the area were alerted to this potential for problems, and provided with a list of consultants who could assist in problem assessment and mitigation strategies.

When land owners were alerted to the problem the construction of a commercial sales warehouse on Northbend Road was already under way. Consultants were employed to assess the potential for problems for this site.

The soils in the area were alluvial, containing organics and silts and sand as well as peat. Wood waste fills were also present. Other structures in this area have been subject to gas intrusion and even crawl space fires due to gas migration from putrescible fills.

Surface tests were conducted using 0.9 m deep bar holes. Trace quantities of methane were discovered on the warehouse site. Since a building permit had already been issued, the extent of methane control measures was at the discretion of the building owner.

## The Solution

The contractor elected to install a passive venting system which could optionally be upgraded to an active system in the future. Figures C-6 and C-7 show the site arrangement and venting pipe concepts. A perimeter gas collection system was installed around the interior of the concrete foundation wall, and piped to four vertical stacks. The location and number of vertical vents was based on experience. In theory, some soil testing would help in calculating the porosity of soils and the maximum stack interval. Elaborate test procedures can result in excess of the price of additional vents.

In theory this gas collection system will allow for venting of methane collecting below the concrete floor. The concrete was assumed to represent a reasonable barrier to gas intrusion into the building. No special measures were made to seal any penetrations through the concrete, or the joint between the concrete floor and bearing wall (although these walls are tied structurally into the slab). Inspection caps were installed in each of the vertical stacks to permit post construction testing and monitoring.

## Post Construction Test Results

The North Bend Road Warehouse was completed in 1988. Post construction tests showed no detectable level of methane in the collection system. Because methane concentrations on the site were minimal to begin with, the test results are not a clear indication that the system is performing well. No ongoing monitoring is planned, and there is no plan to upgrade the system to an active extraction.

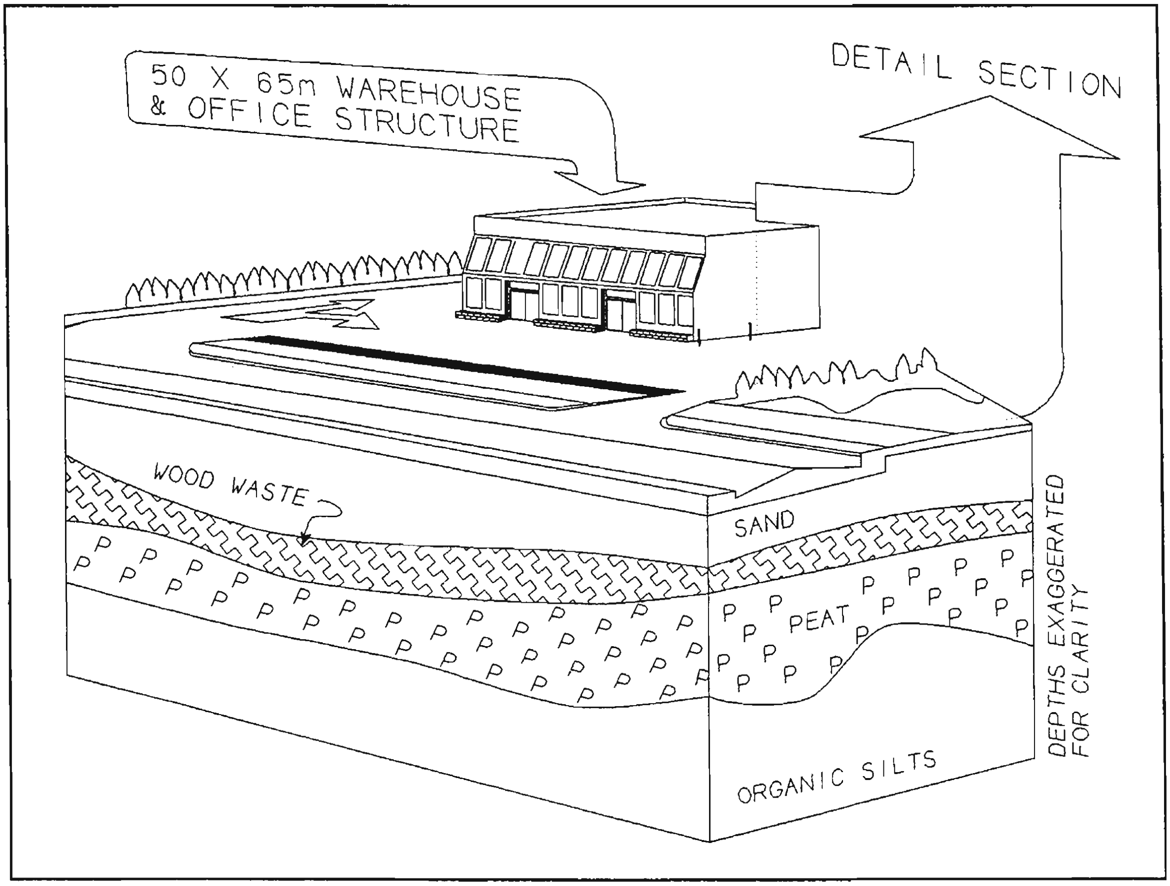



**Figure C-6**
**Section and Site Schematic of**
**Commercial Structure in Coquitlam, B.C.**

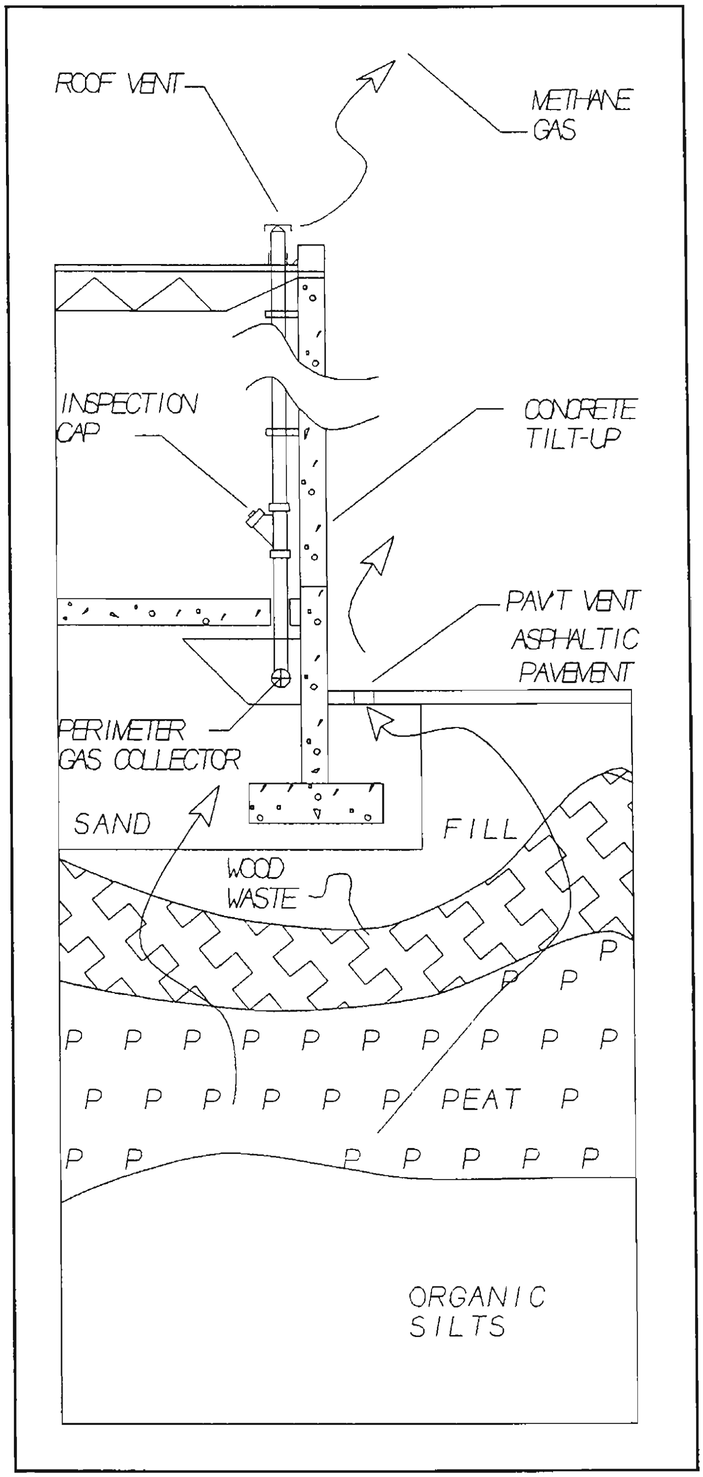



**Figure C-7**
**Detail of Foundation Vents and Passive Piping At a Coquitlam Warehouse**

**CMHC SOIL GAS RESEARCH PROJECT**
**WESTERN CANADA SECTOR**
**CASE STUDY #4**

| | |
|---|---|
| **BUILDING TYPE AND LOCATION:** | Retrofit of existing industrial manufacturing structure, Richmond, British Columbia |
| **GAS TYPE:** | Methane |
| **SOURCE:** | Natural peat, and possibly wood waste or organic silts |
| **TYPE OF CONTROL USED:** | Active extraction and venting |

**CASE STUDY PRECIS:**

The owner was advised by the gas utility that methane was detected near the foundation of their building. Subsequent analysis showed the gas was not from gas pipelines. Consultants were retained to investigate. Further tests revealed that the methane was entering the premises at slab fractures (maximum concentrations in air of 18% were measured during extraction tests). The owner elected (from available options) to install an active extraction system. Post construction monitoring confirmed that the process was effective. Interior gas detection alarms were installed. After 3 years of intermittent observation, the system has required servicing but continues to function if monitoring and repairs are carried out. No municipal authorities were involved.

**The Problem**

The owner of an existing industrial manufacturing structure in Richmond, B.C. was advised by B.C. Gas that methane had been detected near the foundation of their building. Consultants employed by the building owner determined that the source of the gas was natural peat and possibly woods wastes or organic silts below the building. Tests inside the building revealed that methane was entering the premises at slab fractures. The concentrations on occasion rose to explosive levels. Maximum concentrations were in the area of 18% were measured during extraction tests. A methane control system was recommended.

**The Solution**

From a variety of options, the owner elected to install an active extraction system. A schematic of the site plan for the building and soil composition is presented in Figure C-8. Pavement around the building served to trap any gases generated by the peat and wood waste, and direct them into the building.

The gas control schematic is presented in Figure C-9. A Spencer extraction fan with a TEFC motor was used to provide continuous extraction of soil gases. This vacuum blower was connected to a PVC header below the roof. The header was manifolded to 2.5 cm steel vertical pipes attached to the bearing walls, at 20 metre centres. A detailed schematic of gas collection points is presented in Figure C-10. Note that a control valve was installed in each section of vertical piping to permit balancing of pressures throughout the system. A schematic of the active of pumping system is presented in Figure C-11.

No attempt was made to seal the floor slab, or plug any of the cracks that had earlier shown methane infiltration.

**Post Construction Test Results**

Post construction monitoring confirmed that the process was effective. Immediately after the operation of the extraction fan, levels of methane around cracks in the floor slab and the foundation dropped. After a minute, the levels had disappeared. The piping systems seemed adequate to ensure that all soil gases beneath the building were collected and vented.

Because this was a retrofit situation, no municipal authorities were involved. The complete system was operational in 1986. After three years of intermittent observation, the system has required servicing, but continues to function. There is no schedule for maintenance and repair of the vacuum blower. However consultants feel that due to the constant flushing of soil gases beneath and around the building, anaerobic bacteria had been killed. Occasional breakdowns of the system for even periods of weeks should not create problems, due to the time required for anaerobic bacteria to regenerate.

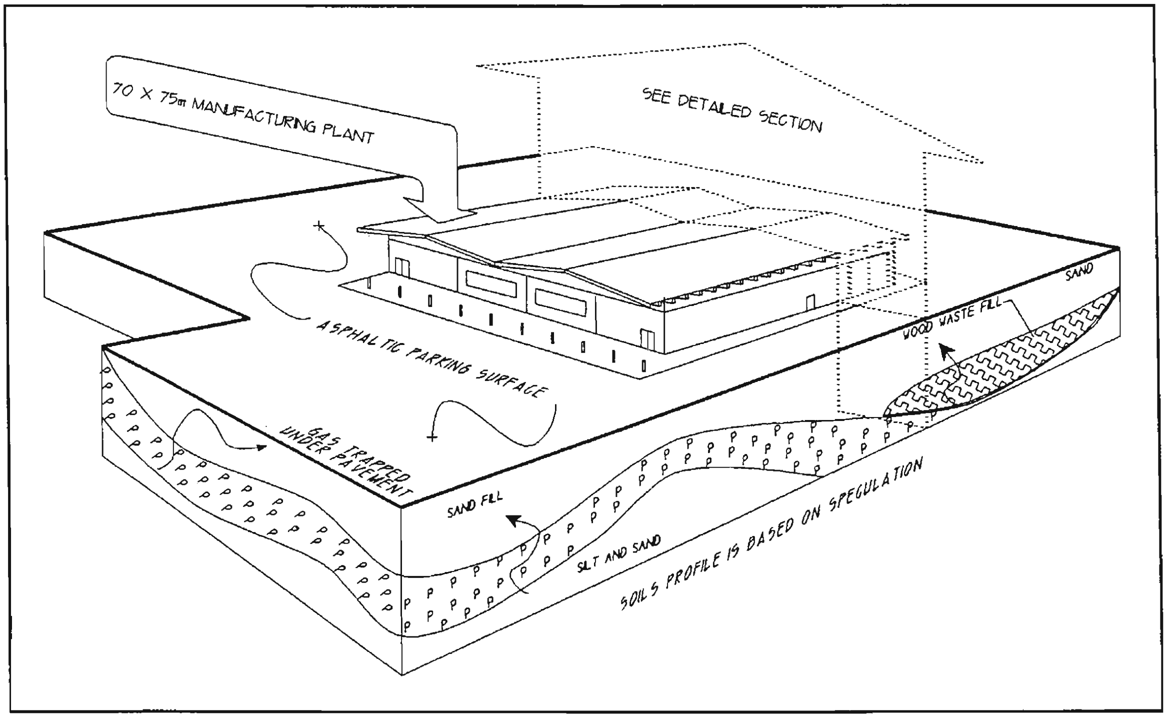



**Figure C-8**
**Schematic and Site Plan of Richmond Industrial Plant**

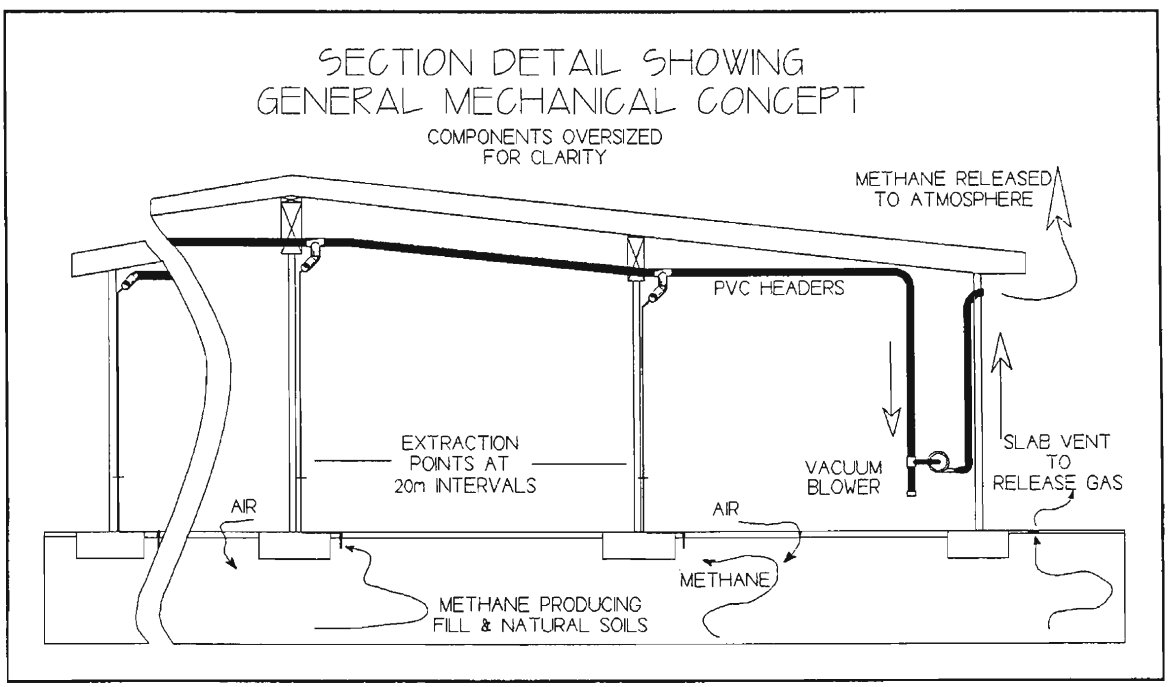



**Figure C-9**
**Richmond Industrial Plant Gas Control Schematic**

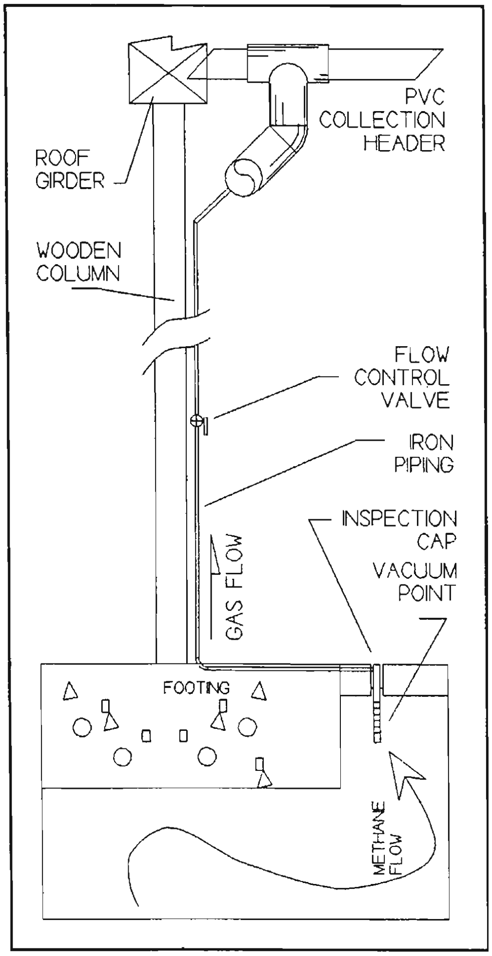



**Figure C-10**
**Schematic Detail of**
**Gas Collection Points**

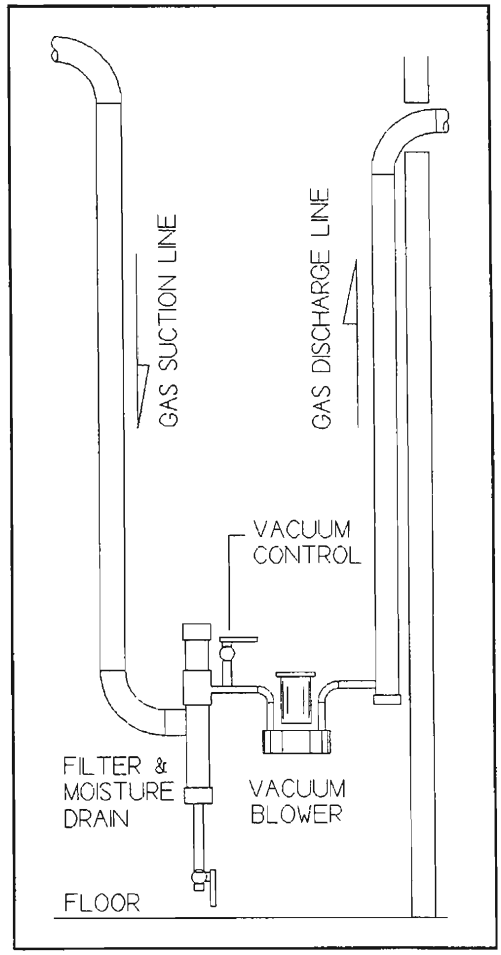



**Figure C-11**
**Schematic of Active**
**Pumping System**

## CMHC SOIL GAS RESEARCH PROJECT
## WESTERN CANADA SECTION
## CASE STUDY #5

| | |
|---|---|
| **BUILDING TYPE AND LOCATION:** | Single family residences, Prince George, British Columbia |
| **GAS TYPE:** | Methane |
| **SOURCE:** | Nearby landfill |
| **TYPE OF CONTROL USED:** | A line of pressurized air control wells was located between the subdivision and the landfill |

### CASE STUDY PRÉCIS:

Several fires in houses next to the Heritage land fill site in Prince George alerted authorities to the presence of methane. A rock trench had been constructed between the landfill and Claxton Crescent, but it was too shallow to be effective. A series of wells were dug between the landfill and the rock trench, 21 metres deep. The wells were manifolded to a 150 mm PVC header and connected to a blower. Initially this system was used to extract soil gases and was shown through testing to be immediately effective in eliminating methane from Claxton Crescent residences. After several days of extraction, the blower was reversed and the wells were used as an air curtain to reduce the flow of gas from the land fill to the subdivision, to assist in aerating putrescibles in the landfill.

### The Problem

The Heritage landfill site in Prince George was closed in 1976. A subdivision was constructed next to the site, with the closest road being Claxton Cres. A 5.2 m deep rock trench between the Claxton Cres. and the subdivision was installed to assist in venting any soil gases migrating from the landfills.

In May 1990 a fire occurred for the second time in one of the residences of Claxton Cres. Testing done by B.C. Hydro revealed methane concentrations in the house of 14%. Testing of neighbouring houses subsequently showed that at least three of the houses had methane concentrations in the explosive range. Continuous pilot lights on furnaces and water heaters may have helped to avoid sparking and explosions. A consultant was employed by the city of Prince George to design and install an effective methane control system.

## The Solution

Figure C-12 provides a plan of new methane control facility, air curtain system, trench and houses. The system incorporates 15 air injection wells 21 m in depth, and 14 m apart. Adjacent to these wells an air supply header was placed, buried to a depth of about 1 metre. A tee was placed on the wells and on the air supply line and each well was connected to the air supply line by flexible connection. Each well was controlled by an adjustable valve to allow for air pressure and volume adjustment. Each well is equipped with a test point to enable pressure or vacuum testing for methane content. Figure C-13 is a cross section of the landfill showing how injection wells will reverse the migration of methane and purge the soil next to the houses. Figure C-14 is a schematic of the well, connection piping and well head assembly and includes details on material composition and dimensions.

The valve and well head is enclosed by an access box with a removable cover to ground level to allow for access for testing of wells and valve adjustment without any above ground protuberances. The wells consist of 6 m of solid pipe at the top and 15 m of slotted pipe at the bottom to enable air to be delivered to (or gas to be extracted) from the same level (or deeper) than the bottom of the landfill. Bentonite seals were provided on the solid section to allow for pressure build up in the slotted pipe. The entire system of wells is connected to a blower which delivers 140 L/s of air to the slotted portions of the wells at adequate pressure to prevent further gas migration.

The existing rock trench provides a convenient vent for air and gas to be expelled even in winter months, since the trench is deeper than frost penetration level.

## Post Installation Test Results

Initially the system was operated on a vacuum so that soil gas was drawn to the wells and away from the houses. This action was shown to clear the soil of methane and may also have eliminated any confined pockets of gas.

Within two days of system operation under vacuum mode, methane levels in the basements of Claxton houses were reduced to undetectable levels.

One week after installation of the system a permanent pressure blower was placed into operation. Tests were again taken in the previously affected houses and no methane detected.

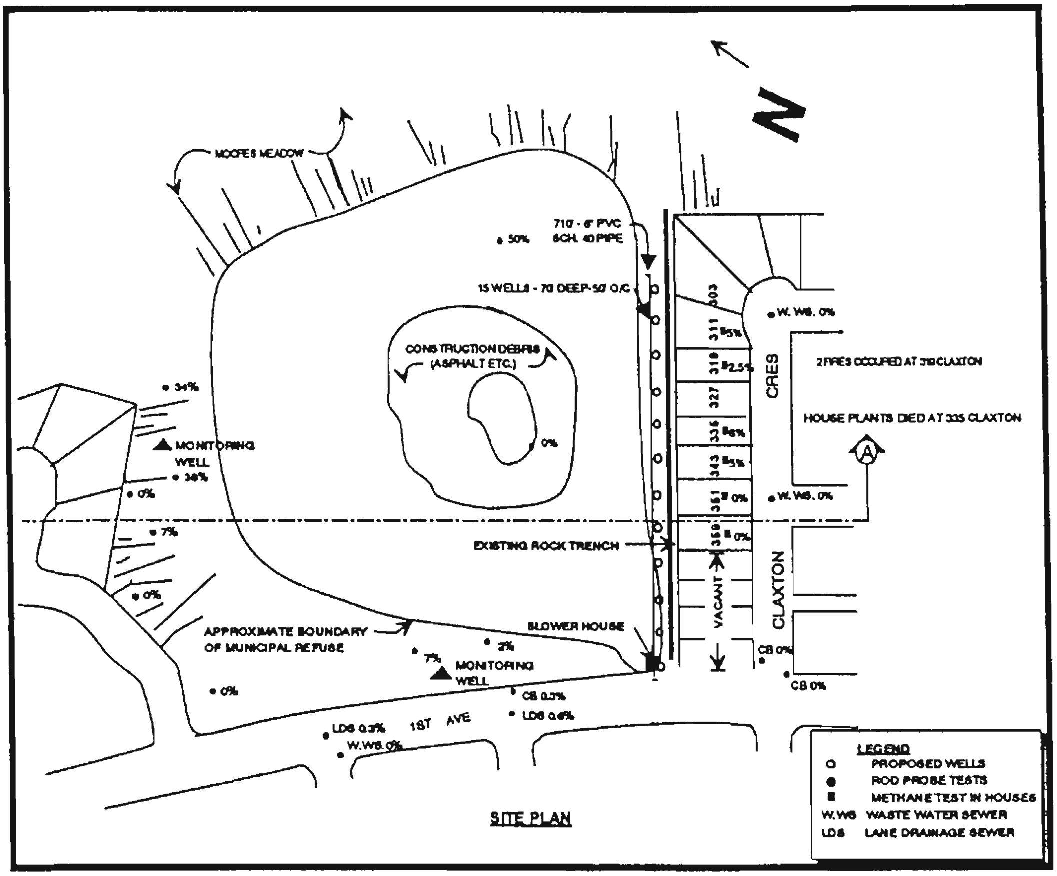



**Figure C-12**
**Plan of Landfill**

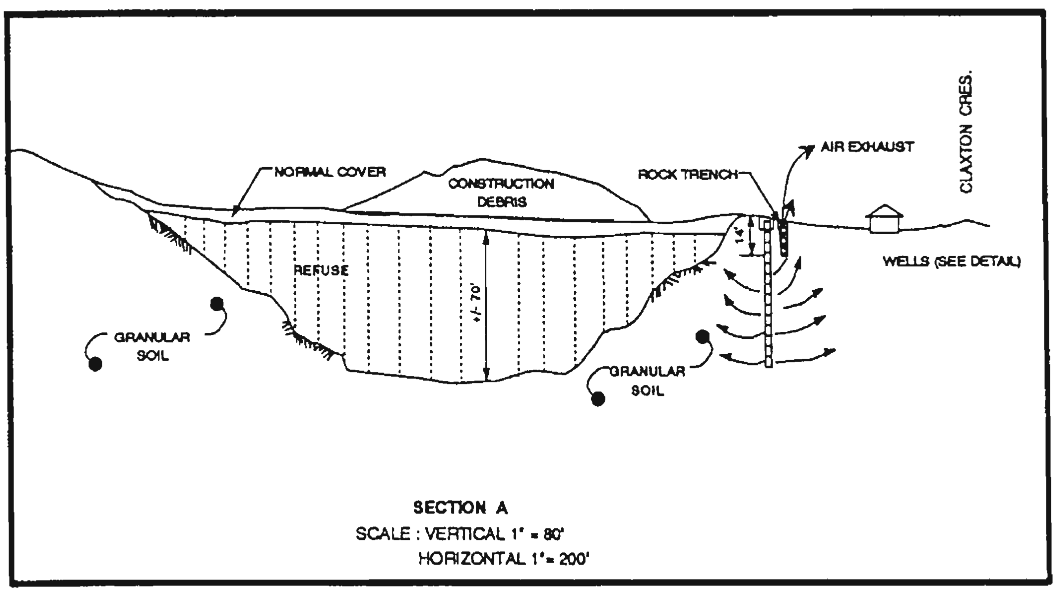



**Figure C-13**
**Section through Landfill**

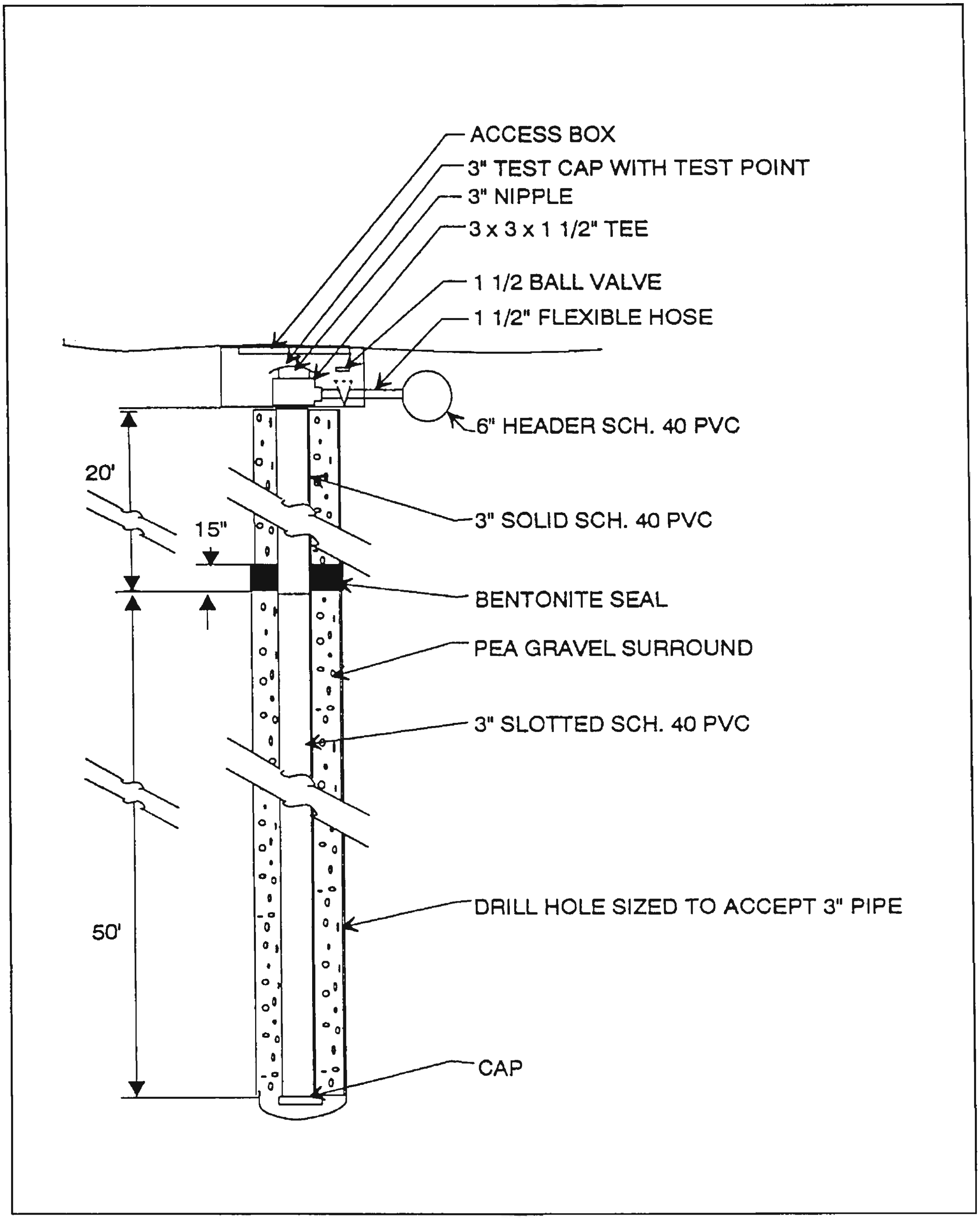



**Figure C-14**
**Wellhead Detail**

**CMHC SOIL GAS RESEARCH PROJECT**
**WESTERN CANADA SECTOR**
**CASE STUDY #6**

**BUILDING TYPE AND LOCATION:** Vancouver College, Burnaby, British Columbia

**GAS TYPE:** Methane

**SOURCE:** China Creek landfill

**TYPE OF CONTROL USED:** A system of perforated horizontal piping located below the building used to passively supply air and actively exhaust soil gases

## CASE STUDY PRÉCIS:

During construction of the Community College, the soils consultant discovered considerable amounts of garbage beneath the construction site, including portions of the Old China Creek Landfill. Architectural features of the proposed building prevented use of a protective membrane beneath the structure. Instead horizontal rows of perforated pipe were placed beneath the building, with every alternate row acting to either exhaust or supply. A blower on a timer was used to actively extract soil gases, with air supply passively through the alternate rows of piping. Spot checks indicate the system has performed well for approximately eight years.

### The Problem

Construction of Vancouver Community College (VCC) began in 1982. After construction was under way the project manager was alerted by the soils consultant that there was garbage underneath the proposed structure and warned of the possibility of methane formation. Further on-site investigations revealed that the structure was being built directly over the Old China Creek Landfill, with considerable amounts of garbage on the site.

Sampling through probes in the soil over the proposed site recorded methane levels as high as 65 percent.

### The Solution

Because the VCC college structure incorporated a large number of piles, elevator shafts and complex features, the use of a membrane barrier was ruled out. Consultants opted to install a perforated horizontal piping system to aerate the material beneath the floor slab, displacing the methane and at the same time driving the methane producing material to a aerobic conditions. To accomplish this, rows of horizontal piping were placed between the rows of piles and every second row was subjected to a vacuum. The vacuum rows were closed off at the far terminus so that a static pressure could be maintained throughout the length of pipe. The alternate rows were used as passive supply ducts, and were connected to the atmosphere. VCC is located in a pocket of land in a wet area and allowance had to be made for water drainage. Consequently the perforated pipe was designed to act as weeping tiles, collecting and draining any water beneath the foundations. The perforated pipe designed for passive air supply was allowed to drain straight into the storm sewer systems. A customized water trap was required for the exhaust pipes, to allow them to operate both as drains and as part of the soil gas extraction system. Figure C-15 illustrates the design of the trap used for the exhaust pipes.

**Post Construction Test Results**

After one month of vacuum blower operation tests showed no discernable methane was being exhausted. A spot test four years later again showed no discernable methane. Due to the lack of methane, the blower was operated on a timer, starting operation at about midnight and shutting down at about 2:00 am. No back-up systems have been installed, and no continuous monitoring has been recommended. It is assumed that the decomposition of landfill waste is now aerobic. It is also assumed that regeneration of methane will require at least a month.

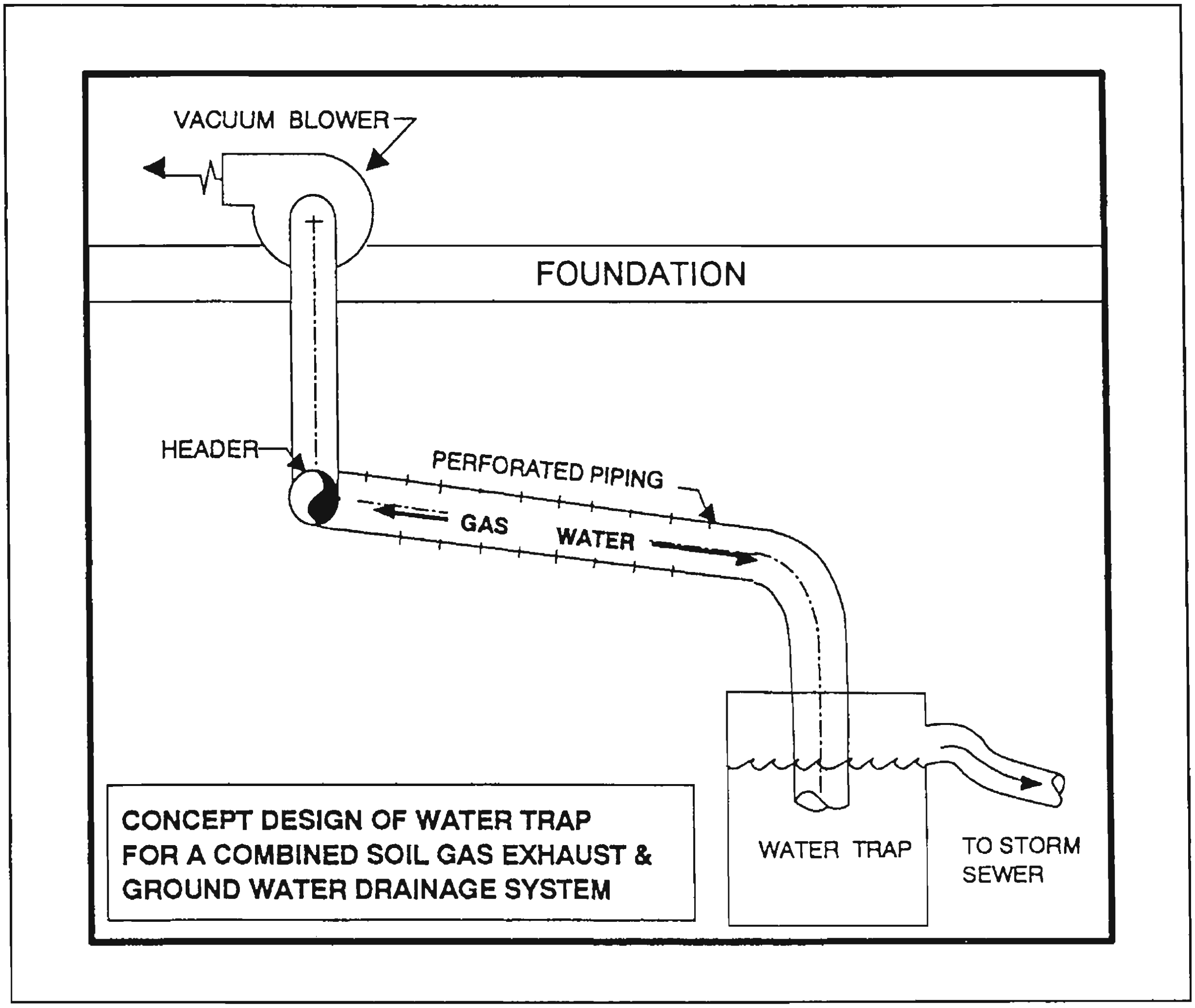



**Figure C-15**
**Detail of Perforated Pipe and Drain**

## CMHC SOIL GAS RESEARCH PROJECT
## WESTERN CANADA SECTOR
## CASE STUDY #7

| | |
|---|---|
| **BUILDING TYPE AND LOCATION:** | Commercial building, Burnaby, British Columbia |
| **GAS TYPE:** | Methane |
| **SOURCE:** | Wood wastes, mulch and peat |
| **TYPE OF CONTROL USED:** | Vacuum extraction through perforated sub-slab piping |

**CASE STUDY PRÉCIS:**

The new Motorola Building in Burnaby, B.C. required soil gas protection to control methane generated from underlying peat formations. Removal of peat was not an option since deposits in this area were reported to be up to 27 m deep. An exhaust extraction system was installed consisting of a perforated piping below the slab manifolded to an exhaust piping system within the building. Initial methane readings on the site were in excess of 60%, and 40% methane was recorded under the building slab immediately after construction. Methane levels were reduced to zero within 60 days after the system startup. The vacuum extractor was subsequently placed on a timer. Readings began to rise and the system was configured for full time operation. Consultants claim part of the difficulty was with maintaining control of methane and that the architect had not had sufficient time to incorporate pavement vents around the building to permit venting of methane from surrounding peat deposits. Thus methane was intruding from lands surrounding the building.

## SOIL GAS RESEARCH PROJECT
## WESTERN CANADA SECTOR
## CASE STUDY #8

**BUILDING TYPE AND LOCATION:** Commercial building, Burnaby, British Columbia

**GAS TYPE:** Methane

**SOURCE:** Natural peat and organic fills

**TYPE OF CONTROL USED:** Perforated air supply wells pressurized by a supply line located under the floor slab prior to pouring the slab

**CASE STUDY PRÉCIS:**

The Slough Estates site had previously been identified as an area with potential methane problems due to large deposits of organic fills and natural peat. An air supply piping system was installed prior to pouring the slab, consisting of ten wells all connected to the same supply line. Each well was supplied with an accessible valve to allow for adjusting of pressures during balancing and commissioning of the system. Some difficulty was encountered in construction of the system since the PVC methane/air supply pipes confused plumbers involved in other work. At the time of writing the system had not yet been connected and no post construction tests results were available.

**CMHC SOIL GAS RESEARCH PROJECT**
**WESTERN CANADA SECTOR**
**CASE STUDY #9**

**BUILDING TYPE AND LOCATION:** Commercial building, burnaby, British Columbia

**GAS TYPE:** Methane

**SOURCE:** Peat and wood waste fill

**TYPE OF CONTROL USED:** Vacuum extraction through pipes around exterior building

**CASE STUDY PRÉCIS:**

The new Thunderbird retail supply building was being constructed in areas suspect of methane generation. Tests inside the building prior to completion indicated up to 70% methane. (An aquarium pump and tubing were used to suction air from beneath the slab through cracks in concrete; the pumped gases were shown to maintain a constant flame at the outlet of the tubing.) A complete exterior piping system was installed across the building (over 30 m). One connection point was provided to install a vacuum blower if necessary. When construction was nearing completion, the municipality refused to issue an occupancy permit until evidence was provided of an effective solution. At that time of writing, the system had not been hooked up.

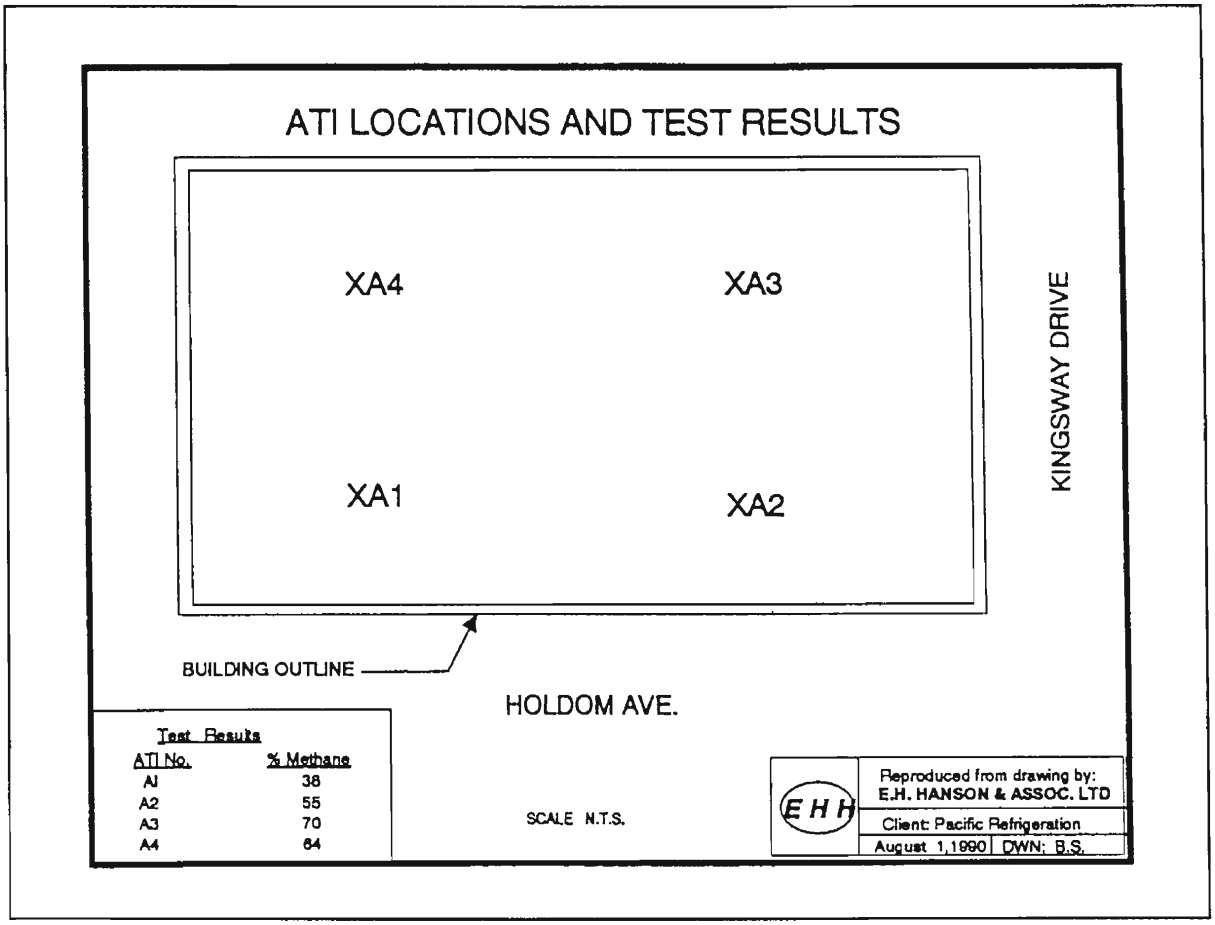



**Figure C-16**
**Plan of Building Showing ATI Locations and Results**

# CMHC SOIL GAS RESEARCH PROJECT
# WESTERN CANADA SECTOR
# CASE STUDY #10

| | |
|---|---|
| **BUILDING TYPE AND LOCATION:** | Commercial building, Burnaby, British Columbia |
| **GAS TYPE:** | Methane |
| **SOURCE:** | Natural peat |
| **TYPE OF CONTROL USED:** | Pressurization pipes on one side of the building, with passive venting on opposite side |

**CASE STUDY PRÉCIS:**

A methane control system was installed in 1990 in the Mandeville Avenue Building. Within several hours of system operations methane concentrations in the building were reduced to undetectable levels except for one corner. After three days of constant operation, all areas of the building were shown to be free from methane. Spot checks indicate the system is performing well.

**CMHC SOIL GAS RESEARCH PROJECT**
**WESTERN CANADA SECTOR**
**CASE STUDY #11**

**BUILDING TYPE AND LOCATION:** Sports complex, North Vancouver, British Columbia

**GAS TYPE:** Methane

**SOURCE:** Premier Street landfill

**TYPE OF CONTROL USED:** Passive gas control using double CPE membrane beneath building foundation

**CASE STUDY PRÉCIS:**

In 1983 the corporation of the District of North Vancouver began construction of a change house for a sports complex located on a closed portion of the Premier Street landfill. The change house was to include dressing rooms and showers. Consultants were employed to design and supervise construction of a passive gas barrier and to prevent infiltration of methane gas, and other landfill gas components, into the building. A gas extraction system was installed at the site to utilize some of the landfill gas as a heating fuel. Accordingly a furnace and hot water tank were retrofitted to accept landfill gas as a substitute fuel. A compressor and a 909 litre pressure tank along with control valves is used to feed the furnace and water tank. Despite massive cracking of the floor slab and foundation the passive barrier has proven effective. The barrier consists of two layers of CPE membrane separated by a sand filled layer. Over an eight year period no methane has been detected immediately below the slab. The fuel supply system has required some maintenance, especially to the compressor and pressure control valves; the original heating appliances are still operating and are reliable.

**CMHC SOIL GAS RESEARCH PROJECT**
**WESTERN CANADA SECTOR**
**CASE STUDY #12**

**BUILDING TYPE AND LOCATION:** Single family residence, British Columbia

**GAS TYPE:** Methane

**SOURCE:** Landfill

**TYPE OF CONTROL USED:** Active collection plus air pressure motivation

**CASE STUDY PRÉCIS:**

During development of a subdivision, the municipal engineering department requested testing of the utilities to determine if methane from a nearby landfill might be inundating the system and causing a potential hazard for the new homes. Spot testing at the adjacent roadway showed high levels of methane in the ground and piped services. A newly constructed recreation centre was also affected. The solution involved a series of air curtain systems installed at key locations around the landfill. Most of the collected methane was extracted and flared; a portion of the gas was used as a supplemental heating fuel for the nearby municipal recreation centre. The air curtain system was omitted at the eastern boundary where migration was thought to be unlikely. Consequently methane managed to migrate through the opening and traversed a distance of 150 m into a subdivision. Additions to the air system so as to completely surround of the landfill, proved effective as a long-term solution.

**The Problem**

In 1983, a municipal engineer requested that the consultants check the utilities on a residential street to investigate the possibility of methane migration from a nearby landfill. Methane was of particular concern because of a subdivision would ultimately accommodate about 165 homes. High concentrations of methane were found in the storm sewers. Storm sewers were particularly affected because they were fitted with open joints to allow water to infiltrate. The storm sewer proved to function well as a gas collection system. Despite warnings to trades, a paving contractor softening pavement with a propane torch around a catch basin managed to ignite the methane. The explosion blew off a dozen manhole covers. After extensive reviews consultants were asked to design a system capable of clearing gas from utilities, keeping gas away from the developing subdivision, and to capture some of the gas for use as a heating fuel.

## The Solution

The methane control system consists of two rows of wells. An inner row, closest to the landfill, used for vacuum extraction. An outer row, nearest the subdivision, was used for air injection. A cross section of the air curtain system, including the landfill and subdivision, is illustrated in Figure C-17. The arrangement of air curtains was intended to create an underground airflow in the opposite direction to which migration of methane was taking place. Three such air systems were installed around the landfill and the adjoining agricultural building. A 60 m gap on one section of the curtain was thought to be acceptable, since there were no homes in this area. Methane collected in a separate vacuum extraction method was used to heat the 2800 $m^2$ recreation building.

## Post Construction Test Results

It took about two months of operation before the subdivision was cleared of methane. This system was not 100% successful. After completion of the subdivision, methane managed to penetrate around the air curtain system, an open field and into the subdivision and inundating the basement of a single family residence. Investigations revealed that the methane had followed an underground river bed, under the frozen ground in the winter time, taking a circuitous path through the 61 m gap path in the air curtain system. Extension of the air curtain system prevented any further problems with methane migration into the subdivision.

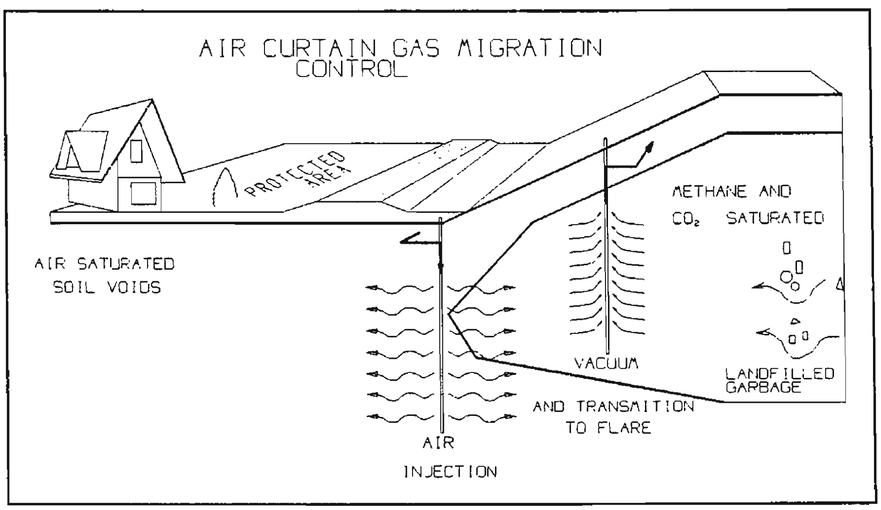



**Figure C-17**
**Conceptual Schematic Showing**
**Air Curtain System**

# CMHC SOIL GAS RESEARCH PROJECT
# WESTERN CANADA SECTOR
# CASE STUDY #13

**BUILDING TYPE AND LOCATION:** Condominium complex in Victoria, British Columbia

**GAS TYPE:** Methane

**SOURCE:** Old landfill

**TYPE OF CONTROL USED:** Extraction wells were placed along one side of the building next to the foundation, and connected to a continuously operating extraction blower

## CASE STUDY PRÉCIS:

A luxury condominium was to be built over top of a depression on a rocky shore line in Victoria. The depression had previously been used as a landfill for a wide variety of waste material. Pre-construction field tests showed methane concentration up to 20%. An extensive methane control system was designed and approved prior to obtaining building permit. Slotted suction wells and connection piping were installed along the perimeter of the building next to the old landfill, and connected to a blower permanently mounted inside the building's mechanical room. Post construction monitoring for a period of several months showed a rapid drop in methane concentration. Methane was undetectable below the building, and in ppm levels at the extraction wells.

### The problem

Extensive high quality property development was taking place along the Victoria waterfront in an area known as the Songhees Development. Pacific Nations' Investments own a portion of this land and designed a condominium/building to accommodate 45 units. The Municipality was reluctant to provide a building permit since the site had previously been used for municipal solid waste disposal. The site had also been a recipient of waste from railway yards, indicating fuel oil, various tars and creosote. A paint factory was also located on the site, raising the possibility of lead contamination. A depression in the waterfront property has been completely filled with this mixed waste, and closed years ago.

During site testing, some of the industrial contaminants were removed. However, complete removal was an excessively hazardous proposition. Methane concentrations were measured up to 20%, and the developer had no choice but to prepare a methane control plan for submission to the Municipality. This plan had to include protection for the building, roadways and utilities including sanitary and storm sewer.

**The solution**

The piping for a gas extraction system was installed in February, 1990. The system consisted of a series of extraction wells 6.1 m deep along the perimeter of the foundation wall, with perforated piping used in the lower half. This system allows for extraction of soil gases from below the footing levels of the building. The slotted suction wells and connection piping were fed into the building and connected to a blower in the mechanical room. An outlet for the extracted gas was installed adjacent to the outlet vent of the exhaust system for the underground parking area. Valves were placed in each of the suction pipes leading in to the storm and sanitary manholes. All of the valves are located in the concrete box, and could be adjusted to vary the amount of suction from the storm sanitary sewers, and the extraction wells. A timer was installed at the blower, but it was left continuously running due to the high methane concentrations. A vacuum blower was operated at 1 kPa. Gas detectors were installed in four locations in the parking level.

**Post Construction Test Results**

The system began operation in early March 1990, at which time exhaust from the blower measured 10 to 100 ppm methane in air. Testing was conducted in five different wells and in the storm and sanitary manholes, and throughout a three month period. The storm and sanitary piping tests consistently showed no detectable methane. Concentrations in all five wells were noticed to drop over the course of the three-month testing period. In one well, levels persisted in the 0.7% range.

Problems were encountered with the gas detector alarms. These alarms kept triggering as a result of a poorly designed parking garage ventilation system, which would draw combustion gases into the garbage room and parking lot blower room, and then shut off before complete evacuation had been achieved. The Nutech Methane detectors (100 ppm) were frequently triggered in both these locations, until the parking lot ventilation system was re-configured. The methane system had succeeded in revealing problems in the building unrelated to methane.

Recent high readings have been experienced on at least one occasion due to an unknown cause. Snow melt may have brought hydrocarbons into the foundation area, or the walls may be unable to prevent methane migration through all portions of the slab.

**CMHC SOIL GAS RESEARCH PROJECT**
**WESTERN CANADA SECTOR**
**CASE STUDY #14**

**BUILDING TYPE AND LOCATION:** Condominium complex, Victoria, British Columbia

**GAS TYPE:** Methane

**SOURCE:** Abandoned landfill containing municipal and industrial waste

**TYPE OF CONTROL USED:** A series of wells located around the perimeter of the foundations used for both active extraction of soil gas and active injection of clean air

**CASE STUDY PRECIS:**

Ocean Park Towers is one of the first multi-family residential buildings in Western Canada built directly over a garbage dump. In a similar fashion to the neighbouring Pacific Nations building, (Case Study #13), a developer of a condominium complex (Ocean Park Towers) was required to install an effective methane control system to protect the new building from methane generated by municipal waste that had been used as fill for depressions along a rocky shoreline in Victoria. Unlike the neighbouring building, the Ocean Park Towers system involved both an injection and an exhaust piping system, with two blowers. This two blower system was felt to be warranted because the Ocean Park Towers is located directly on top of the old landfill, whereas the Pacific Nations development only straddled portions of the landfill.

Figure C-18 shows the piping system layout, including vacuum and pressure blowers. Figure C-19 shows some details at the injection points. The use of two blowers in this system was thought to provide a significant measure of confidence for system performance, and provides an interesting comparison with the active extraction system next door. At the time of writing, however, no post construction test results were available.

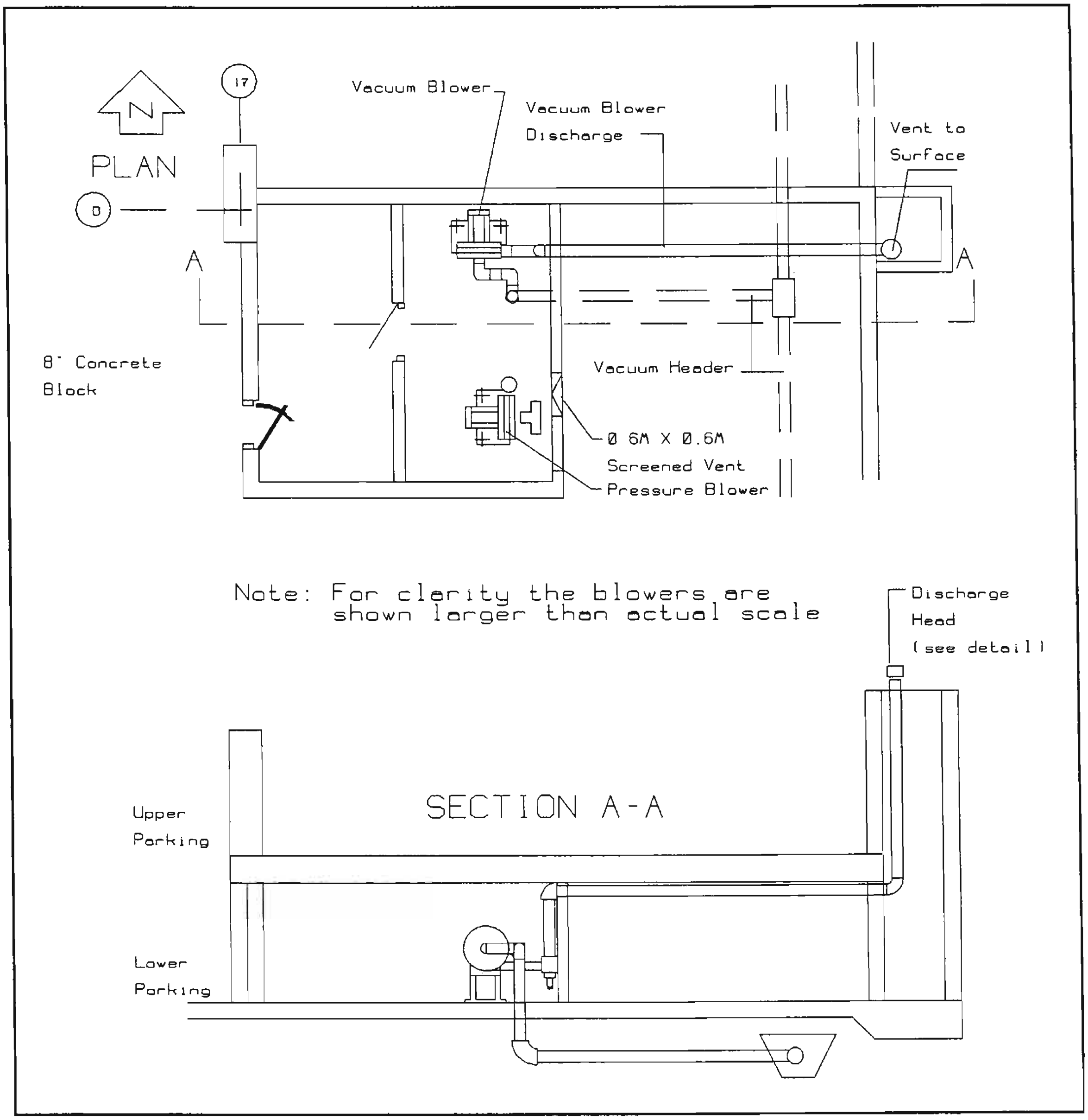



**Figure C-18**
**Schematic Showing General Arrangement**
**at the Blower Control Room**

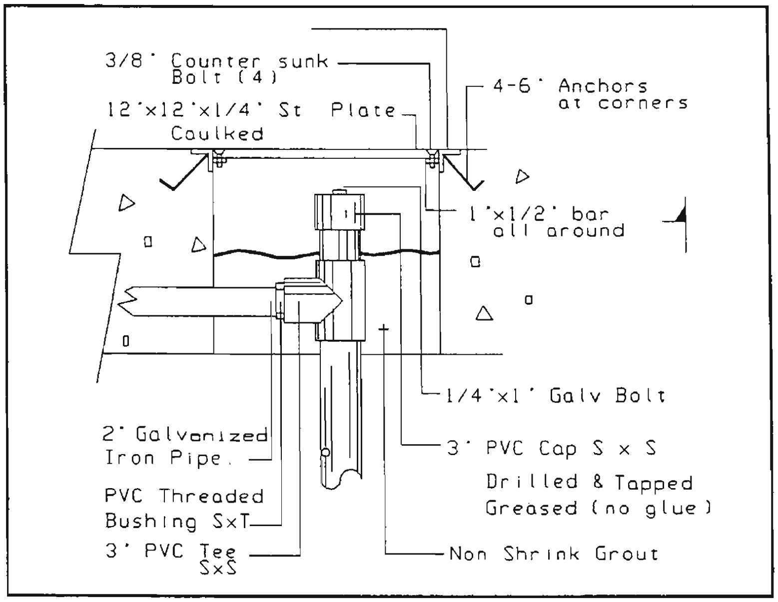



**Figure C-19**
**Typical Arrangement at an Injection Well**

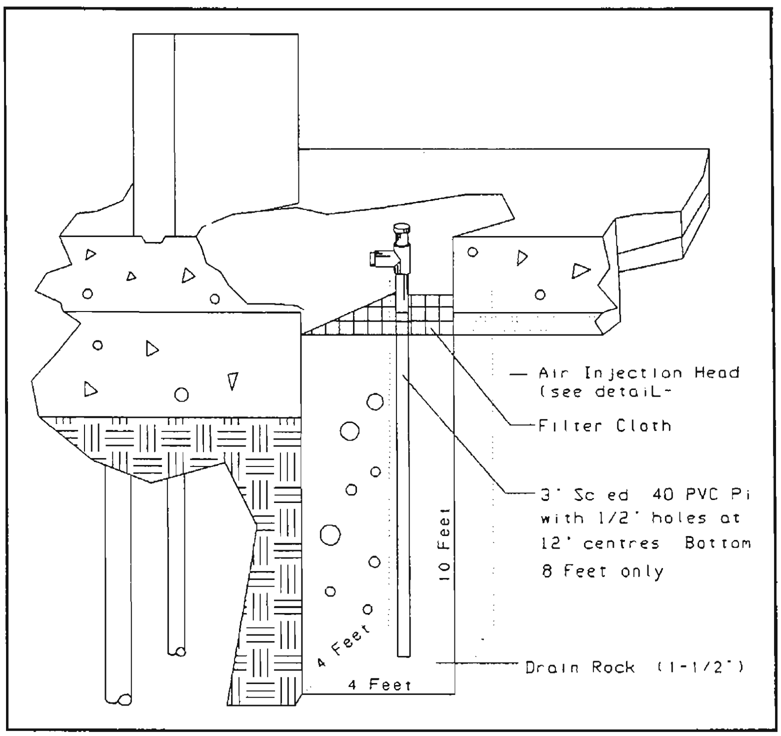



**Figure C-20**
**Placement of Injection Well at Parkade Slab**



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## CMHC SOIL GAS RESEARCH PROJECT
## WESTERN CANADA SECTOR
## CASE STUDY #15

**BUILDING TYPE AND LOCATION:** Single family residences, Burnaby, British Columbia

**GAS TYPE:** Methane

**SOURCE:** Landfill

**TYPE OF CONTROL USED:** Three-prong approach consisting of a trench line with polyethylene, a pressurized air well between the trench and the landfill, a series of extraction wells uphill from the trench

**CASE STUDY PRÉCIS:**

In 1982, problems were encountered with methane gas migrating uphill from the Stride Avenue landfill site, into the single-family residences. The first strategy employed to purge methane was the excavation of a 6.4 m deep trench uphill from the landfill. The trench was back filled with drain rock and lined with a high density polyethylene geomembrane. At the bottom of the trench a horizontal perforated pipe was installed. It was hoped that the high density polyethylene barrier would in itself curtail the gas migration as a passive system, so that blowers would not be required. This did not occur, however, and gas migrated under the barriers. Subsequently a vacuum was induced by blower at the horizontal pipe. This also failed to stop the migration of the gas under the barriers. Ultimately, a series of pressure wells and monitoring wells located between the trench and the landfill were continuously pressurized using a blower. Migration of methane was stopped only when the 21 m deep wells were pressurized. Figure C-21, a cross section of the area, shows the location of soil waste, pressure wells, trench and monitoring wells.

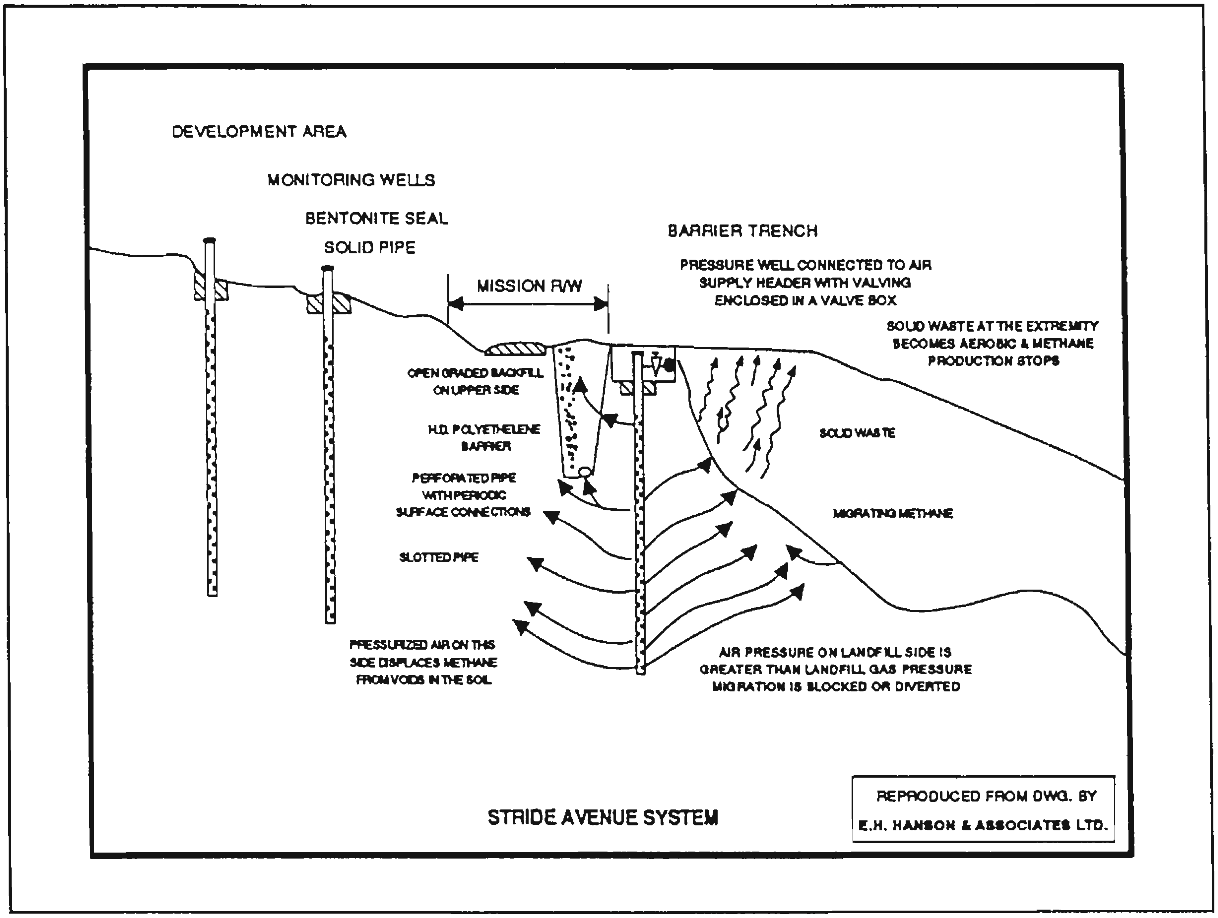



**Figure C-21**
**Cross Section of Area**

**CMHC SOIL GAS RESEARCH PROJECT**
**WESTERN CANADA SECTOR**
**CASE STUDY #16**

**BUILDING TYPE AND LOCATION:** Truck repair maintenance facility, Coquitlam, British Columbia

**GAS TYPE:** Methane

**SOURCE:** Nearby commercial landfill (Leeder landfill)

**TYPE OF CONTROL USED:** Passive exhaust methane control system converted to an active pressurized system

**CASE STUDY PRÉCIS:**

A commercial truck repair facility was built over a landfill that had received putrescibles prior to 1980. At the time of construction, consultants designed a passive foundation venting system, consisting of pipes beneath the slab, and a vertical vent fitted with a turbine cap. The ground was very unstable so piled foundations were constructed. Over time, the ground settled beneath the building creating a large cavity. The foundation venting system actually contributed to the collection of methane, by channelling methane under the paved area to the vents. The methane production was greater than the capacity of the passive vents, thus methane accumulation occurred.

A plumber fixing a broken water pipe on the foundation perimeter inadvertently, and unknowingly, started a ground fire below the foundation. The next day, truck mechanics noted that the walls and floors of their truck bay were hot enough to fry eggs. Firemen investigated and discovered a gas fire under way, which they would not put out for fears that explosive levels of gas would accumulate.

A two-stage retrofit to the methane control system was proposed which involved the continuous air injection into the cavern and then later a second set of perimeter wells would serve to extract methane. Only the first stage of this retrofit strategy was implemented. The volume of flow created by the pressurization blower managed to reduce concentrations of methane to a reasonable level. The owner elected not to complete the second stage.

**CMHC SOIL GAS RESEARCH PROJECT**
**WESTERN CANADA SECTOR**
**CASE STUDY #17**

**BUILDING TYPE AND LOCATION:** Large proposed subdivision plan, Richmond, British Columbia

**GAS TYPE:** Methane and hydrogen sulphide

**SOURCE:** Marsh lands, including marine depositions of organic material covered by silt

**TYPE OF CONTROL USED:** Subdivision layout was organized to avoid pockets of contaminated soils, excavation of the most productive pocket, backfilling of site with sand to help deodorize marsh gas and testing of all sites prior to construction to determine control requirements

**CASE STUDY PRÉCIS:**

Approval was given to Progressive Construction Limited for residential subdivision of land in the extreme western hedge of Richmond, next to the ocean. This area had been known by the Indians in the area as land of the bubbling waters, and had many pockets of organic silts and marine deposits that generated a combination of methane, carbon dioxide and hydrogen sulphide. Many years ago, farmers in this area had managed to trap gas and use it for heating. Some of the ditches on the coastal side were heavily odorous due to the presence of hydrogen sulphide.

Consultants were employed to prepare a strategy for controlling marsh gases in this area. As a result a thorough testing program was undertaken which involved bar hole testing, a drilling program with augers, a gas extraction testing of the rate of marsh gas production, and simulation of typical foundations at hazardous locations.

A cross section of the soil composition, based on the auger testing, is presented in Figure C-22. A plan of the subdivision area, showing the distribution of methane producing sub-soils, and the location bar holes, test pits, auger holes and simulations, is illustrated in Figure C-23.

The result of the testing indicated that concentrations of methane are significant in some pockets below the silt, but the storage and the rate of production is not normally sufficient to create a hazardous condition for above ground structures. The consultants pointed out that once ditches are filled, some other mechanism should be in place to allow for venting the contaminated sand and organic deposits below the silt.

The methane control strategy for the entire area including the recommendations are:

- removing the organic materials for reuse or disposal. Filling of ditches with porous material to allow constant venting over long areas;
- using river sand on tops of trenches to help deodorize hydrogen sulphide (sands contain elemental iron which reacts with $H_2S$);
- wherever possible, avoid the penetration of the silt barrier during surface construction;
- drilling and testing of each residential lot in suspect areas to assess the need for gas vents and/or membrane applications; and
- testing of utilities after insulation to insure that methane is not breaching the silt barrier.

At the time of writing, the heavily contaminated pockets of organics have been excavated and removed from the site. Construction of residential buildings over the suspect areas has not yet been undertaken.

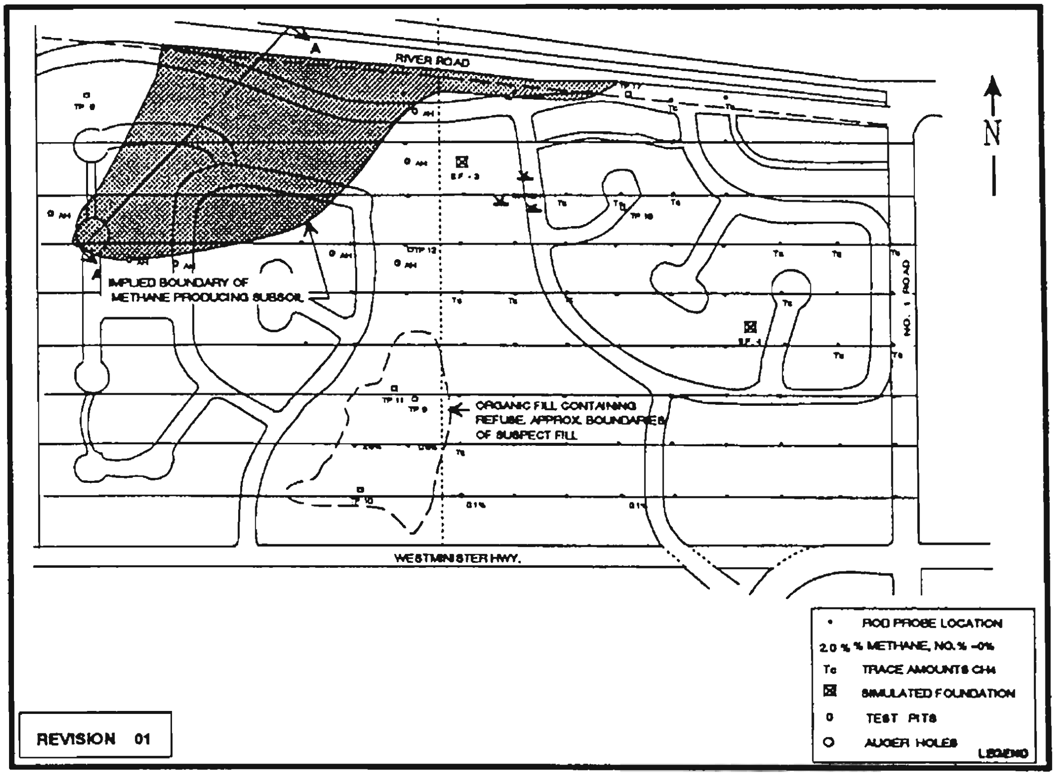



**Figure C-22**
**Plan of Terra Nova**

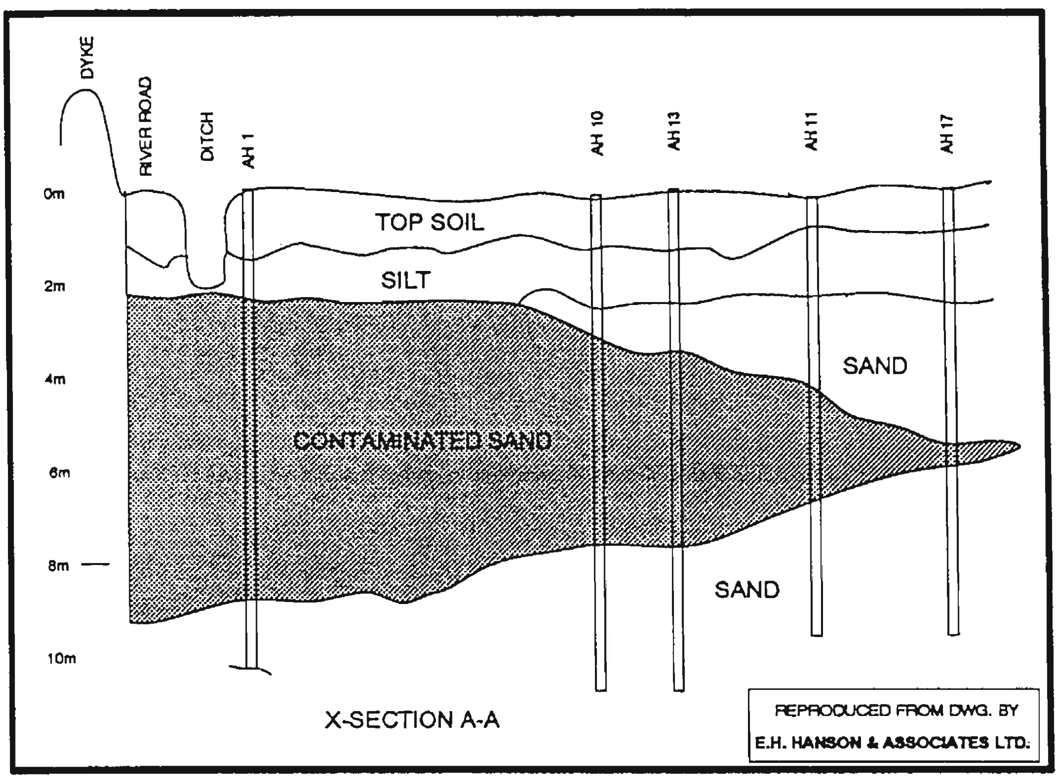



**Figure C-23**
**Section through Contaminated Zone**

**CMHC SOIL GAS RESEARCH PROJECT**
**WESTERN CANADA SECTOR**
**CASE STUDY #18**

**BUILDING TYPE AND LOCATION:** Retirement housing complex, Penticton, British Columbia

**GAS TYPE:** Odours, possible hydrogen sulphide, possible heavy metals

**SOURCE:** Prior use of site by an orchard chemical formulation plant

**TYPE OF CONTROL USED:** Excavation of topsoil and replacing with clean fill, more extensive sealing during construction of crawl space

**CASE STUDY PRÉCIS:**

A retirement housing complex was planned for construction on a lot in Penticton, British Columbia that had previously been occupied by Oliver Chemicals, a manufacturer of pesticides and other products for farmers in the area. During initial excavation work on the site, peculiar odours were reported, and the B.C. Ministry of Environment, Waste Management Branch was asked to investigate. Further excavation of the site showed similar odours and dark coloration of the soils. Previous use of this site suggested that lime salt or formulations were present with dormant oil. Two tests of soils from the site showed a surface contamination of 0.9% hydrocarbon and 1.6% sulphur. The same location at a 1.2 m depth showed little change in hydrocarbons with a reduction in sulphur to less than 0.5%.

On the recommendation of the Ministry of Health, the top 0.6 m of material was removed and replaced with fresh fill and top soil. In addition, on recommendation from the Ministry of Health, the floor of the crawl space was to be effectively sealed from underlying material. The occupants of the site were not to be permitted to grow vegetables or other consumable items on the land.

Discussions with building inspectors indicated the extra sealing measures involved in construction consisted of laying a sheet of polyethylene on top of the clay parts and pouring a slush coat of concrete in the crawl space. The polyethylene was held tight to the wall. No odours were noticed on site after the contaminated materials have been taken to the dumps. No complaints have been received since, although post construction testing was not undertaken.

**CMHC SOIL GAS RESEARCH PROJECT**
**WESTERN CANADA SECTOR**
**CASE #19**

| | |
|---|---|
| **BUILDING TYPE AND LOCATION:** | High density residential, commercial buildings and open space, recreational property |
| **GAS TYPE:** | Organic and inorganic based gases, methane, benzene |
| **SOURCE:** | Waste fills, industrial chemical spillage |
| **TYPE OF CONTROL USED:** | Excavation, treatment and disposal of offending soils was considered along with in situ controls. Passive gas venting systems in combination with synthetic barriers are to be installed. Optional active gas extraction and disposal systems are being considered. |

## CASE STUDY PRÉCIS:

The former Expo 86 site which is located in the central part of Vancouver at False Creek contains industrial chemical wastes and other refuse deposits. Prior to development, specific sections will be either sealed or the soils remediated. Some soils remediation methodologies are to be tested in 1991 and disposal of some soils at industrial landfills is being considered. The site consists of 9 abutting parcels of land on 82.5 ha. at the north shore of False Creek. The south shore has already been developed extensively into town houses and garden apartments. The soils assessments show that the area of greatest contamination (parcel #9) contains significant levels of methane and hydrocarbon gases. As the first step towards a solution this Parcel has been designated as open space park. The intent of the designation as parkland is to limit any excavations into the contaminated soils. The parkland preparations call for the grounds to be covered with synthetic membranes and the captured gases passively vented. The discharges will be monitored, and if it is warranted, a gas treatment/filtration process installed.

### The Problem

False creek is small sea inlet which was the focus of industrial and commercial activity for the City of Vancouver beginning in the 1890's. It was a desirable location for the myriad industries serving the CPR railway, marine forges and wood sawmills on the West Coast.

The 82.5 ha on the Northern half of the shoreline is more commonly known as the site for the 1986 World Exposition. In the decades preceding the worlds fair, the grounds were filled and levelled to serve as industrial water frontage. Portions of the land surrounding the inlet have been filled with refuse materials of many types including wood waste, cattle manure, heavy metals and industrial hydrocarbons. Up to 12 metres of contaminated fill have been identified.

In the course of decades of industrial activity, waste chemicals were absorbed into the fills or discharged into the waterway. Contaminants found in the sludge of the inlet beds have been dredged and previously disposed by ocean dumping. Land based contamination levels were highest in the vicinity of a former coal gasification plant and at the CPR maintenance facility.

The designation of the site for a worlds fair was preceded with the purchase of the property by Crown Corporations. The ensuing worlds fair served as a focus for a massive redevelopment of the land and helped expedite the first major infrastructure improvements in the area. The opposite side of the inlet has been extensively redeveloped for townhouse and high rise condominiums.

At the completion of the fair, the site was purchased by private investors who intend to develop the land into residential and commercial properties. This sales transaction was subject to environmental assessments and acceptable remediation of the lands by the former owners who now are essentially the people of British Columbia. Assessment have been completed and have been the subject of much controversy.

Assessments of the land are based on the separate examination of 9 parcels which make up the original property. The testing of the site was undertaken using truck mounted drills together with soil sample extraction for analysis. Permanent water table monitors and gas samplers were installed in boreholes. This was combined with surficial bar hole testing for combustible and trace gases. Results show that each parcel varies in contamination levels and consequently, the types of remediation will vary across the site.

The highest contamination is at parcel #9 which surrounds the site of the former coal gasification plant. At this point, significant levels of methane and coal tar based vapours were encountered (naphthalene, toluene, benzene). In addition, cyanide and heavy metals have been recorded in ground water and soil. Risk analyses indicate that the contaminants on the site require control to protect the public.

**The Solution**

Each parcel of land will be treated according to the contaminant levels. At most locations isolated pockets of contaminated soils will be excavated for lower foundations structures. Where acceptable, these soils will undergo remediation, be reused or be removed from the site to industrial landfills. Since no contamination criteria levels have been legislated for this province, the B.C. Ministry of the Environment has adopted the criteria used by Quebec.

Soils gases at some locations with low hazard levels will be controlled to prevent intrusion at underground structures. Detailed designs for the controls have not been done as yet but they may involve both passive and active types of systems using perforated collectors and blowers.

Parcel #9, which has the most serious soil gas problem will be the first area to be developed and made accessible to the public. At an early stage and after careful consideration for public exposure, it was decided that the soils at this parcel be isolated rather than disturbed. It was stipulated that no foundation excavations will be done here and to facilitate this decision, the site was zoned as a park.

The park design is now in final preparation stages. Conceptually the soil gases are to be controlled using horizontal low permeability barriers and be channelled and vented away from park users. As well, ground water movement will be partially immobilized using vertical bentonitic slurry walls. This will limit but not eliminate contaminated ground water seepage into the inlet.

The control of soil gases will be intensely pursued in the site preparation. The existing surface, which is already predominantly paved will be levelled with porous fill and resealed using a high density polyethylene liner. Above the liner, drainage water will be collected and removed; below the liner a network of horizontal perforated gas collection pipes will be installed. The surface will then be filled with mineral soils and landscaped to provide a finished park surface. Initially the gases will be passively collected and vented in a controlled fashion, possibly at elevated points using lamp standards. The gases will be monitored and if deemed appropriate, the system could be upgraded to active extraction. Gas treatment would be installed if test results demonstrate that the requisite emission standards by free venting are not met. Treatment may involve activated carbon filter systems.

**CMHC SOIL GAS RESEARCH PROJECT**
**WESTERN CANADA SECTOR**
**CASE STUDY #20**

| | |
|---|---|
| **BUILDING TYPE AND LOCATION:** | Detached single family residence, Blarmore, Alberta |
| **GAS TYPE:** | Sewer gas, possibly coal methane |
| **SOURCE:** | Organic wastes from sewage |
| **TYPE OF CONTROL USED:** | No control strategies implemented as yet; house abandoned |

## CASE STUDY PRÉCIS:

In 1988, the Canada Western Natural Gas Company (CWNG) during routine checks along gas pipelines in a Blarmore housing sub-division, with underground detection equipment, tracked high concentrations to a house belonging to a local Dentist who was away on vacation at the time. After analysis by CWNG it was concluded after drilling over 400 test bores, that gas leakage from pipelines in the local grid was not the source. Methane levels in the house were measured at less than 1%. Failing this, an abandoned coal mine near the property was suspected as a source. Energy Resources Conservation Board (ERCB) officials' were called in to investigate levels of coal methane levels showed no detectable levels. The source was finally traced to sump hole located in the basement of the house where a build up of black, organic sludge had been developing over an extended period of time (possibly 2 to 3 years). A sample of the sludge was neutralized and tests found it to be producing methane. It is suspected that a inoperable backwater valve in the building drain has caused sewage to backup into the sump. After the investigations began, the house was abandoned and has not been reoccupied.

### The Problem

Although there had been no complaints by the homeowner about the gas fumes, the CWNG were obliged to quarantine the building until it was conclusive that no NG grid pipe leakage was responsible. Once they were convinced of there findings however, it became the responsibility of the ERCB, who are responsible for appraising coal reserves in the province, investigate the possibility that a nearby abandoned coal mine did not have a coal seam that extended below the house or that no coal methane from the mine had somehow infiltrated the soil around the house. ERCB measured concentrations in mine openings nearby and found none to be excessive. The geology of the terrain implied that it was unlikely the gas stemmed from the mine since the coal seam was on a higher sedimentary strata than the house. As the investigation drew closer to the house, it was found that the levels of gasses were starting to increase. ERCB test holes dug 1 m below the surface in the backyard of the house yielded measured concentrations of flammable gas as high as 60%. It was difficult to distinguish the exact type of gas sampled on site. Coal methane and natural gas are very similar though coal methane is inherently cleaner.

The only logical solution was that the source was nearby and it finally concluded after sampling sludge taken from a sump in the basement of the house, that partial failure of the sanitary system - ie. a blocked back-water valve - had caused sewage to back up into the soil surrounding the house. No strong odours were detected in the house until after the sump was opened.

**The Solution**

The solution at this point seems to be that the property will require excavation and repair to the plumbing system. The householder has received a settlement for his property and it is not known at this time when any remediation work will begin.

# CMHC SOIL GAS RESEARCH PROJECT
# WESTERN CANADA SECTOR
# CASE STUDY #21

| | |
|---|---|
| **BUILDING TYPE AND LOCATION:** | Commercial retail store with below grade basement and concrete foundation walls, Milk River, Alberta |
| **GAS TYPE:** | Oil and gasoline related hydrocarbon product and vapours |
| **SOURCE:** | Numerous gas stations both active and abandoned facilities |
| **TYPE OF CONTROL USED:** | Interceptor drain tile installed with sump. Wastewater from interceptor drain pumped to storm sewer and discharged to sanitary storm sewer for eventual treatment at municipal waste treatment facility |

**CASE STUDY PRÉCIS:**

In 1978, the owner of the Milk River Pro Hardware Store registered a complaint with Alberta Environment (AE) over a problem with obnoxious hydrocarbon fumes entering the basement of his store preventing use of basement for warehouse storage. A follow-up investigation undertaken by AE staff indicated substantial hydrocarbon contamination had already occurred adjacent to the site in a shallow groundwater flow system upgradient of the Hardware store. Further study indicated that the actual leak or spilling causing this problem had occurred a considerable amount of time prior to reporting of the vapour incidence to AE. After a historical review of the area, it was determined that 7 to 10 gasoline station retail outlets had previously, or were presently operating in the vicinity. To determine the exact source of the spill or leakage would have required an extensive investigation and therefore this alternative was not pursued. A decision was made by AE to assist the store owner in correcting the problem by increasing drainage.

## The Problem

Initial study indicated that determining the source of the outlet would not be practical for time and economic reasons. The owner of the hardware store was requesting immediate assistance to eliminate the odour problem in his store. Fumes appeared to only be a problem when groundwater levels were higher than the basement floor height. Soil testing in the vicinity of the store showed that a considerable area had been contaminated by the hydrocarbon product.

The testing also revealed that the product had migrated a substantial distance prior to being reported. The actual product being transported by the shallow groundwater flow system emerged as a very thin film that could not be easily separated from the wastewater collected.

## The Solution

An interceptor drain tile system was constructed near the store with a pump well and pump assembly above the elevation of the store basement. It was felt that a tile drain outlet could be constructed in the path of the groundwater flow system. This would enable the product, transported in the groundwater to be collected and discharged into the towns sanitary sewer system for treatment and disposal. With the water table below the level of the store basement elevation, it was felt that vapours could be kept out using positive pressure air displacement if required.

## Post Construction Test Results

The interceptor drain effectively lowered the groundwater table adjacent to the Pro Hardware Store. Product actually being collected at the tile wastewater discharge has almost ceased except in the spring when natural groundwater tables are at their peak. Vapours in the basement have subsided and are no longer a problem since the installation of the system. Bacterial slime growth occurs regularly in the pump well immediately adjacent to the pump assembly and this requires regular maintenance. The build-up in the well does not seem to reduce the flow capacity of the system. The system is at present still functioning effectively.

## CMHC SOIL GAS RESEARCH STUDY
## WESTERN CANADA SECTOR
## CASE STUDY #22

**BUILDING TYPE AND LOCATIONS:** Residential Dwellings, Southern Alberta

**GAS TYPE:** Gasoline Products

**SOURCE:** Gas Bar

**TYPE OF CONTROL:** Passive venting, groundwater collection

**CASE STUDY PRÉCIS:**

In 1979, gasoline fumes were reported to be entering the basements of several residential dwellings in Southern Alberta. When the vapours became so strong, several families were evacuated. Fire department officials ordered the owners of an independent service station to conduct pressure testing of a fuel tank. A leak was found discovered; the tank was removed. Soon after the vapours disappeared and hence no further action was taken.

When heavy rains occurred one month later, gasoline vapours returned to the residence. A subsurface investigation was launched. Boreholes drilled into the subsurface indicated that a typical flood plain geology. Up to two metres of grey silt overlay a fine sand gravel and hard, grey silty clay till. Hydrogeologic studies indicated large variations in the direction of groundwater flow and water table elevation.

A gasoline sheen was also encountered during the subsurface investigation. The accompanying Figure C-24 shows the product thickness on the water table. In response to this discovery, two large diameter extraction wells were installed to control the migration of the free product. At the same time, affected residences were inspected and sealing to prevent soil gas ingress was recommended.

Due to regulatory problems, the cleanup was abandoned. By December, winter frost had set in, the vapour problems in many dwellings were enhanced. Investigations were again commenced. A shallow vapour survey was initiated to trace the product. The results suggested that the gasoline travelled south and southeast. Drilling confirmed the existence of a secondary plume, as shown on the accompanying Figure C-25.

### Control Strategy

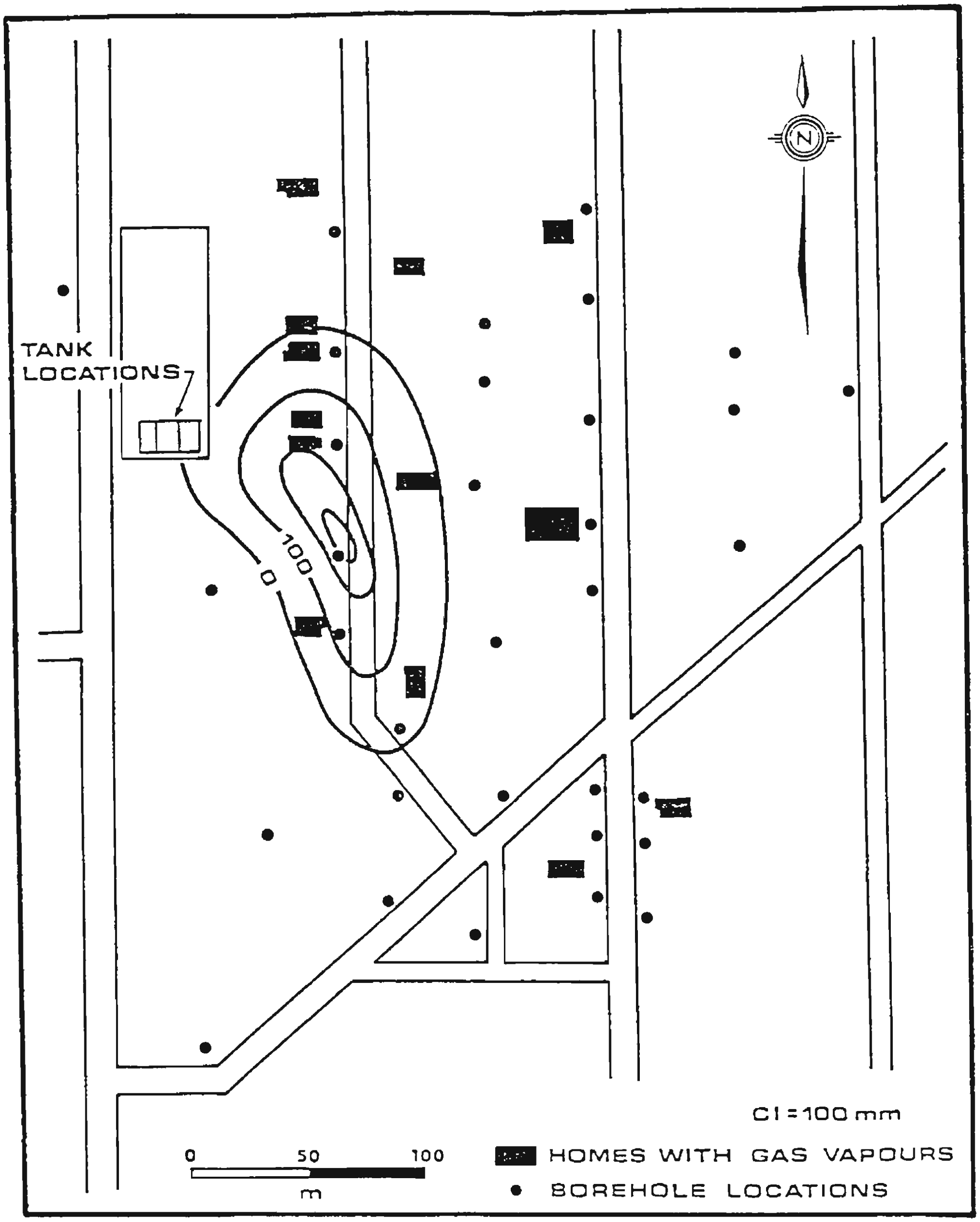
Based on the results of the hydrogeological study, three contaminant control/recovery facilities were installed. Each well consisted of a slotted large diameter culvert fitted with an explosion proof water table depression pump and a floating scavenger.

To alleviate the vapour problems in the homes, two different methods were employed. Firstly, all basements were inspected and sealed wherever possible to reduce the opportunity for ingress of gasoline vapours. The concrete basements in many of the dwellings where vapour problems had occurred were generally in poor condition, and hence complete, cost-effective sealing was difficult. The most severe problems tended to be in those areas where natural earth materials were still exposed in dug out basements. Complete sealing was not possible so a series of passive artificial vents were installed, as shown on adjoining Figure C-26. The passive artificial vents were added to eliminate the vapours during critical winter months, where seasonal frost would prevent the vapours from escaping naturally through surficial sediments. In the most critical areas, these vents were designed such that they could be equipped with a suction fan.

Throughout the project each borehole was monitored at regular intervals. A further leak was detected at the nearby service station. Despite the negative results in previous tank pressure tests, a large crack was discovered in a second tank. The tank was removed. Finally in the fall of 1980, the cleanup was abandoned.

**REFERENCE:**

O'Connor, M.J. and L. W. Bouchout, 1983. Gasoline Spills in Urban Areas: A Comparison of Two Case Histories. In Proceedings of a Seminar on Groundwater and Petroleum Hydrocarbons - Protection, Detection, Restoration. Petroleum Association for Conservation of the Canadian Environment.

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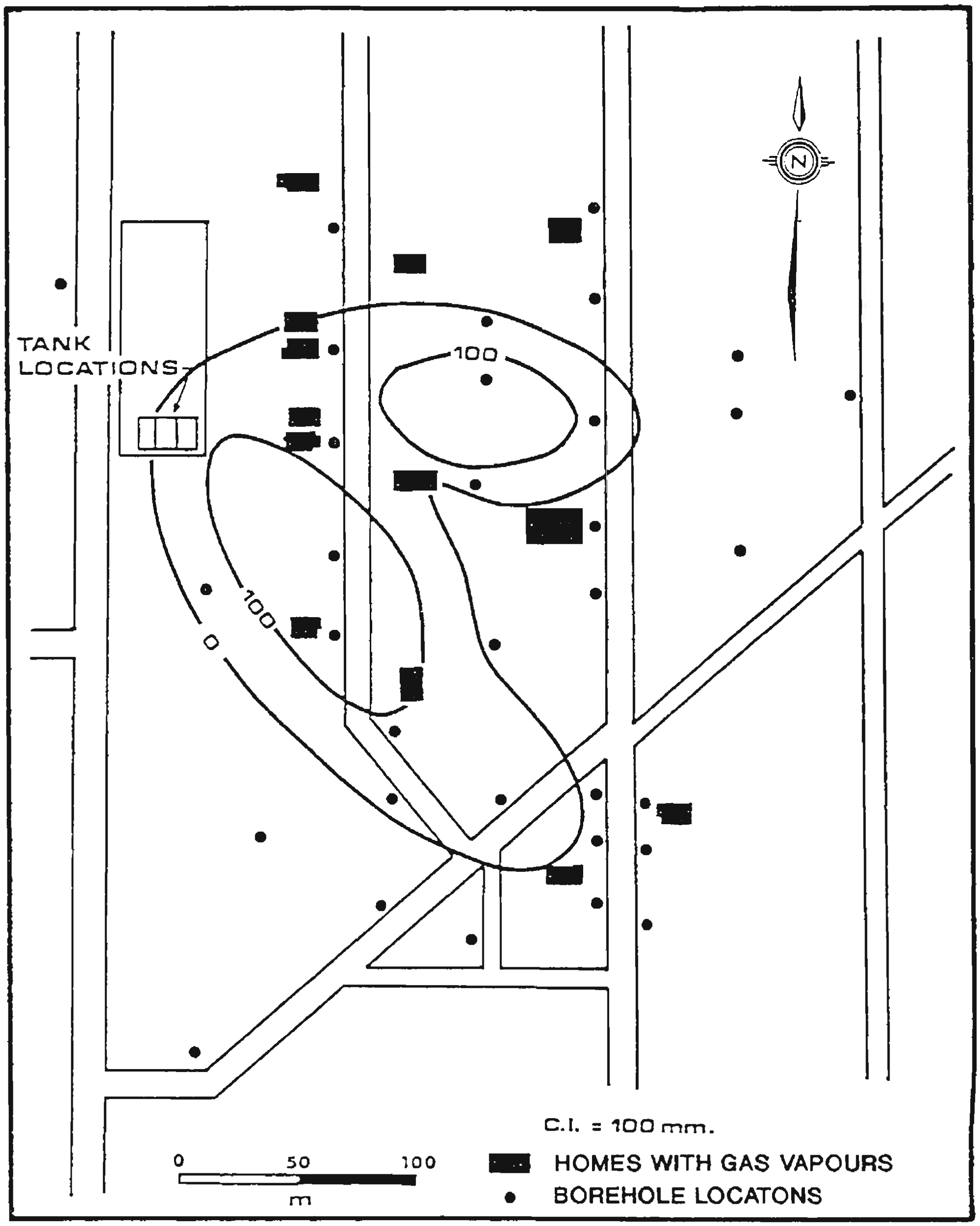
PROJECT No. ONT29396.AO.

**FIGURE C–24: GASOLINE THICKNESS (mm) IN SEPTEMBER, 1979**
**(Source: O'Connor and Bouchout, 1983)**

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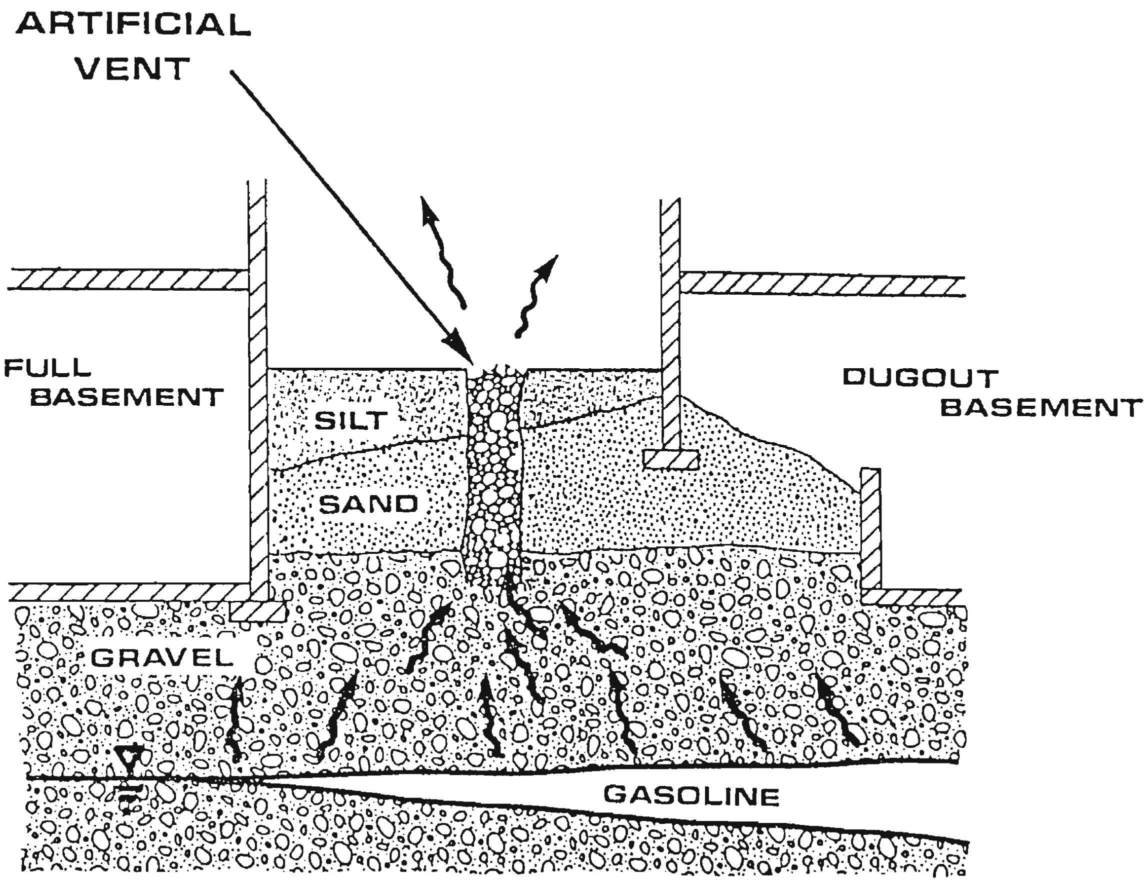
PROJECT No. ONT29396.AO

**FIGURE C-25:
GASOLINE THICKNESS (mm) IN
DECEMBER, 1979
(Source: O'Connor and Bouchout, 1983)**

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PROJECT No. ONT29396.AO

**FIGURE C–26:**
**ARTIFICIAL VENT (PASSIVE)**
**(Source: O'Connor and Bouchard, 1983)**

# CMHC SOIL GAS RESEARCH STUDY
# WESTERN CANADA SECTOR
# CASE STUDY #23

**BUILDING TYPE AND LOCATIONS:** Residential Dwelling, Western Canada

**GAS TYPE:** Gasoline Products

**SOURCE:** Gas Bar

**TYPE OF CONTROL:** Groundwater extraction, pressurization, soil vacuum extraction

## CASE STUDY PRÉCIS:

In early December 1980, gasoline fumes were detected in several sanitary sewer manholes in an urban subsurface. The fire department ventilated the sewer and began monitoring vapour levels on a daily basis. In late December, vapours were detected in nearby basements. In January 1981, a nearby service station (A) was closed due to a faulty connection (Refer to Figure C-27 for orientation). Subsequently, all underground tanks were pressure tested, and were found to be in sound condition.

By late March 1981, several residences opposite Station A were still experiencing gasoline vapour problems. At the request of the fire department, the petroleum company drilled four shallow boreholes near the affected residence. Strong vapours were noted; however, no liquid gasoline was observed at the groundwater table. During April 1982, accounting records were audited several times indicating that approximately 8,000 L of fuel could have been lost in the 6 months prior to the line leak. Most of the product was assumed to be unleaded gasoline. In view of the persistent odour problem and the possible connection with the accounting records, a full investigation was initiated.

A total of 55 boreholes were eventually drilled in the study area to determine groundwater conditions, the extent of gasoline contamination, and site stratigraphy. Boreholes were drilled on the east and west sides of the highway, around residences, and at three gasoline stations. The stratigraphy on the west side of the highway consisted of dry, loose gravel to compact brown gravel containing some sand, silt with occasional cobbles, and boulders. Thickness of the gravel ranged from 4 to 8 metres. On the east side of the highway, the surficial gravel was much thinner, having been partially replaced by silt or fine sand. Underlying the surficial geology is a dense low permeability till formation. The elevation of the till surface dips regionally to the northeast; however, the surface itself is highly undulated. The till stratum played an important part in controlling the direction and extent of contaminant flow. The accompanying

Figure C-28 shows a simplified structure section of the till surface, the position of till channels relative to the three service stations, and a nearby residence.

A composite map outlining the distribution of subsurface gasoline in the study area is shown on Figure C-29. It is apparent that most of the gasoline was confined to the channels on the till surface. It was also noted that Stations B or C could also have contributed to the vapour problem within the residence.

The most pronounced odours were encountered in houses where the basement floor slab was founded in gravel or gasoline was present under the structure. Lesser, but still significant, vapour problems were found in areas where surficial silt deposits were found. One house located on silt had a shallow dugout basement with a natural soil floor, less than one metre above the water table; no gasoline vapours were recorded in the dwelling.

In total, eight concentration recovery wells were installed in the area. Water table depression pumps equipped with floating Scavengers were placed in the wells to recover the product. Groundwater was discharged directly into the storm sewer while the recovered gasoline was held in trucks or tanks at each location.

Several controls were implemented to control the subsurface vapours. This involved:

- daily monitoring in the sewer line by the fire department
- all sewer traps were filled with water, and where odours persisted, the basements were sealed from the inside
- during the summer, sufficient ventilation was achieved by leaving basement windows open. In the winter, additional fans were used to maintain positive air pressure in the basements.
- vapour pressure in the groundwater reduced by installing two artificial active vents in the lane behind the affected residences. A large explosion-proof fan was fitted to the vents and a smaller fan was installed on the lid of one of the recovery wells.

It was concluded that recovery wells by themselves had virtually no effect on the level of gasoline vapours. Sealing of the basements was adequate to eliminate fumes in several residences. Pressure systems installed on four homes provided sufficient protection such that no further ingress of vapours could be detected. All homes were habitable throughout the winter.

**REFERENCES:**

O'Connor, J.J. and L.W. Bouchout, 1983. Gasoline spills in Urban Areas: A Comparison of Two Case Histories. In Proceedings of a Seminar on Groundwater and Petroleum Hydrocarbons - Protection, Detection and Restoration. Petroleum Association for conservation of the Canadian Environment.

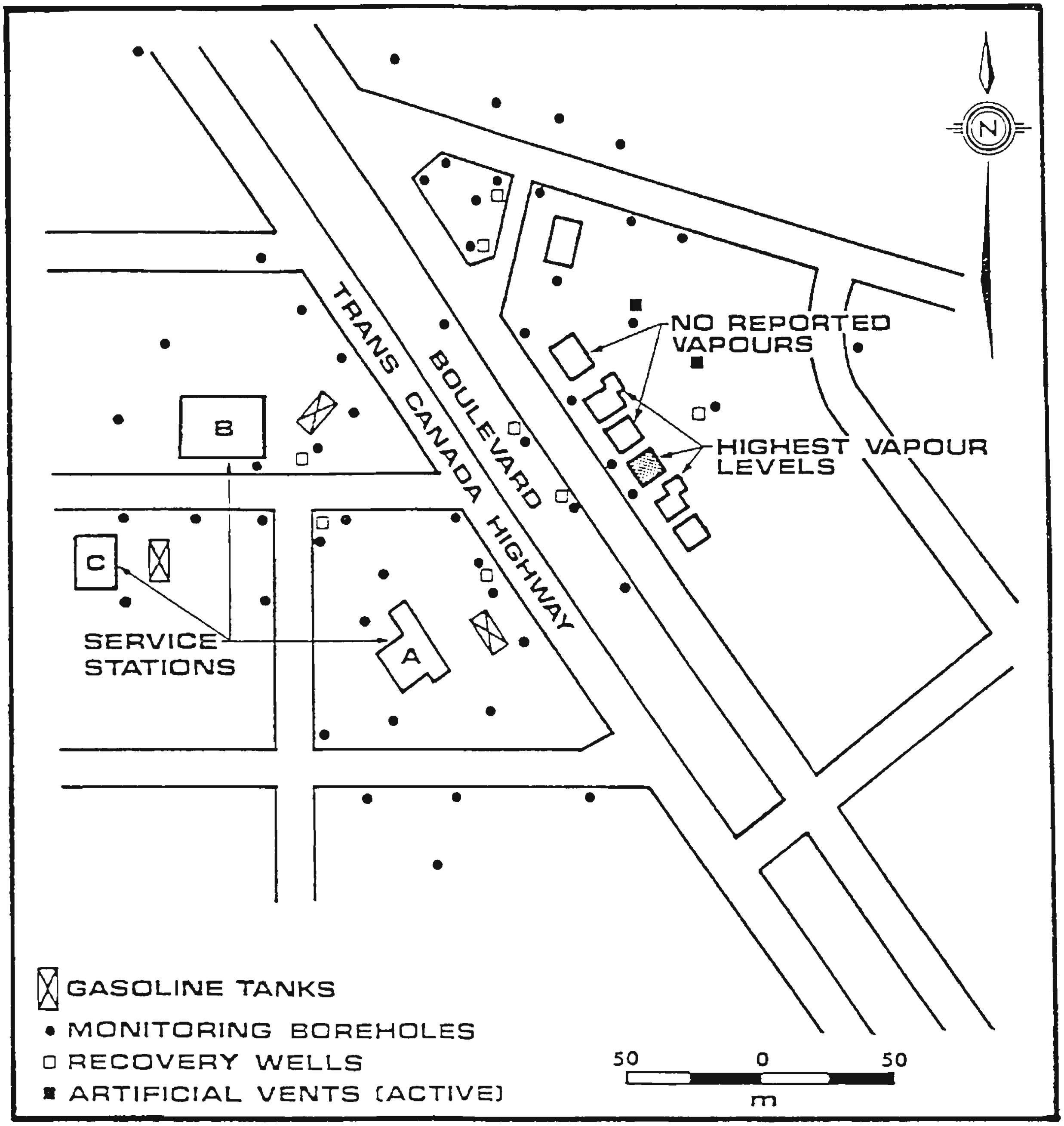


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**FIGURE C–27: SITE PLAN (Source: O'Connor and Bouchard, 1983)**

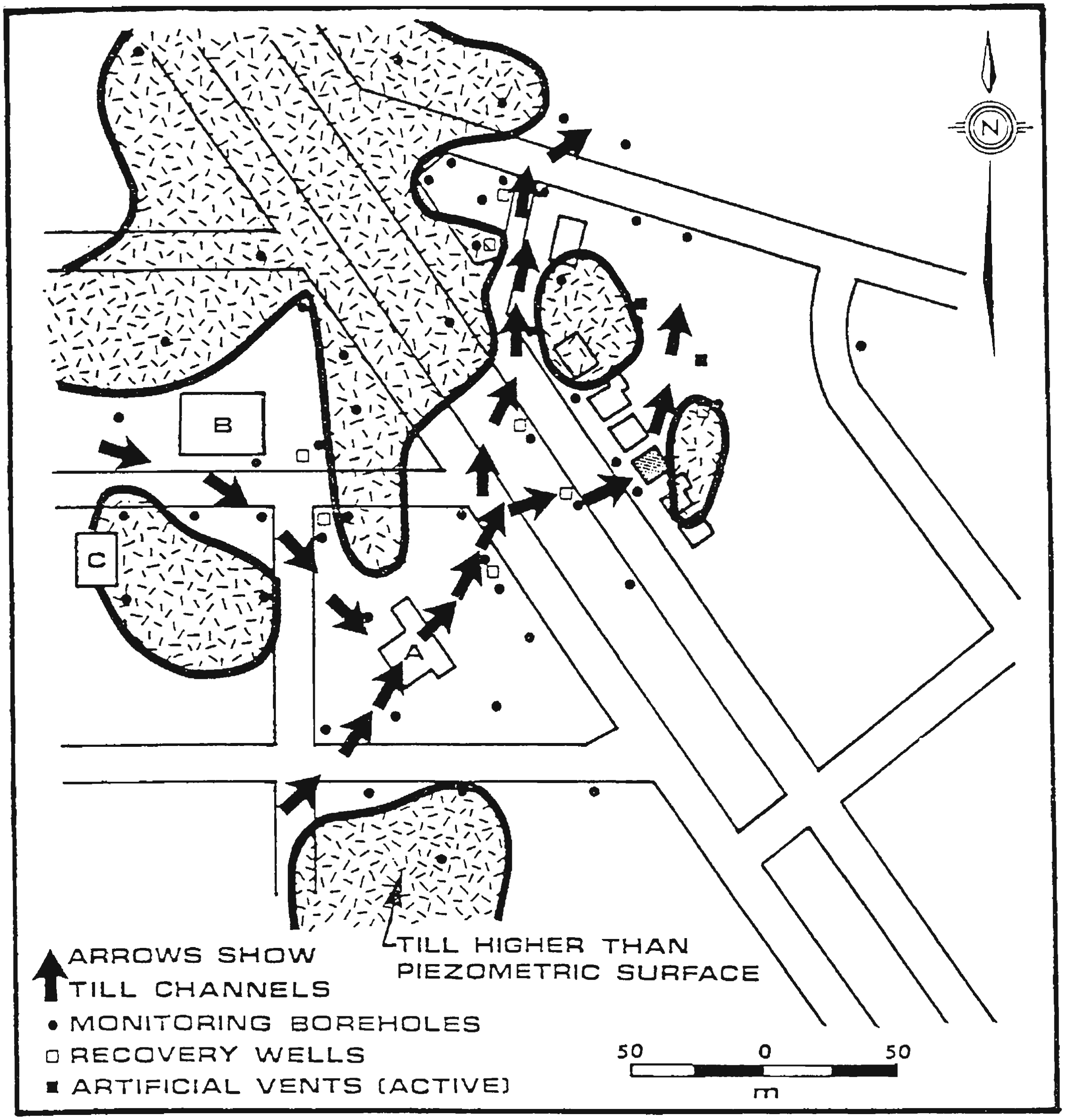


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**FIGURE C–28:**
**LOCATION OF TILL HIGHS**
**(Source: O'Connor and Bouchard, 1983)**

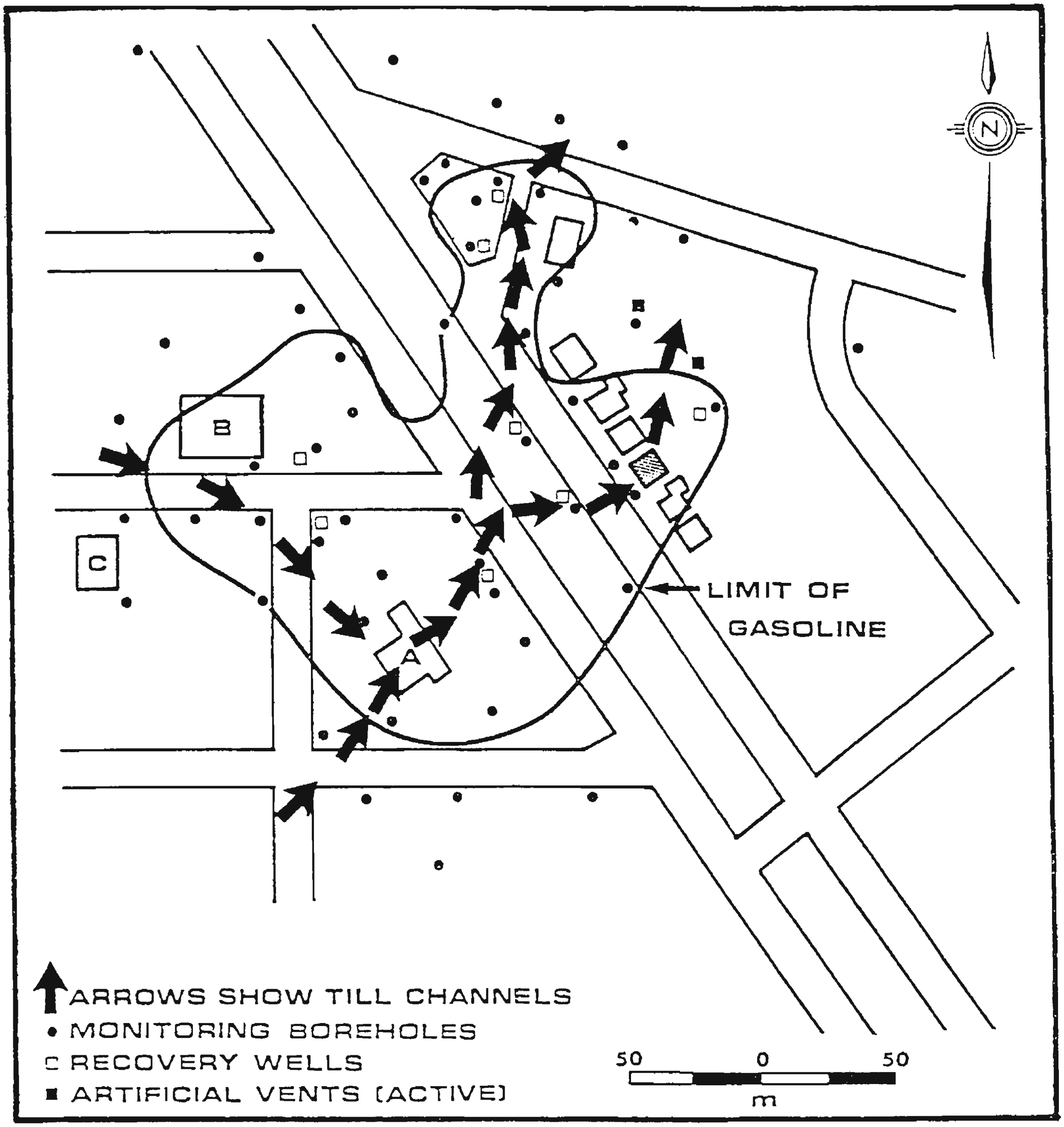


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**FIGURE C–29:**
**DISTRIBUTION OF SUBSURFACE GASOLINE**
**(Source: O'Connor and Bouchard, 1983)**

## CMHC SOIL GAS RESEARCH STUDY
## WESTERN CANADA SECTOR
## CASE STUDY #24

**BUILDING TYPE AND LOCATIONS:** Business building

**GAS TYPE:** Gasoline vapours

**SOURCE:** Leaking underground storage tank

**TYPE OF CONTROL:** Soil vapour extraction

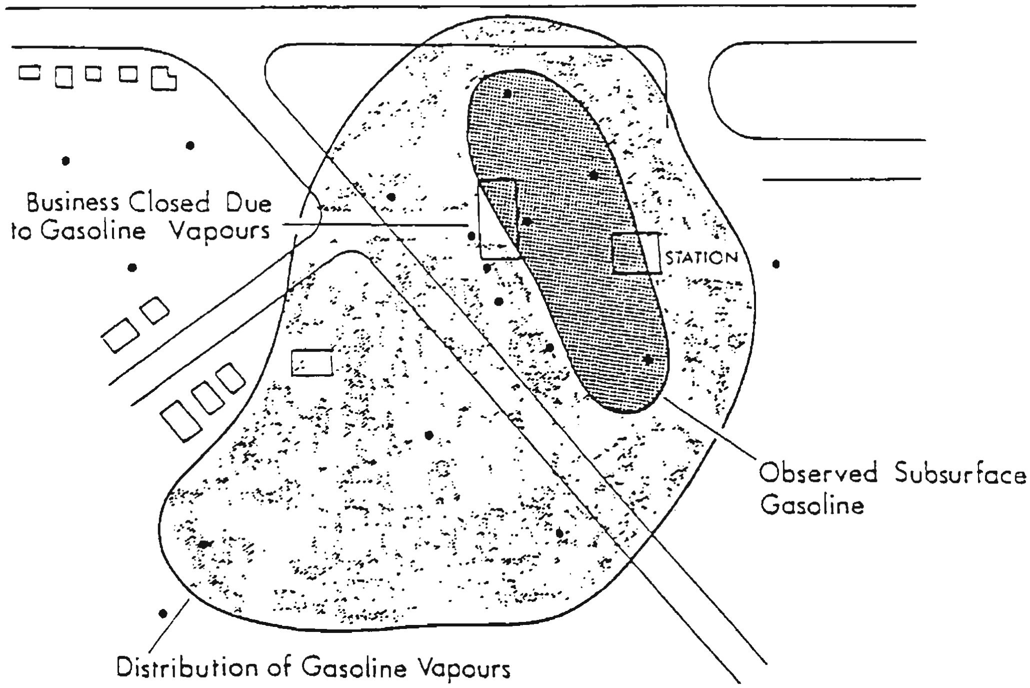
**CASE STUDY PRÉCIS:**

After several underground storage tank leaks at an independent service station were discovered, liquid gasoline appeared in downgradient sewer lines. As a consequence of elevated vapours in the sewer system, a sewer lift station exploded and a commercial establishment near the gasoline station was forced to close because of gasoline fumes.

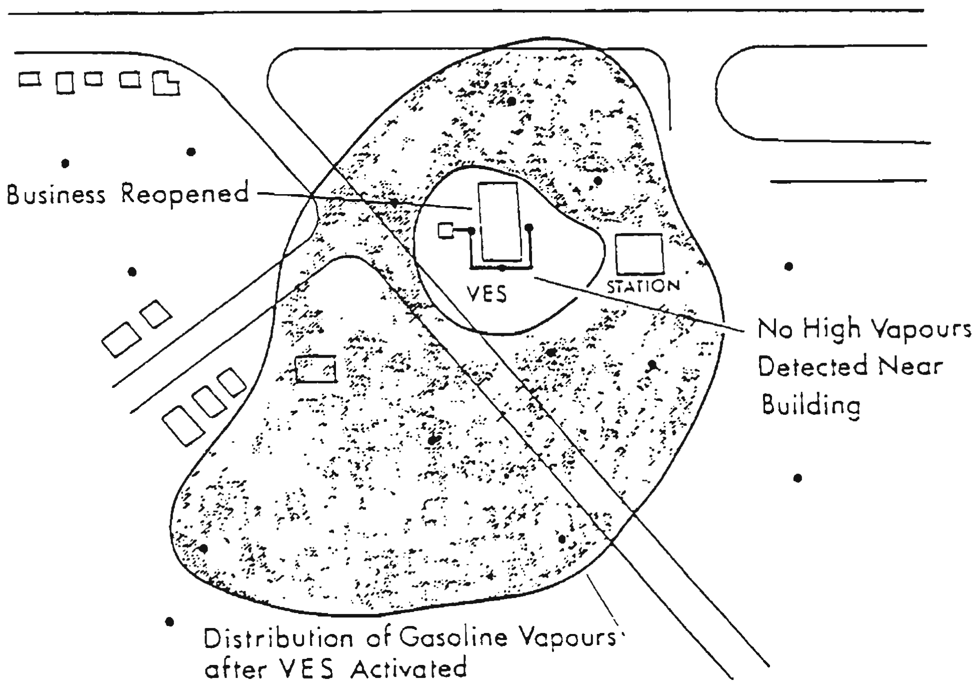
Consultants were contacted to perform an investigation. It was discovered that gasoline vapours had travelled over a much greater area than the liquid product. The consultants installed a vapour extraction system adjacent to the affected building. Steps were taken to seal visible cracks as much as possible. Within a few hours following startup of the system, no vapours could be detected within the building. After several months, regular monitoring revealed that measurable vapours were present in the subsurface at areas remote from the vapour extraction system, but no significant vapours were detected near the building. Refer to Figure C-30.

**REFERENCE:**

O'Connor, M.J. Agar, J.G. and King R.D., 1984. Practical experience in the Management of Hydrocarbon Vapours in the Subsurface. Presented at the NWWA/API Conference on Petroleum Hydrocarbons. Houston, Texas, November, 1984.




**ORIGINAL DISTRIBUTION OF CONTAMINANTS**




**DISTRIBUTION OF VAPOURS AFTER SEVERAL MONTHS**

| | |
|---|---|
| CH2M HILL ENGINEERING LTD.<br>WATERLOO ONTARIO | **FIGURE C–30:**<br>**DISTRIBUTION OF SUBSURFACE VAPOURS**<br>**(Source: O'Connor et.al., 1984)** |
| PROJECT No. ONT29396.AO | |

**Appendix D**

# INTERNATIONAL CASE STUDIES

# CMHC SOIL GAS RESEARCH STUDY
# INTERNATIONAL SECTOR
# CASE STUDY #1

**BUILDING TYPE AND LOCATION:** School building, homes; Love Canal, Niagara Falls, N.Y.

**GAS TYPE:** Toxic landfill gases

**SOURCE:** Industrial dump

**TYPE OF CONTROL:** Demolition

**CASE STUDY PRÉCIS:**

Love Canal was the notorious birthplace of many North America's hazardous waste dilemmas. As the world watched the well publicized account in early 1978, residents of a closely knit neighbourhood in Niagara Falls learned how New York state had found toxic waste in a 6.8 ha open space in the centre of their community. Approximately 20,000 tonnes of chemical wastes buried 20 to 30 years earlier had apparently begun to spread into the nearby school and local houses. By August 1978, New York State declared the Love Canal area a health hazard. The 99th Street School was closed, 255 families were evacuated, and President Carter declared the Love Canal area a national disaster.

The Love Canal was originally excavated in the late 1800s for the purpose of generating hydroelectric power. The project was halted and abandoned until 1947 when the Hooker Electrochemical Company obtained a title to the land and then used it as a site for toxic waste disposal. By 1953, the site was sold to the Niagara Falls School Board with a deed disclaiming responsibility. The site was also used from 1953 to 1954 for disposal of municipal wastes. Home building in the vicinity of the Canal accelerated, and a school was built in the middle of the site on 99th Street. Figure D-1 shows the location of the school. The problem first became evident in late 1977 when significant rainfall caused water levels in the canal to rise and caused lateral migration. Soon after, residents near the canal site began to complain of chemical odours, surface contamination, chemical residue in sumps, and injury to children.

Although the spread of contamination to nearby homes was believed to be related to contaminated water entering nearby sumps, the possibility of soil gas entry into homes cannot be ruled out. Given the volatile nature of many of the compounds present in the Love Canal waste, partitioning towards the air phase (soil gas phase) will occur. Consequently, migration can occur by means of soil gas transport as well as by groundwater. Although there was not a great deal of effort aimed at recognizing soil gas entry, the data strongly suggests that soil gas influx was in fact a contributing mechanism. The review here will concentrate on that perspective.

Some of the first investigative work was performed by the Department of Health of the State of New York. On June 26-27, 1978, 34 basements were inspected and air samples were obtained. Observations by staff found that (Dept. of Health, N.Y. State, 1978):

- Houses with no sumps were free from chemical odour (with one exception, where new cracks in the basement floor were observed with seepage).
- The source of odour was exclusively the sump; wall contribution was minimal.
- Self-help measures had been taken in several instances and were effective. These consisted of plywood sump covers and, in one case, enclosed in a cupboard.
- One or two houses had excessively dangerous concentrations in the upstairs of the home.
- The odour from parts of the landfill was obnoxious where covering was incomplete.

Recommendations included:

- Drainage and clay covering be commenced immediately.
- Some enclosure and venting be completed.
- A few families be evacuated until remedial sump venting has been completed and shown to be effective (sump venting was a remedial measure which investigators initially believed would be effective).

The initial sampling effort at the site was aimed at collecting ambient air samples in order to provide information for some form of planned remedial action. Six representative outdoor samples on the landfill area and two samples from basement air were collected. Additional samples from the basement air were also taken to study the effect of ventilation. (One sample was taken with ventilation, another without.) Ventilation was accomplished by installing a vent fan in the basement window. This procedure was hoped to provide information on possible remedial action (Bush et al, 1978). The sampling locations are shown on Figure D-1. Sampling was completed by four methods:

- tenax cartridges (two in tandem)
- poropak N cartridges
- tenax cartridges (three in parallel)
- grab samples (125 mL)

In the homes, all sampling was completed at a height of 600 to 900 mm above the basement floors. Analysis was completed with GC/FID/ECD and MS.

Partial results for the detectable compounds from several of the analyses are summarized on Table D.1. On Table D.1, the worst case contamination detected in the ambient air over the landfill is compared with contaminant levels found indoors at sample locations 2 and 6. Concentrations of contaminants indoors generally exceeded outside ambient concentrations. On occasion, exceedances were one or two orders-of-magnitude. It is interesting to note that vinyl chloride was not analyzed as part of the VOC scan. Given the confirmed presence of trichloroethylene, it would also be expected that vinyl chloride would be present in either the soil gas or groundwater. Vinyl chloride is recognized as a breakdown product of tetrachloro and trichloroethene (Vogel et al, 1987).

**Table D.1**
**GC/MS Estimated Levels of Organics ($\mu g/m^2$)**

| Compound | Highest Outside Ambient Concentration | Indoor Ambient Sample 2 | Indoor Ambient Sample 6 |
|---|---|---|---|
| Chlorobenzene | .120 | 1.08 | 37.2 |
| Chlorotoluene | 3.19 | .4 | ND |
| Chlorotoluene 2 | .19 | .65 | 441.0 |
| Trichloroethene | .04 | .16 | ND |
| Dichlorobenzene | .44 | 2.36 | 181.0 |
| Trichlorobenzene | .80 | 22.3 | 154.0 |
| Benzene | .24 | .62 | 1.12 |
| Methylbenzene | 2.75 | 24.1 | 343.0 |
| Dimethylbenzene | 5.62 | 9.19 | 12.2 |
| Ethylbenzene | .24 | 64.5 | 2.20 |
| Chloronaphthalene | .60 | ND | 2573.0 |

Source: Bush et al, 1978.

As indicated previously, a trial option for remediation involved the installation of a fan within a basement window. Monitoring of indoor air quality was completed with the fan installed at two locations (2 and 6). Upon completion of sampling, the fan was disconnected 7 and 2 days, respectively, at locations 2 and 6 before sampling was again conducted. The results on these analyses are presented in Table D.2. In nearly all cases, indoor air contamination was worse when the fan was in operation. Only for the case of toluene (at sample location 2) and α-BHC (a pesticide) was the reverse pattern observed. The α-BHC compound is considered as semi-volatile, and may therefore be unrelated to soil gas entry.

**Table D.2**
**Analytical Results of Ambient Indoor Air with Basement Fan On/Off ($\mu g/m^3$)**

| Compound / Fan | Indoor Ambient Sample 2 | | Indoor Ambient Sample 6 | |
|---|---|---|---|---|
| | Off | On | Off | On |
| Toluene | 380 | 55 | ~ 60 | 6250 |
| $CCl_4/CH\ Cl_2$ | ND | ~ 7 | ND | ~ .6 |
| Trichloroethene | ND | 19 | ND | 32 |
| Tetrachloroethene | 8.1 | 102 | 1.2 | 60 |
| p-Dichlorobenzene | ND | ND | ND | 205 |
| Chlorobenzene | ~ 9 | ~ 100 | ND | ~ 90 |
| 1,3,5-Trichlorobenzene | ND | .9 | ND | 44 |
| 1,2,4-Trichlorobenzene | 5.0 | 29 | ND | 111 |
| 1,2,3-Trichlorobenzene | 1.7 | 6.7 | ND | 32 |
| δ-BHC | ND | ND | ND | ND |
| α-BHC | 0.07 | ND | 0.07 | ND |
| β-BHC | ND | ND | ND | 3.0 |

Source: Bush et al, 1978.

Following the initial sampling effort, Bush et al (1978) summarized some items of concern in developing a future sampling protocol for Love Canal. Several of the items under consideration included:

1. Should sump water samples be taken at the same time as air samples?

2. Since concentrations seemed to vary with weather (rainfall, etc.), should there be some consistent weather pattern for some time period preceding sampling? If so, what?

3. What data needs should be recorded - air temperature, water temperature, humidity, odour, etc.?

4. What cartridge should be used?

Following the initial sampling round, a further sampling effort involving 99 sample locations was initiated. This sampling round involved the sampling of basement ambient air of nearly all ring 1 houses and the 99th school building. The results are not tabulated here; readers are referred to Bush et al (1978). The results are shown graphically on Figure D-2. The bars on Figure D-2 indicate the number of times the aggregate limits (based on proposed or adopted federal and/or state standards) were exceeded at each site based on the concentrations of six selected compounds. Some of the more notable results for houses on 99th Street included: house 700 with toluene at 4330 $\mu g/m^3$; house 742 with toluene at 1755 $\mu g/m^3$; house 476 with toluene at 5703 $\mu g/m^3$, etc. On 97th Street, house 703 had toluene at 3600 $\mu g/m^3$, chlorotoluene at 3000 $\mu g/m^3$; house

799 with tetrachloroethene at 1140 $\mu g/m^3$. As seen on Figure D-2, it was also apparent that many of the homes without sumps had contamination indoors representative of the landfill. This would suggest that contaminated water is not the only transport mechanism involved here. Figure D-2 also indicates that contamination had migrated across 99th Street. Other samples taken from houses on Calvin Street (north of the landfill) also revealed similar contamination, especially with respect to toluene.

Because of the concern that these chemicals might pose a human health risk to some residents, most of the homes closest to the canal in ring I and II were purchased from the residents voluntarily in 1978. Location of ring I and II are shown in Figure D-3. Subsequently, a fence was erected around the perimeter of ring II to enclose the site and restrict access. The 99th Street School as well as the homes within the fence were later demolished.

Concern remained, however, over health risks to residents beyond ring II, and in 1980 President Carter determined that, "... the adverse impact of chemical wastes in the Love Canal waste landfill... is of sufficient severity and magnitude to warrant an emergency declaration...". This declaration followed release of a preliminary study that indicated some Love Canal residents have suffered chromosomal damage because of exposure to toxic chemicals (a study that was later discredited by another study from the Center for Disease Control in Atlanta). The area affected by the declaration was termed the "Emergency Declaration Area", and boundaries were established as shown on Figure D-3. Contained within these boundaries were about 650 private residential properties and about 300 public housing units. The Love Canal Area Revitalization Agency (EDA) was established by the New York State Legislature and authorized to purchase the property from EDA residents who chose to relocate from the EDA.

Given that the Center for Disease Control study concluded a lack of correlation between Love Canal and chromosomal damage of EDA residents, the EDA requested the Department of Health and Human Services (DHHS) to determine if the EDA was habitable. The DHHS concluded it was habitable providing the landfill site was effectively sealed off. In December 1982, the Congressional Office of Technology Assessment was asked to review the decision. In June 1983, the Office of Technology Assessment reported that based on the information presented, it was not possible to conclude whether or not unsafe levels of toxic contamination existed in the EDA.

The major shortcomings of the previous work conducted by the EPA and DHHS was a lack of specific criteria for determining habitability. Consequently, in August 1983, a task force comprised of scientists from the CDC and New York State Department of Health began to develop habitability criteria.

After several meetings, the task force established habitability criteria using a combination of relevant Federal and New York State standards, criteria, or guidelines for residential purposes, and a comparison of levels of select Love Canal Indicator Chemicals (LCICs) in EDA with those in a similar area outside the EDA. The intent of this approach was to determine if chemicals from the Love Canal had reached the EDA in sufficient quantity to create a significant difference between the EDA and other control areas. (This approach avoids a health risk approach.)

The habitability criteria called for three environmental sampling studies including an air assessment, a soil assessment, and a soil assessment for dioxin. The air assessment (which is of interest to the soil gas study) was aimed at evaluating if the three habitability criteria were satisfied:

1. if the house is located in a neighbourhood judged to be habitable (i.e. as judged by other criteria),

2. if the results of the air comparisons show that retesting and/or remediation are not necessary, and

3. if remediation is performed and is shown successful. Remediation will be considered successful if LCICs are reduced to the same levels as found in habitable areas.

Prior to the start of the habitability sampling, pilot studies for the soil and air were conducted in order to test the feasibility of implementing the above criteria. The data obtained in the pilot program was used to: test the sampling and analytical methods proposed for the comparison studies, provide preliminary data on levels and statistical distributions of the LCICs, and provide a basis for determining the number of samples that needed to be taken to produce statistically valid results for the comparison studies.

One of the first tests involved the determination of the LCICs. However, in determining the LCICs, investigations would have to account for contaminants within the EDA which may have been present from other sources; other sources possibly being emissions from nearby industries, vehicle traffic, pesticides applied to lawns, etc. In order to avoid dealing with non-Love Canal compounds and their appropriate standards, etc., considerations for habitability were based on chemicals originating from the Love Canal waste site only. Details about which LCICs were chosen are given below.

The group of LCICs was chosen based on their ability to migrate from the Love Canal into the EDA and persist there. This approach was viewed as being the most optimal since it was not possible to emphasize optimal analytical detection limits, accuracy and reliability. In addition to this criteria, two other criteria were also applied, specificity (ubiquity), and evidence of a gradient. The problem posed by "ubiquitous" chemicals (those commonly found in the environment) is two-fold: first, the presence of a substantial background level of a chemical in the EDA greatly diminishes the ability to detect a small increase due to an emission from the Love Canal; and second, variations in the level of background chemicals between the EDA and comparison areas can lead to faulty conclusions. Because of these problems, a desirable property of indicator chemicals is that they are not likely to be present in the environment (either in the EDA or the comparison areas) as a result of emissions from sources other than Love Canal. The report (Icair, Life Systems and CH2M HILL, 1988) emphasized "that ubiquitous chemicals originating from the waste site are not of any less concern than non-ubiquitous chemicals, only that ubiquitous chemicals are not the best choice to determine the extent of migration". Evidence of a gradient was another way to ensure that chemicals are appropriate indicators of migration from the landfill. This characteristic is expected of chemicals moving away from the waste site but is not expected of chemicals which reach the EDA by migration from other sources.

The indicator chemicals were chosen as described above and summarized on Figures D-4 to D-7. The chemicals that met the selection criteria for air were:

- chlorobenzene
- 2-chlorotoluene
- 4-chlorotoluene

In addition to the above task, an evaluation of the contaminant levels was required. Unfortunately, few guidelines for standards directly relevant to the types of residential exposure (inhalation of air) had been established by State or Federal health or environmental agencies. Other standards such as Threshold Limit Values (TLVs), derived by the American Conference of Governmental Industrial Hygienists (ACGIH) may be "adjusted" to derive new values. This approach was judged to be inappropriate for two reasons:

- There was no generally accepted procedure for making this adjustment, therefore the resulting value would be subject to debate and controversy.

- Any extrapolation performed by the technical review committee would bypass the necessary and proper scientific, administrative, and public reviews that are involved in establishing these guidelines.

Another approach to evaluate the magnitude of the problem could include a risk assessment. A risk assessment process includes three basic steps:

- The concentration of chemicals is determined
- The amount of exposure (dose) is estimated
- The health consequences of this exposure is predicted based on available toxicological dose-response data

However, this approach was also deemed inadequate for several reasons. First, it was difficult to identify and quantify all toxic chemicals in all media (air, water, soil), especially at a complex site such as Love Canal where at least 200 different chemicals were identified. Secondly, there was insufficient toxicology data on many of the chemicals present. Furthermore, uncertainty about interactions further complicate the assessment. Finally, the risk assessment process depends on data that are subject to change as new toxicological or epidemiological studies are performed.

A third possible approach, based on health studies was also rejected. Experience has shown that it is very difficult to detect the effects of exposure to low-level environmental pollution in small population groups. Health studies performed in 1978, when the population of the EDA was large, provided no definitive evidence, and any such studies done now, when the residential population was much smaller, would almost certainly not be sufficiently sensitive to detect any abnormal health effects.

The method of evaluation chosen for the EDA was a comparative approach with another similar neighbourhood. This approach involved the comparison of environmental sampling data from neighbourhoods and residences in the EDA with results from similar inhabited communities in western New York not affected by a chemical landfill.

Based on a pilot study performed on indoor air in occupied homes in the EDA and comparison areas, only 1 in 30 samples from the EDA and 1 in 31 from the comparison areas had measurable levels of chlorotoluenes. No detectable levels of chlorobenzene or chlorotoluene were observed from 33 occupied homes in the EDA or from outdoor air in either location. Because the air LCICs were detected so infrequently, it was concluded that any measurable concentration of LCICs in the EDA should be considered significant and as such analysis of air in comparison areas was not required.

The pilot study underwent review from March to May 1987. Two changes in the air assessment were recommended:

- The combination of the two isomers of the same compound (chlorotoluene) into a measurement of total chlorotoluene.
- The consideration of any detectable air LCIC concentration as significant; this resulted in the air in comparison areas not being sampled.

As part of the sampling program, both indoor and outdoor air was sampled. Indoor air was specifically sampled because chemicals volatilizing from subsurface soils into basements could result in considerably higher concentrations than in ambient air. Given that soil in the immediate vicinity of the Love Canal was used as fill in at least one location (the 93rd Street School), such soil may also have been used elsewhere in the community. The implementation of an indoor air sampling program was viewed as advantageous for the purpose of detecting contamination possibly transported via shallow groundwater seepage. Alternatively, sump water samples could also be taken; however, sumps also serve as a collection point for spilled domestic products. Domestic products could obscure measurements of Love Canal chemicals.

When the program commenced, separate regions within the EDA were subdivided for classification purposes. The seven regions are shown on Figure D-8.

The air LCIC comparison study collected indoor air samples from 562 residences during four sampling periods in 1987. During the air comparison study, attention was given to developing protocols to track the source of a LCIC should a detectable concentration be found in a residence. The sampling plan was also designed to evaluate potential seasonal and diurnal variations in concentrations of LCICs.

The results of the sampling program in the EDA indicated that chlorobenzene was not detected at all, and chlorotoluene was detected in only one home. After careful review of all the data, the Technical Review Committee determined that the presence of chlorotoluene could not be attributed to Love Canal (Wm. Reilly letter to Ms. Lois Gibbs, May 14, 1990).

Following the air and soil sampling program and evaluation, four of the regions within the EDA (regions 4-7) met all of the habitability criteria, three regions (EDA 1-3) were termed not suitable since soils had higher levels of LCICs than soil from EDA 4-7 and other comparison areas. Regions 1-3 were termed appropriate for other purposes (i.e. commercial or industrial) without remediation (New York State Department of Health, 1988).

**REFERENCES:**

New York State Department of Health, 1988. Fact Sheet, Love Canal EDA Habitability Study, September 1988.

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Vogel, T.M., C.S. Criddle, and P.L. McCarty, 1987. Transformations of halogenated aliphatic compounds. Environ. Ser. Technol., 1987, 21, 722-735.

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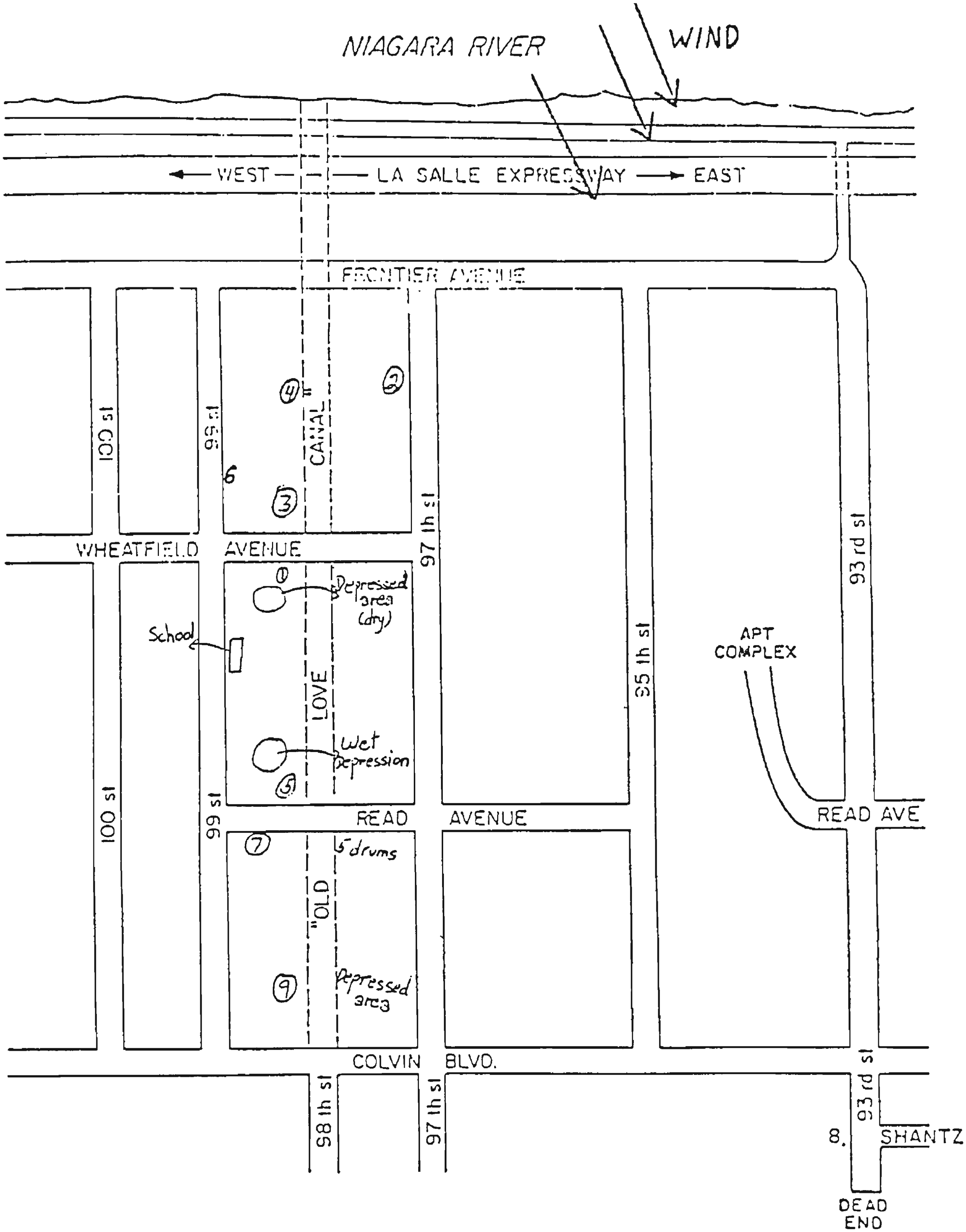


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**FIGURE D–1:**
**LOCATION OF SCHOOL AND INITIAL AIR SAMPLING LOCATIONS LOVE CANAL**
**(Source: Dept of Health, 1978)**

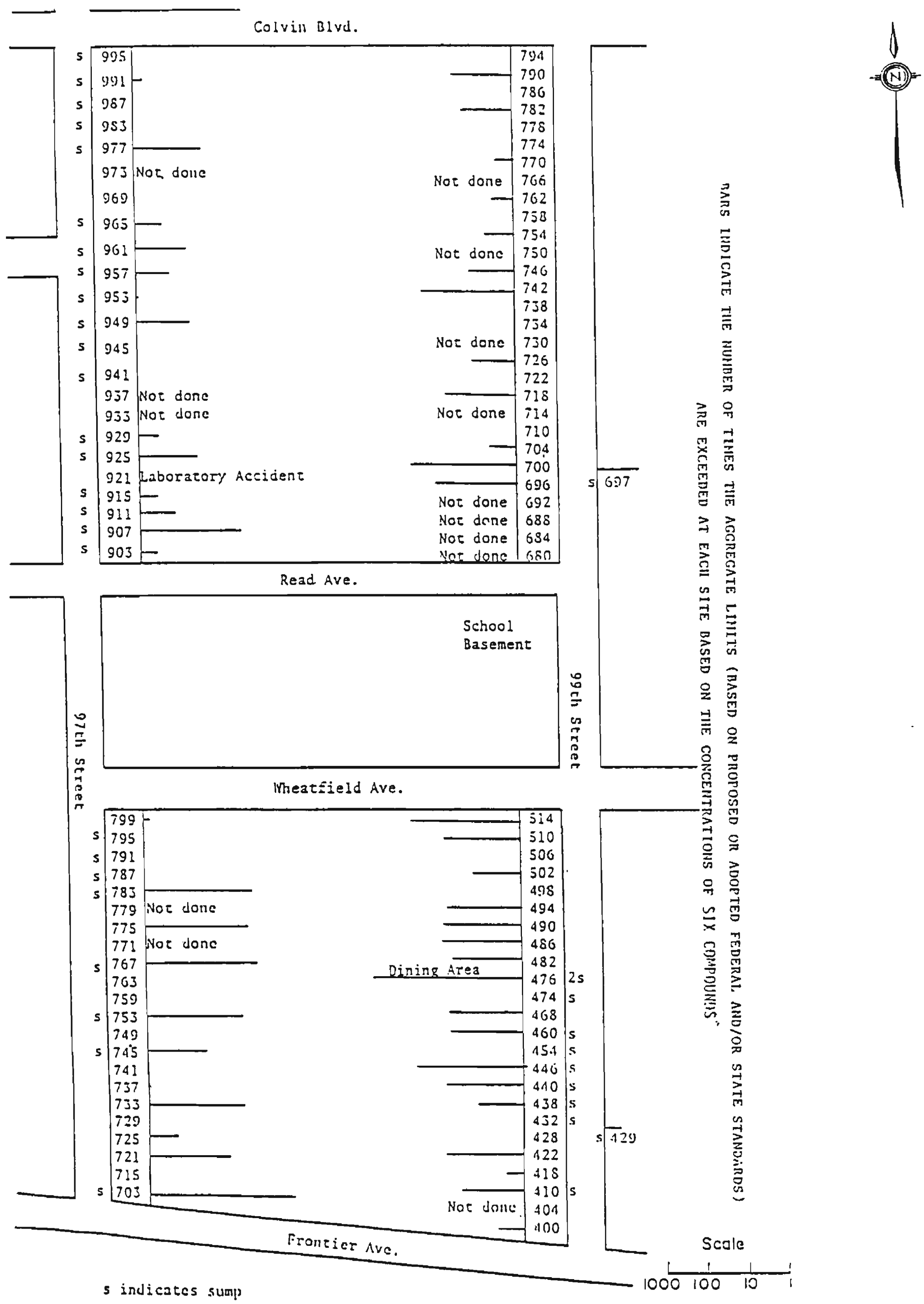


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**FIGURE D-2:**
**AIR SAMPLING RESULTS ON RING I HOMES**
**(Source: Bushet al., 1978)**

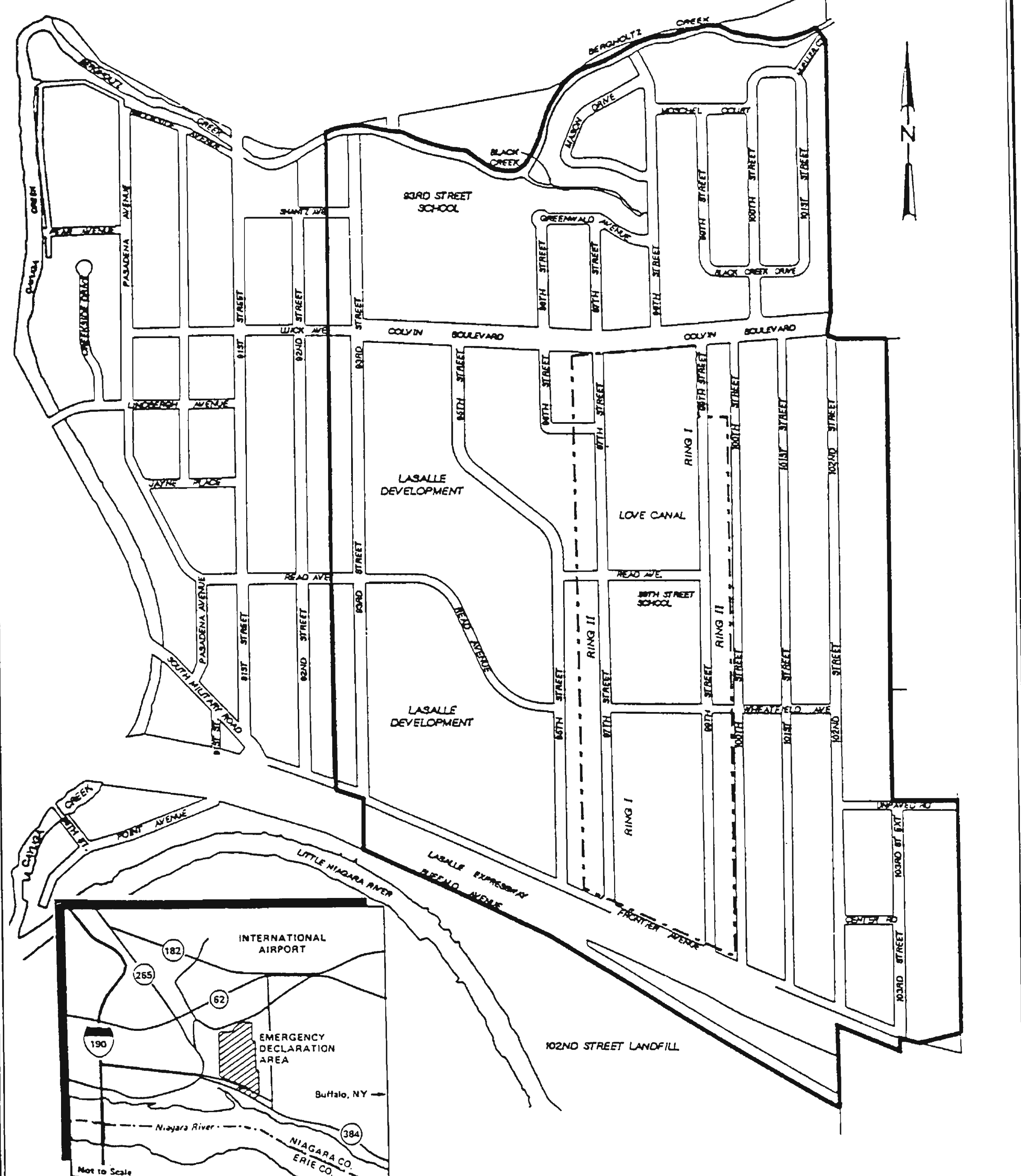


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**FIGURE D-3: FIGURE DEPICTING EMERGENCY DECLARATION AREA (Source: Icair & CH2M HILL, 1988)**

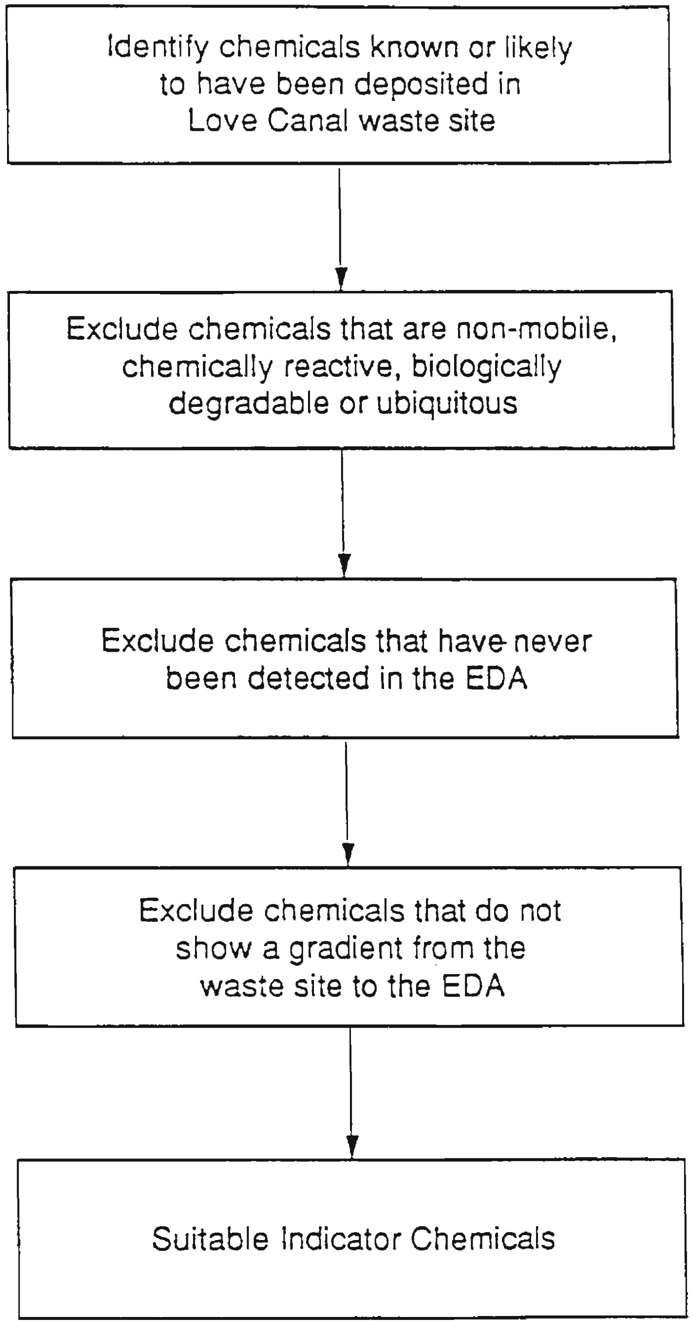


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**FIGURE D–4:**

**LCIC SELECTION PROCESS**
**(Source: Icair & CH2M HILL, 1988)**

## CHEMICALS LIKELY TO HAVE BEEN DEPOSITED AT LOVE CANAL

**Halogenated Organics**

- Carbon Tetrachloride
- Chloroform
- 1,1-Dichloroethylene
- Trichloroethylene
- Tetrachloroethylene
- Hexachloroethane
- Hexachlorobutadiene
- Hexachlorocyclopentadiene

**Benzene and Derivatives**

- Benzene
- Monochlorobenzene
- 1,2-Dichlorobenzene
- 1,3-Dichlorobenzene
- 1,4-Dichlorobenzene
- 1,2,4-Trichlorobenzene
- 1,2,3,4-Tetrachlorobenzene
- 1,2,4,5-Tetrachlorobenzene
- Pentachlorobenzene
- Hexachlorobenzene
- Benzoic acid
- Benzoyl chloride
- Benzyl chloride
- Benzal chloride
- Benzotrichloride

**Phenols**

- 2,4-Dichlorophenol
- 2,4,5-Trichlorophenol
- 2,4,6-Trichlorophenol
- Pentachlorophenol

**Toluene and Derivatives**

- Toluene
- 2-Chlorotoluene
- 4-Chlorotoluene

**Naphthalene and Derivatives**

- Naphthalene
- Chloronaphthalenes
- Dichloronaphthalenes
- Trichloronaphthalenes

**Acids and Derivatives**

- Acetic acid
- Acetyl chloride
- Acetic anhydride

**Pesticides and Related Products**

- $\alpha$-BHC
- $\beta$-BHC
- $\gamma$-BHC
- $\delta$-BHC

**Metals**

- Arsenic
- Antimony
- Chromium
- Copper

**Other**

- Carbon disulfide
- Dioxin (TCDD)

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Source: Adapted from *Love Canal Emergency Declaration Area: Proposed Habitability Criteria* (1986)

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**FIGURE D–5:**
**CHEMICALS LIKELY TO HAVE BEEN DEPOSITED AT LOVE CANAL**
**(Source: Icair & CH2M HILL, 1988)**

## LOVE CANAL CHEMICALS EXCLUDED AS INDICATOR CHEMICALS

| Reason for Exclusion | Chemicals Excluded |
|---|---|
| Chemical Reactivity | Acetyl chloride<br>Acetic anhydride<br>Benzoyl chloride<br>Benzyl chloride<br>Benzal chloride<br>Benzotrichloride |
| Biological Degradability | Acetic acid<br>Benzoic acid<br>Dichlorophenol |
| Ubiquity | Benzene<br>1,4-Dichlorobenzene<br>Chloroform<br>Trichloroethylene<br>Toluene<br>Naphthalene<br>Carbon disulfide<br>Tetrachloroethylene<br>1,1-Dichloroethylene<br>Hexachloroethane |
| Low Migration Potential | Arsenic<br>Antimony<br>Copper<br>Chromium<br>TCDD<br>Hexachlorobenzene<br>Trichloronaphthalenes<br>Hexachlorobutadiene<br>Hexachlorocyclopentadiene |

Source: Adapted from *Love Canal Emergency Declaration Area: Proposed Habitability Criteria* (1986)

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**FIGURE D–6:**
**LOVE CANAL CHEMICALS EXCLUDED AS INDICATOR CHEMICALS**
**(Source: Icair & CH2M HILL, 1988)**

## EVALUATION OF CHEMICALS BASED ON DETECTION AND GRADIENT CRITERIA

| Class | Chemical | Air: Detected In EDA | Air: Decreasing Gradient | Soil: Detected In EDA | Soil: Decreasing Gradient |
|---|---|---|---|---|---|
| Solvents | Carbon tetrachloride | Yes | No | Yes | No |
| Benzenes | Monochlorobenzene | Yes | Yes | Yes | Yes |
| | 1,2-Dichlorobenzene | Yes | No | Yes | Yes |
| | 1,3-Dichlorobenzene | No | NA | No | NA |
| | 1,2,4-Trichlorobenzene | No | NA | Yes | Yes |
| | 1,2,3,4-Tetrachlorobenzene | Yes | No | Yes | Yes |
| | 1,2,4,5-Tetrachlorobenzene | No | NA | No | NA |
| | Pentachlorobenzene | Yes | No | No | NA |
| Phenols | 2,4,5-Trichlorophenol | No | NA | No | NA |
| | 2,4,6-Trichlorophenol | No | NA | No | NA |
| | Pentachlorophenol | No | NA | Yes | No |
| Toluenes | 2-Chlorotoluene | Yes | Yes | No | NA |
| | 4-Chlorotoluene | Yes | Yes | No | NA |
| Naphthalenes | Chloronapthalenes | No | NA | Yes | Yes |
| | Dichloronapthalenes | No | NA | No | NA |
| Pesticides | α–BHC | No | NA | Yes | Yes |
| | β–BHC | No | NA | Yes | Yes |
| | γ-BHC | Yes | No | Yes | Yes |
| | δ-BHC | No | NA | Yes | Yes |

NA = Not applicable, since chemicals that were never detected in EDA were not considered further

Source:

Adapted from *Love Canal Emergency Declaration Area: Proposed Habitability Criteria* (1986)

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**FIGURE D–7:**

**EVALUATION OF CHEMICALS BASED ON DETECTION AND GRADIENT CRITERIA (Source: Icair & CH2M HILL, 1988)**

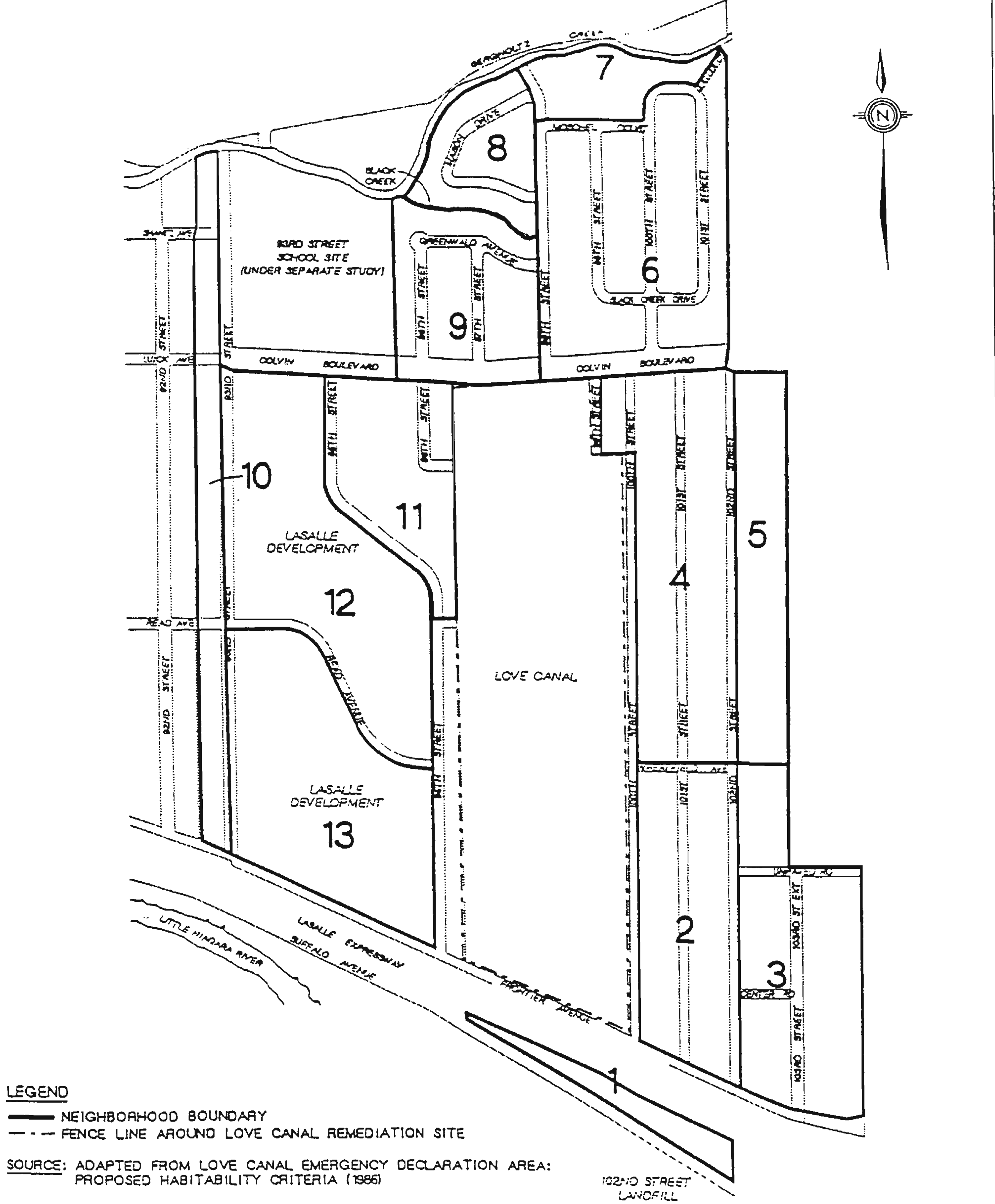


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**FIGURE D-8:**
**MAP OF NEIGHBOURHOOD BOUNDARIES IN THE EDA**
**(Source: Icair & CH2M HILL, 1988)**

**CMHC SOIL GAS RESEARCH STUDY**
**INTERNATIONAL SECTOR**
**CASE STUDY #2**

**BUILDING TYPE AND LOCATION:** A 27-building public housing development, containing 1500 family units

**GAS TYPE:** Methane

**SOURCE:** Landfill

**TYPE OF CONTROL:** Concrete slab, surface sealing, active system

**CASE STUDY PRÉCIS:**

The construction of a 27-building public housing development was constructed on refuse-filled land. The composition and age of the refuse varied considerably in different locations. During the construction of the buildings (three- and seven-storey apartment houses), a crawl space of approximately 1 metre was left between the landfill and the basement floor. The foundation walls totally enclosed 7 to 12 separate crawl space compartments under each building. Individual compartments varied in size from 15 to 210 $m^3$ in volume. There was no gas exchange between compartments.

On the advice of a consultant, a 75 mm concrete slab was poured directly on top of the fill under each building. It was hoped that the slab, resting on the fill and meeting the walls, would be effective in sealing out all gases generated in the fill.

A preliminary survey was conducted about 15 months after construction was complete. Five buildings were selected as a sample for preliminary testing. Various gases including oxygen, carbon dioxide, carbon monoxide, hydrogen sulphide, and combustible gases were monitored within the crawl spaces of each of the buildings. Oxygen, carbon dioxide, and combustible gases were measured with portable meters; carbon monoxide and hydrogen sulphide was measured with Draeger detector tubes. The results of the preliminary survey indicated that of the 27 buildings tested, 10 were found unsatisfactory, 15 were satisfactory, one was borderline, and the last one had no access to the crawl space. Those buildings which were rated as unsatisfactory had combustible gas concentrations between 10 and 24 percent of the lower explosive limit (LEL), deficient oxygen, and excessive carbon dioxide levels. Hydrogen sulphide was not detected in any of the locations. Carbon monoxide was found in only one building; however, it was traced to leakage from an illuminating gas service line. As a result of these initial findings, further testing was initiated.

To determine the rate of soil gas intrusion into the crawl spaces (i.e. carbon dioxide and methane), the air in two adjacent subcompartments was completely cleared with a portable blower. One of the compartments was flooded with 10 to 15 cm of water; the other compartment was left dry. The gas concentrations in both compartments were measured 1, 2, 5, 7, 11, and 23 days later. In the first 24 hours, a decrease of 2.0 to 2.5 percent of oxygen, and an increase of 2.0 to 2.5 percent carbon dioxide was noted. On subsequent days, the oxygen levels increased somewhat and carbon dioxide levels dropped, stabilizing at 10 percent and 1 percent, respectively. Combustible gas reappeared only after 5 days and remained throughout the observation period at the detection threshold. No important differences were noted between the flooded and dry spaces.

The investigators (First et al, 1966) concluded that the above tests indicated that a column of water several centimetres high was incapable of holding back gases, and that the crawl space was in equilibrium with the fill beneath. It was noted that the gas concentration across the sealing slab came to equilibrium in a few hours. Before ventilation, the gases were in equilibrium at an oxygen concentration of 12 percent, a carbon dioxide concentration between 5.0 and 5.5 percent, and a combustible gas concentration between 22 and 24 percent LEL. After ventilation of the crawl space, there were only enough of the gases stored in the fill material to produce the equilibrium concentrations noted above, and the rate of production of gas at the time was too slow to noticeably increase the internal volume of gases over the 23-day period.

The slow generation rate theory was only valid for a short period of time. Six months later, following the first summer of occupancy, explosive atmospheres were detected in two of the buildings and concentrations greater than 50 percent LEL were found in five others. Six other buildings showed methane concentrations between 10 and 50 percent LEL (less than 17 percent oxygen, and more than 2 percent carbon dioxide). These 13 buildings represented nearly half of 27 apartment houses in the development.

The crawl spaces were ventilated with the use of a small axial-flow skid mounted fan (Coppus Vano SMA175 Blower, 1/2 hp motor) which was wheeled by hand from building to building. The blower delivered 700 L/s as it discharged a jet of high velocity air to the remote parts of the crawl spaces. Tests indicated, however, that occasional ventilation would be inadequate as a remedial measure since in some of the crawl spaces the soil gas concentrations rose rather quickly after ventilation. Table D.3 below indicates how quickly methane build-up could occur after ventilation.

| Table D.3<br>Rate of Methane Intrusion into a Crawl Space<br>of one of the Buildings | | |
|---|---|---|
| **Clock Time** | **Elapsed Time Since Ventilation (minutes)** | **% LEL (ventilated for 1 hour prior to start)** |
| 14:10 | 0 | 0 |
| 14:45 | 35 | 3.5 |
| 15:00 | 50 | 6.5 |
| 15:35 | 85 | 16.0 |
| 20:30 | 380 | 105.0 |

One other observation noted by the investigators was that in several cases, soil gas entry was significant, yet other adjacent compartments essentially had no or limited amounts of soil gas. The investigators speculated that the thickness of the concrete pad or differential settlement may have contributed to these differences.

In order to remedy the situation at this housing complex, an attempt was made to seal the crawl space floors. Attempts were made to create a gas tight barrier by treating four crawl spaces in one of the following ways:

*Space 1.* All joints between foundation walls, pillars, and floor slabs were filled with two applications of Flintkote C-13-A asphalt emulsion.

*Space 2.* An entire crawl space slab was treated with two applications of Flintkote C-13-A asphalt emulsion.

*Space 3.* An entire crawl space slab was treated with a single application of Flintkote No. 70 asphalt emulsion. (Both asphalt water emulsions were recommended by the Asphalt Institute and by the Flintkote Co. for this service.)

*Space 4.* An entire floor was treated with two applications of water glass (sodium silicate).

Five days after the applications, the atmosphere in the treated subcompartments were tested as were the adjacent compartments. The coatings had no appreciable effect on gas concentrations. Theorizing that the coatings may not have had sufficient time to dry, the compartments (which were treated)were again ventilated and re-tested 8 days later. Substantial methane was again discovered. Investigators concluded that treating of basement floors was not a practical procedure.

Several reasons (although not specifically measured) were cited as possible reasons for soil gas entry into the buildings at this site: pressure increases in the landfill due to gas production activity, expansion of gases because of heating (high temperatures notably in landfill sites), atmospheric pressure changes, wind pressure, or tidal variations on subsurface water levels.

As an additional part of this study, longer term trends were observed and recorded for this site. After several years of monitoring, the following pattern was noticed. Each year, combustible gas concentrations increased in early spring and peaked during July and August and then declined slowly until minimal readings were observed during January and February. The investigators concluded that the seasonal variations were associated with subsurface temperatures in two ways: a) rising temperatures in the spring simulated microbial activity and increased gas production, and b) higher underground temperatures increased the pressure of existing gas reserves against the floor slabs.

Since methane seepage into the crawl space was extremely rapid, mechanical equipment was installed in a manner as shown in Figure D-9. An inlet and outlet unit was installed at opposite corners of the ventilated space so that incoming air would sweep across the entire sub-basement spaces. Two 125 mm holes were drilled through the concrete floor with a diamond tipped hole cutter. The ventilation fan equipped with non-sparking wheels exchanged 70 L/s, sufficient to provide two air changes per hour. This proved adequate to prevent accumulations of detectable quantities of combustible gas.

After 5 years, no significant gas concentrations were detected even when ventilation blowers were turned off. In all, continuous testing extended over seven years. The above information proved valuable for the construction of a new theatre on the site.

<u>The Theatre</u>

The problems which were encountered above provided valuable information before the construction of a theatre commenced. The theatre was constructed directly on the ground over a thin layer of crushed gravel. Two runs of perforated drain pipe (15.2 cm in diameter) were embedded in the crushed gravel along the full length of the building. Strips of building paper were laid down over the pipe to prevent concrete from filling the pores.

The sub-slab gases were vented with the use of two centrifugal exhausters located on the roof of the structure (refer to Figure D-10). Each exhauster was rated at 165 L/s with a static vacuum of 760 Pa. The exhauster was totally enclosed in a weather-proof enclosure. A pilot light for each unit was installed in the manager's office so that the operation of the units could be remotely monitored.

**REFERENCE:**

First, M.W., F.J. Viles, and S. Levin, 1966. Control of Toxic and Explosive Hazards in Buildings on Landfills. Public Health Reports, Vol. 81, No. 5, May 1966.

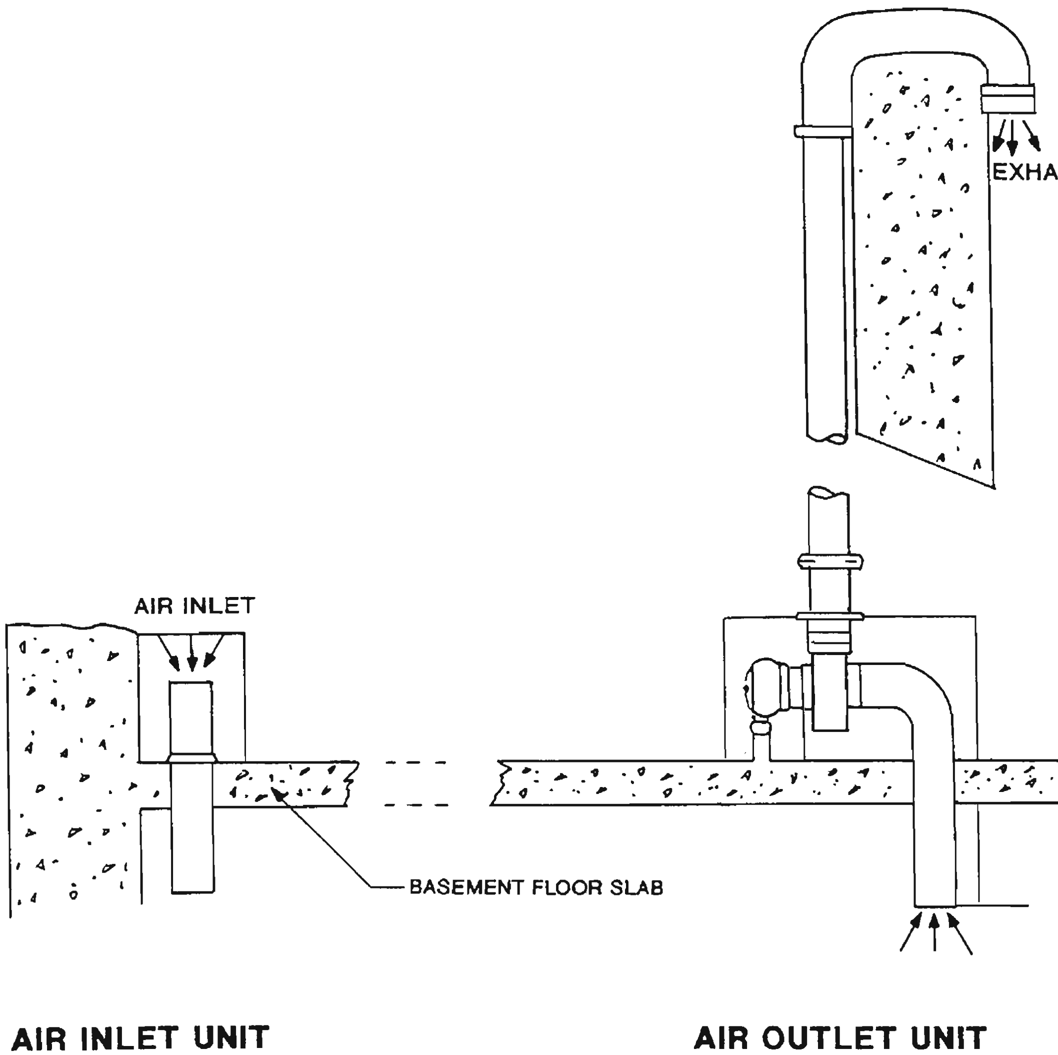


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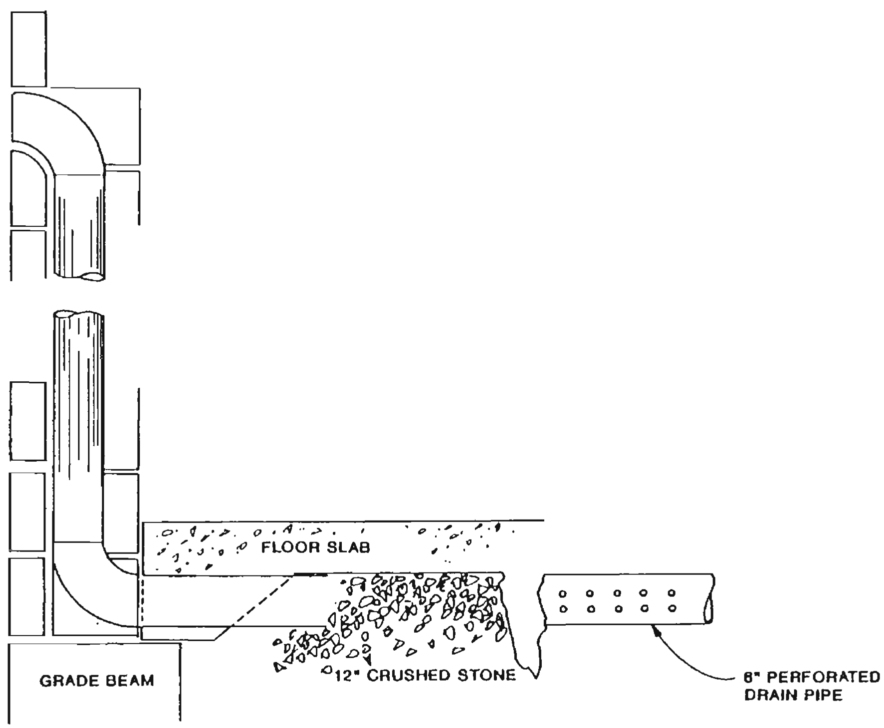
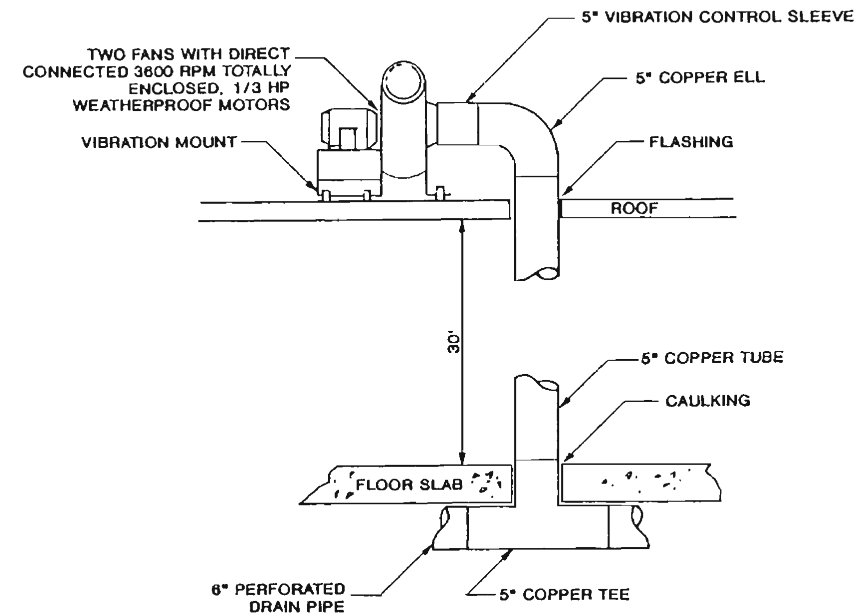
**FIGURE D-9:**

**SUB-SLAB MECHANICAL VENTILATION EQUIPMENT**




AIR INLET UNIT




AIR OUTLET UNIT

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FIGURE D–10:
SUB–SLAB GAS VENTILATION ON THE THEATRE

## CMHC SOIL GAS RESEARCH STUDY
## INTERNATIONAL SECTOR
## CASE STUDY #3

**BUILDING TYPE AND LOCATION:** Residential dwellings, Seattle

**GAS TYPE:** Methane, VOCs

**SOURCE:** Landfill

**TYPE OF CONTROL:** Active pumping

**CASE STUDY PRÉCIS:**

A decision in the 1960s to develop the Midway Landfill site in an abandoned gravel pit subsequently forced the City of Seattle to deal with one of the most serious landfill gas migration problems the nation has ever faced. Before the landfill gas problem was even discovered, within a year of the landfill closure (1984), an active pumping system was operating at the site. However, the operation of this system proved ineffective. Testing of nearby structures revealed that methane had migrated large distances around the landfill. Based on testing completed in the area, methane had migrated as far as 900 m from the landfill boundary and had affected close to one thousand homes (Johnson, 1986).

In response to the methane problem, the City of Seattle immediately drilled 37 additional gas extraction wells on the perimeter of the landfill. The intent of this installation was to draw back the gases from the offsite areas. In order to draw back the gases, heavy pumping was required. This unfortunately caused another problem. Due to the high vacuums, excessive oxygen was being drawn to the subsurface. As a result, accelerated aerobic digestion occurred. This was especially true in the dry summer periods when the ground surface was dry. Daily monitoring of wells in the summer in one area revealed that the subsurface temperature jumped from 30 to 45 degrees Celcius. A depression was also noticed in a part of the landfill. The pumping wells were immediately shut down or the pump capacity reduced. A large track-mounted backhoe dug up the area where the depression was noticed. The steaming refuse immediately burst into flames as it was uncovered. It was quickly extinguished by water and backfilled with clay. The fire was out within 1-1/2 days (Johnson, 1988). Fearing another fire, the City reduced onsite methane extraction wells by two-thirds until the rainy season in the fall when full pumping could again be resumed. Future well designs will include a short and a long pipe. The short pipe would only be used in the winter, thereby limiting the amount of oxygen drawn to the subsurface.

Since a large volume of subsurface gas still remained offsite, and the potential for methane migration into buildings was possible, the City and the Department of Ecology installed several additional gas extraction wells in the neighbourhoods surrounding the landfill. These wells were installed as an emergency measure only. The operation of such wells proved effective in not only reducing the surface gas reservoir but also in reducing indoor methane concentrations to zero (Johnson, 1986). Further analysis of the discharge from these wells showed no health hazards were created by venting to the atmosphere.

Given the complex nature of methane migration around the Midway Landfill, it was apparent that a good understanding of the subsurface was necessary for the long-term containment of gases from the landfill. As such, an investigation was launched to understand current migration pathways as well as evaluate the role of volatile organic compounds at the site. The study involved three components:

- install offsite probes, monitor methane concentrations and pressure to describe the operation of the present gas extraction wells
- define the pathways around the landfill where previous or future gas might leave the landfill boundaries
- define the chemical characteristics of the landfill gas

At the beginning of this study, several offsite areas were known to have elevated gas concentrations including:

- 80% $CH_4$ at shallow depths northwest of the site
- 40% $CH_4$ at shallow depths west, south and east of the site
- 90% $CH_4$ at depth north, east and south of the site

Based on initial measurements of methane at shallow and deep elevations, isopaths were created to show the effect of methane concentrations over time. Figures D-11 and D-12 show the degree of methane migration at shallow and deep elevations, respectively, early in this study (February 1986). As seen on Figure D-11, which is the isopleth of the shallow soil zone for February 1986, methane was detected northwest of the landfill in concentrations over 75%, north of the landfill in concentrations over 25%, east of the landfill in concentrations over 40%, and southwest of the landfill in concentrations over 40%. Figure D-12, the deep zone isopleth for February 1986, shows that methane was detected in all directions away from the landfill in concentrations over 90% in some areas. These two isopleths represent the status of landfill gas migration at the time that the completed Phase I onsite gas migration control system was put into continuous operation.

The effect of the offsite control wells placed in the various locations east of the landfill can be seen on Figure D-11. This figure shows a deep soil zone east of Interstate 5, surrounded on the three sides with concentrations of gas above 5%.

However, the areas near the offsite control wells do not indicate concentrations of gas over 5% by volume in the shallow soil zone.

Figures D-13 and D-14 show the maximum shallow and deep gas concentrations during the first half of September 1986. This represents the status of migrated landfill gas seven months after Phase I onsite migration control system was put into continuous operation. As seen from these figures, a significant reduction of gas has been noted east, south and west of the landfill site. However, one shallow area west of the landfill still had over 25% gas by volume; this was believed due to peat bog in that area. Further isopleths for December 1987 are shown in Figures D-15 and D-16. As seen on these figures, much of the gas has been vented; however, it was a slow process especially for methane found at depth.

An additional isopleth was also generated for the pressure gradients around the Midway Landfill. The pressure gradients in December 1987 are shown on Figure D-17. Pressure gradients were studied to determine if vacuums created onsite are pulling back previously migrated offsite gas, or if gas is being allowed to migrate across property boundaries. As seen on this figure, however, the gas is effectively being pulled back toward the landfill.

Conclusions reached in this part of the study indicated that the large gas reductions in the shallow soil zones had occurred. This condition also dropped methane concentrations in basements and crawl spaces in the vicinity of the landfill.

Another objective of the study was aimed at determining pathways for offsite migration. Such pathways included both utility corridors and natural geologic pathways.

In order to evaluate if underground utility corridors were contributing to offsite migration, information was retrieved on the location of major sewer, water, telephone, natural gas and power lines in the area. The information was transferred to a common base map and compared to methane isopleths. No obvious connection between these two maps were apparent. Additional monitoring also revealed that no significant gas had been reported in structures and vaults or utilities for several months after the gas pumping system was activated.

The natural geologic pathways were also evaluated. To identify potential geologic pathways for gas migration, aquifers underlying the study area were examined for evidence of undersaturation. Undersaturated zones (as they were referred to in the report, Parametrix, 1988) are a portion of the geologic medium in which soil pores are not completely filled with water, therefore allowing the transport of gases. The potential gas migration pathways were defined by correlating adjacent borehole logs. Potential sources (the landfill or peat bogs) and receptors (areas where the undersaturated zones meet the surface) were reviewed in relation to the potential pathways.

The geologic deposits in the study area were found to contain a variety of sediments with varying hydraulic properties. Despite the complexity, however, distinct hydrostratigraphic units were defined. It was found that a set of undersaturated zones that connect to the landfill form a system of gas migration pathways through which landfill gas can move away from the landfill. These interconnected zones were found to be mainly located to the east and southeast of the landfill, with a small but notable lobe to the northwest. These pathways appeared to occur almost exclusively within an upper gravel aquifer as shown in Figures D-18 and D-19.

Conclusions reached by the investigators indicated that the upper gravel aquifer formed the major gas migration pathway to the east and southeast of the landfill, allowing gas to migrate up to 800 m from the landfill. This affected area extended from Interstate 5 to the east of Military Road. Similarly, the Upper Gravel Aquifer could also have been a gas migration pathway for a limited distance northwest of the landfill (Parametrix Inc., 1988).

The third component of the investigation at the Midway Landfill involved the characterization of the landfill gas on- and offsite. This component of the work was designed to "fingerprint" the onsite subsurface gas components as well as offsite gases and evaluate the relationship between these two compositions.

Prior to the work conducted by Parametrix (1988), the University of Washington Department of Environmental Health examined concentrations of a selected number of inorganic and organic compounds from the inlets of three of the onsite temporary flares. The findings of that study concluded:

- combustible gas concentrations ranged from 34 to 36% by volume
- carbon monoxide concentrations ranged from 10 to 10 ppm
- hydrogen sulphide concentrations ranged from 0.9 to 18 ppm
- hydrogen cyanide was below the detection limit at the locations sampled
- numerous volatile organic compounds were detected with concentrations of selected compounds ranging up to approximately 45 ppm. Major compounds detected included: benzene, toluene, several chlorinated solvents, and numerous alkyl and aromatic hydrocarbons.

Based on the past activities at the site, the consultant conducted a survey on a target group of volatile organic compounds. The target compounds included:

- 27 of 29 VOCs included in the Clean Water Act CERELA/RCRA Consent Order "Priority Pollutant" VOCs list. (However, acrolein and acrylonitrile were later deleted from this group by USEPA.)

- 8 other additional VOCs added at the time of compilation of the Hazardous Substances List

- 3 additional VOCs that were not on the "official" Hazardous Substance Lists but results for which were routinely included in previous work. This included: tetrahydrofuran, trichlorofluoromethane, trichlorotrifluoroethane.

Gas samples were obtained from both onsite and offsite probes and flares. It was anticipated knowledge of both on- and offsite gas concentrations would provide information on the potential extent and direction of subsurface landfill gas migration. Knowledge of the chemical constituents of the offsite subsurface gas helped to determine whether the offsite subsurface gas originated from the landfill or from unrelated offsite sources. If the chemical "fingerprint" of an offsite subsurface gas sample closely matched that of the onsite subsurface gas, there would be reason to suspect that the offsite gas constituents may have migrated with methane and other major landfill subsurface gas constituents.

Several USEPA HSL VOCs were found in both onsite and offsite subsurface gas samples. The compounds most frequently found together were the BTX group compounds (benzene, toluene, total xylenes, ethylbenzene, and styrene). Vinyl chloride was very often associated with the BTX compound group in onsite subsurface gas samples, but in offsite subsurface samples, it was found much less frequently than the BTX group. Figures D-20 to D-22 graphically display the distribution of VOCs at different locations in the vicinity of the Midway Landfill.

Maximum onsite concentrations for BTX-group compounds and vinyl chloride were in the 17 to 31 ppm range. All the maximum contaminant concentrations for BTX group compounds and vinyl chloride were from one onsite gas extraction well (44D-O) that operated at a relatively low gas flow rate. Arithmetic mean onsite concentrations for these compounds were in the 2 to 4 ppm range.

Maximum offsite concentrations for the BTX group compounds and vinyl chloride were less than 0.3 ppm. Arithmetic mean offsite concentrations were in the low parts-per-billion range, often near or below the detection limit.

Interpretation of the results for other compounds was less clear for several reasons: 1) a lack of clear-cut patterns of geographic distribution, 2) extremely low concentrations reported, and 3) quality assurance/quality control issues related to trace contaminant levels present in laboratory blanks.

Other USEPA HSL VOC target compounds present in both on- and offsite subsurface gas samples included:

- chlorobenzene
- tetrachloroethene

- methylene chloride*
- tetrahydrofuran*
- trichlorofluoromethane*
- chloroethane
- acetone*
- 2-butanone*
- trichlorotrifluoroethane*
- 1,1-dichloroethene

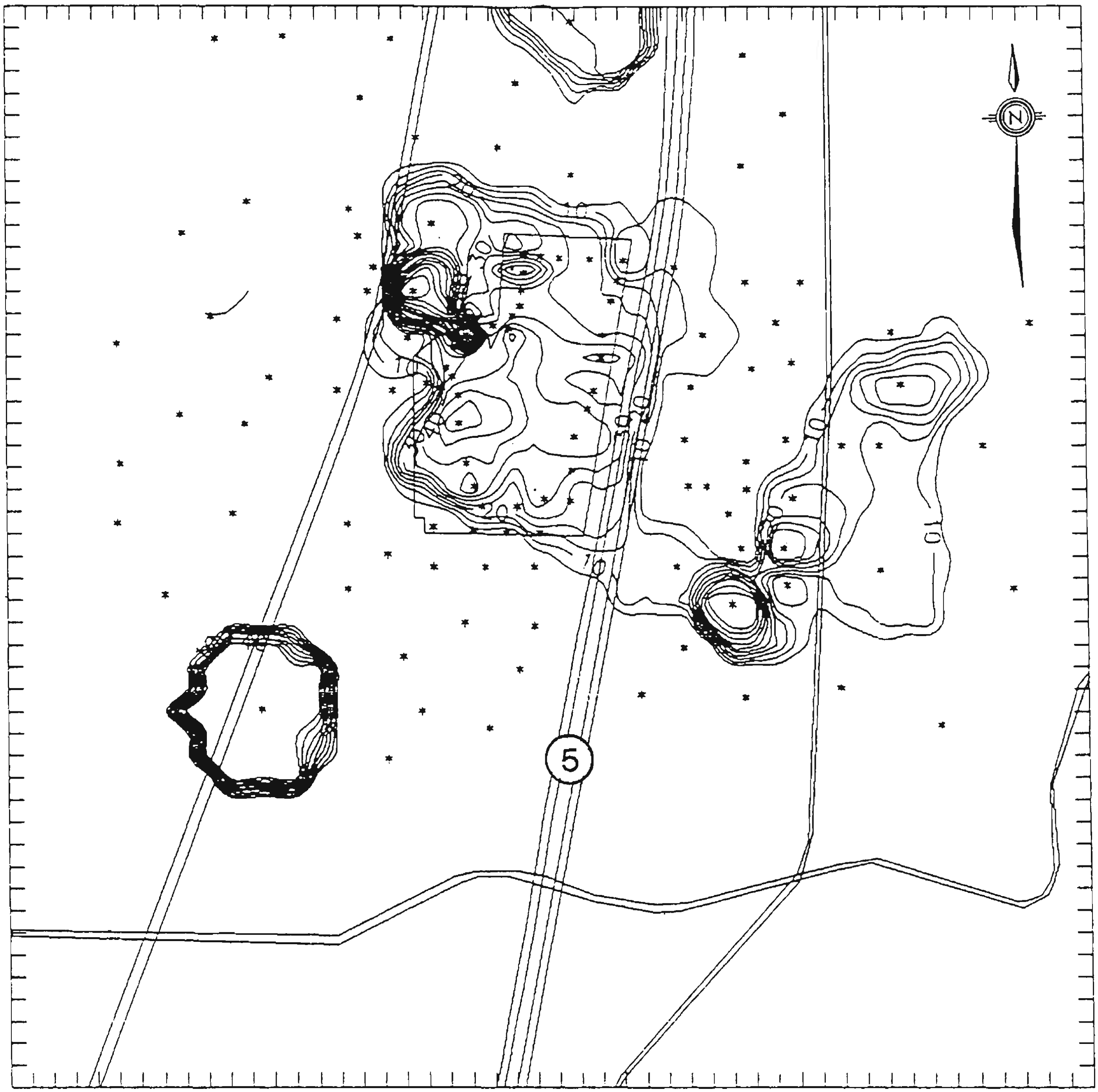
The results for the compounds listed above were interpreted cautiously because several (asterisked items) are known laboratory contaminants. In general, the compounds in this list were found less frequently and in lower concentrations than BTX group compounds and vinyl chloride.

Parametrix (1986) reached a conclusion that offsite migration of notably benzene, toluene, total xylenes, ethylbenzene, and styrene had occurred. The studies initiated at Midway, however, were not designed to explain the decreasing concentrations further from the site. Possible mechanisms suggested included: biodegradation, chemical interactions, physical adsorption, and volatilization of the compounds.

**REFERENCES:**

Johnson, B., 1986. Methane Gas Seeps into Seattle Community Homes. World Wastes, vol. 29, no. 13.

Parametrix, 1988. Midway Landfill Remedial Investigation Landfill Gas Technical Report. Report prepared for Seattle Engineering Department Solid Waste Utility, March 1988.




Note All sets of probes and wells may not be shown

SCALE IN FEET

0 500 1 000

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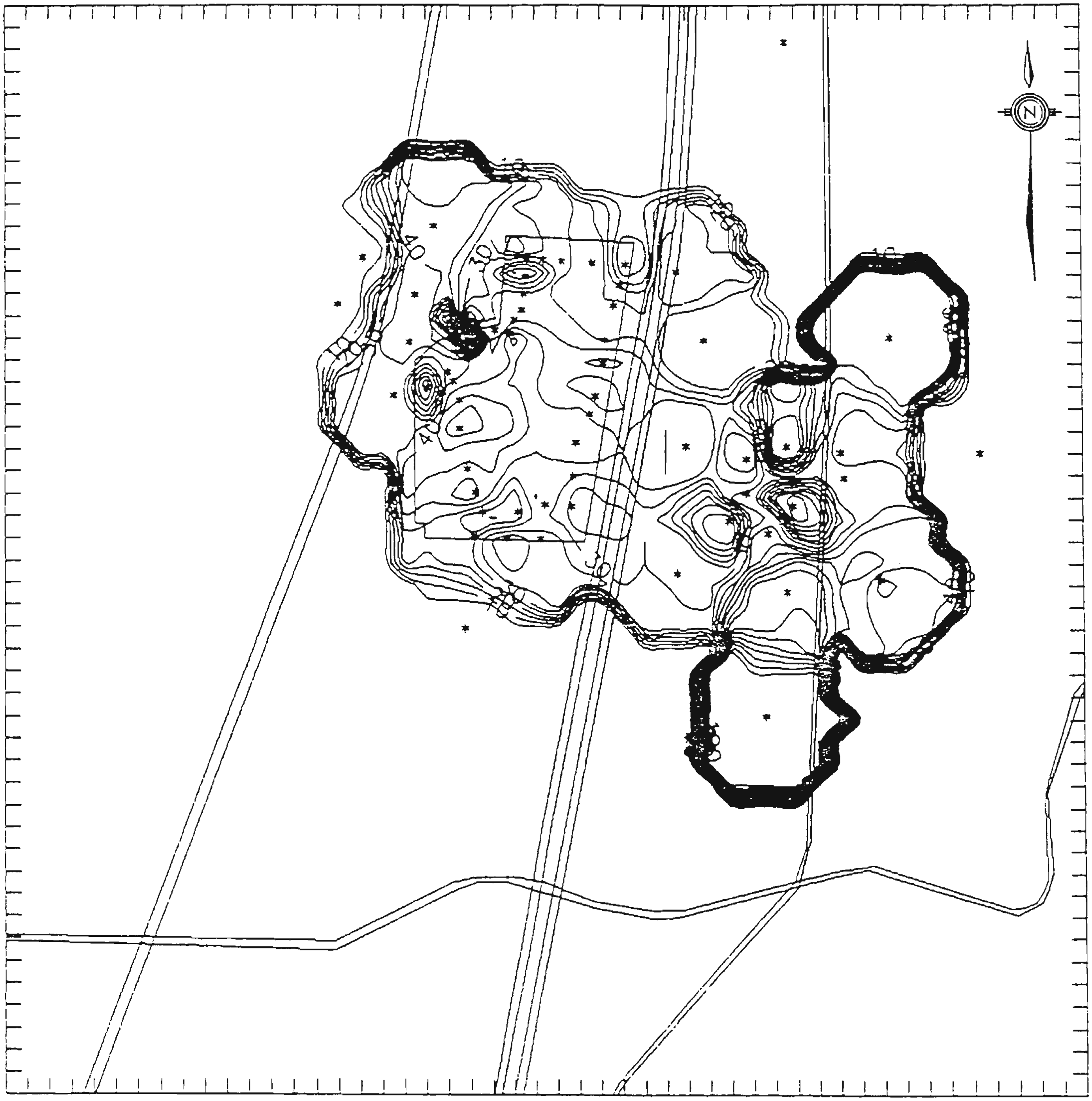
**FIGURE D-11: SHALLOW GAS CONCENTRATION ISOPLETH, FEB/86 (Source: Parametrix 1988)**



Note All sets of probes and wells may not be shown

SCALE IN FEET

0 500 1 000

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**FIGURE D-12: DEEP GAS CONCENTRATION ISOPLETH, FEB/86 (Source: Parametrix, 1988)**


Note: All sets of probes and wells may not be shown.

SCALE IN FEET
0 500 1,000

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**FIGURE D-13: SHALLOW GAS CONCENTRATION ISOPLETH, SEPT/86 (Source: Parametrix, 1988)**


Note All sets of probes and wells may not be shown

SCALE IN FEET

0 500 1 000

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**FIGURE D–14: DEEP GAS CONCENTRATION ISOPLETH, SEPT/86 (Source: Parametrix, 1988)**


Note: All sets of probes and
wells may not be shown.

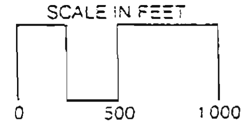


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**FIGURE D-15:
SHALLOW GAS CONCENTRATION
ISOPLETH, DEC/87
(Source: Parametrix, 1988)**

Note: All sets of probes and wells may not be shown.

SCALE IN FEET

0 500 1,000

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**FIGURE D-16:**
**DEEP GAS CONCENTRATION ISOPLETH, DEC/87**
**(Source: Parametrix, 1988)**

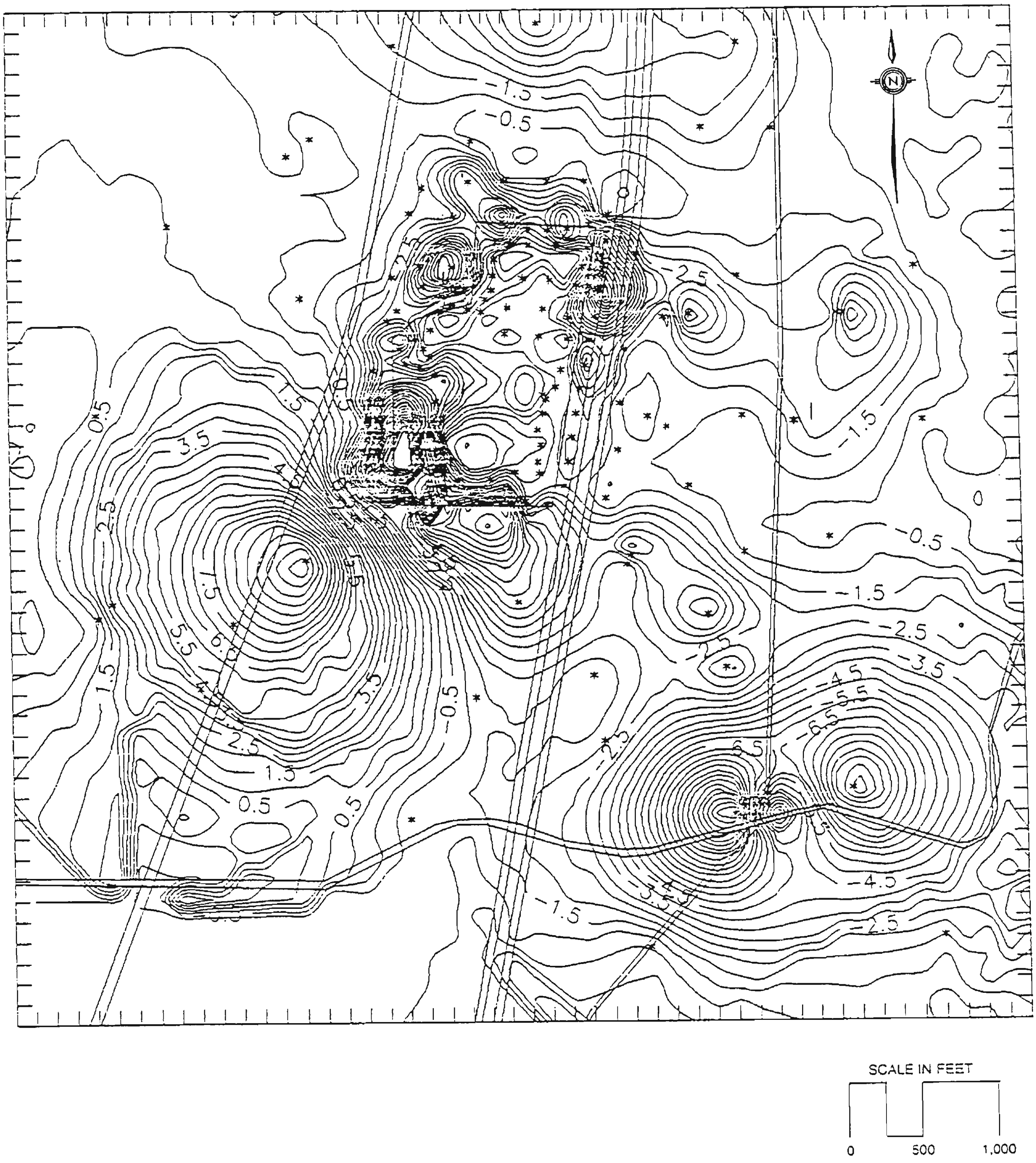


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**FIGURE D-17:**

**PRESSURE GRADIENTS DEC/87**
**(Source: Parametrix, 1988)**

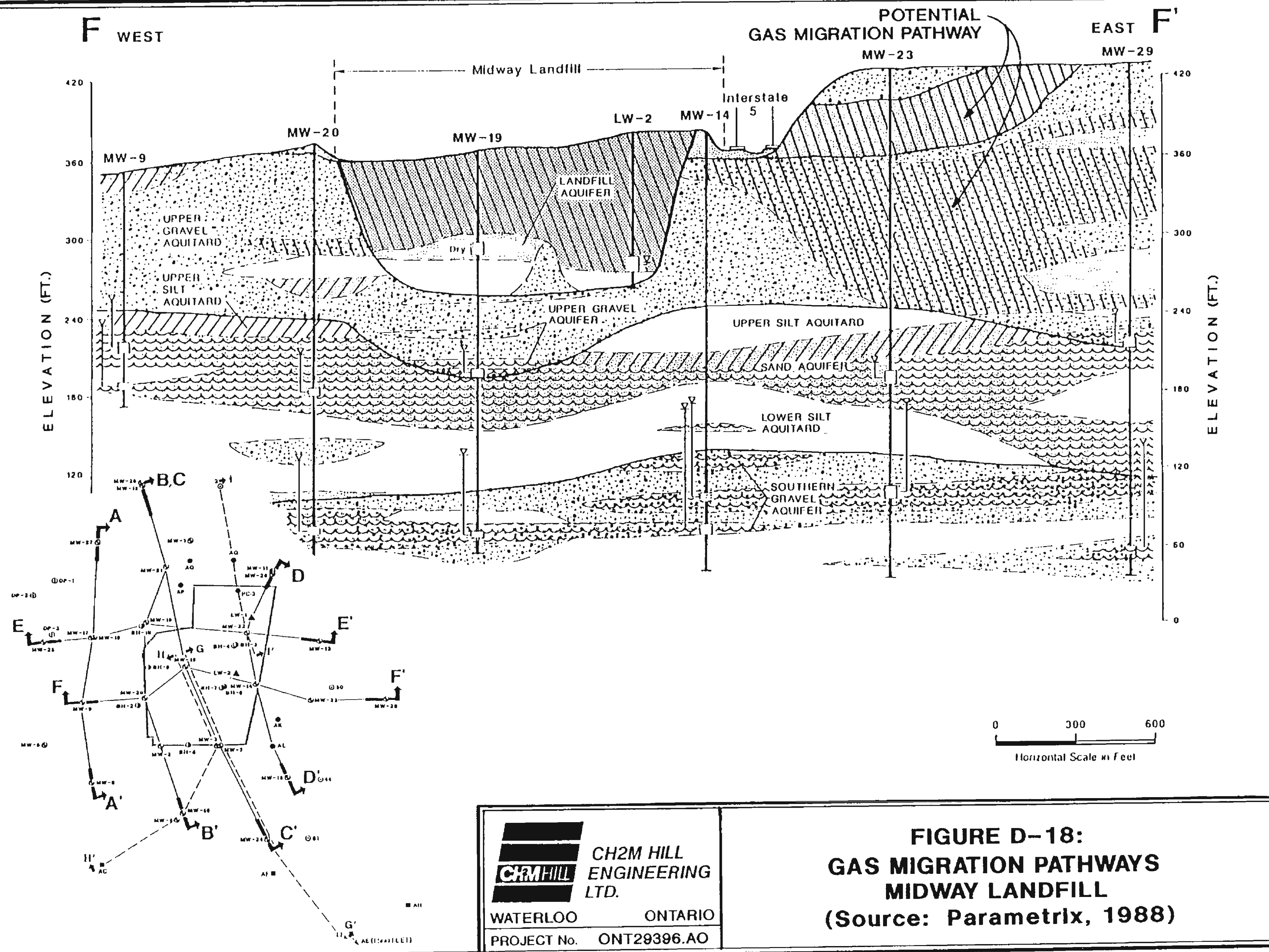


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**FIGURE D-18: GAS MIGRATION PATHWAYS MIDWAY LANDFILL (Source: Parametrix, 1988)**

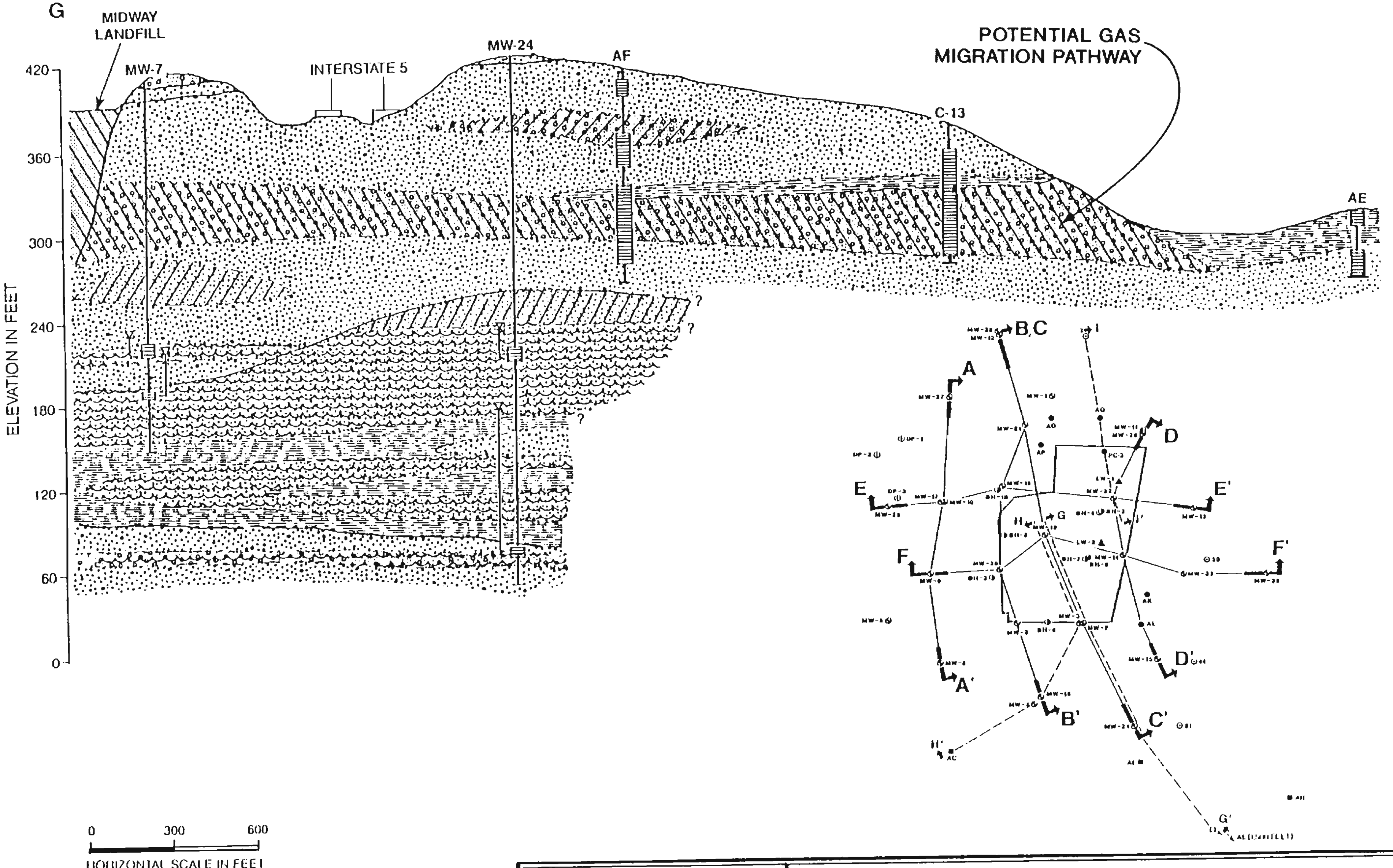


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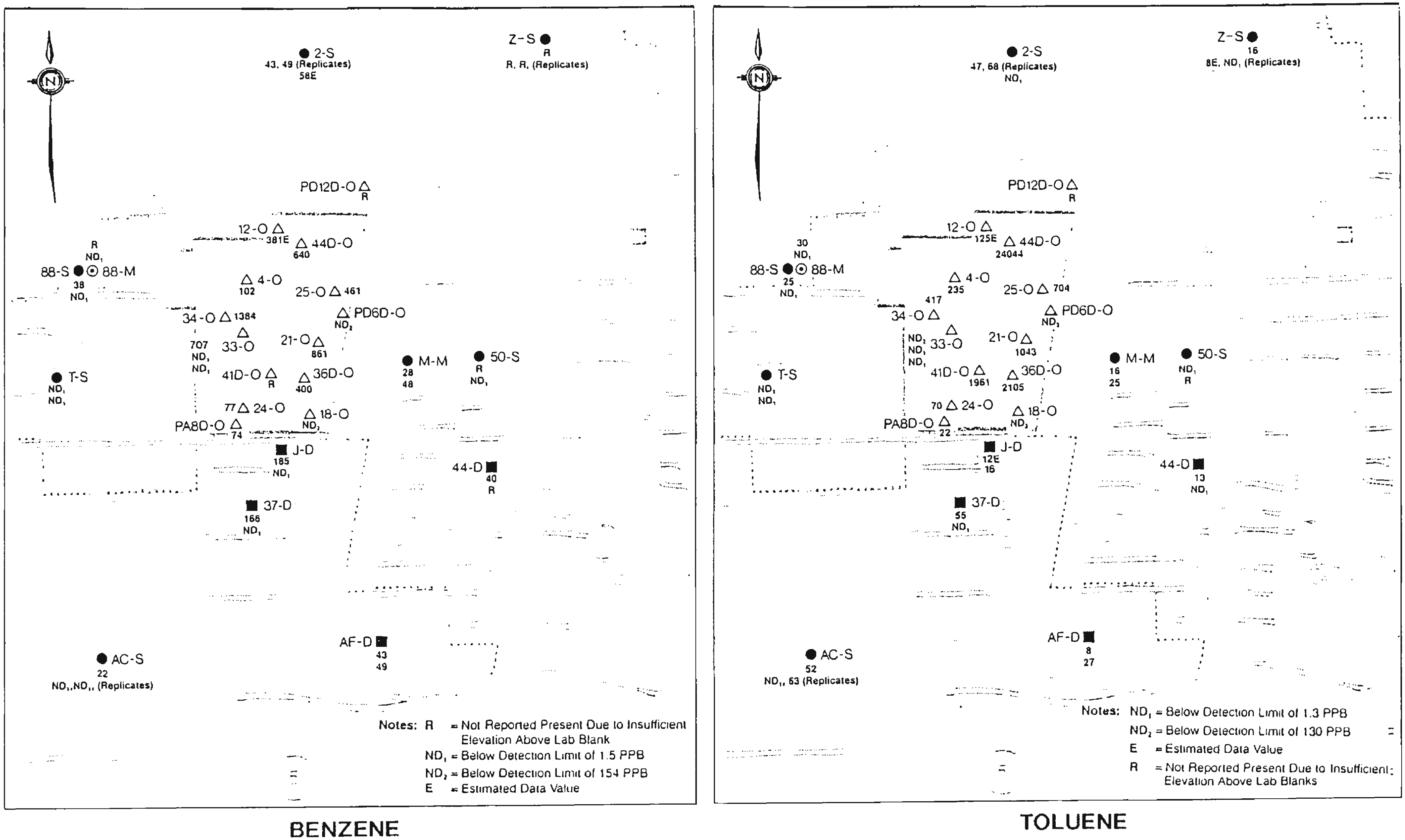
**FIGURE D–19:**
**GAS MIGRATION PATHWAYS**
**MIDWAY LANDFILL**
**(Source: Parametrix, 1988)**




**LEGEND:**

- ● Shallow Probes
- ⊙ Medium Probes
- ■ Deep Probes
- △ On-Site Control Wells

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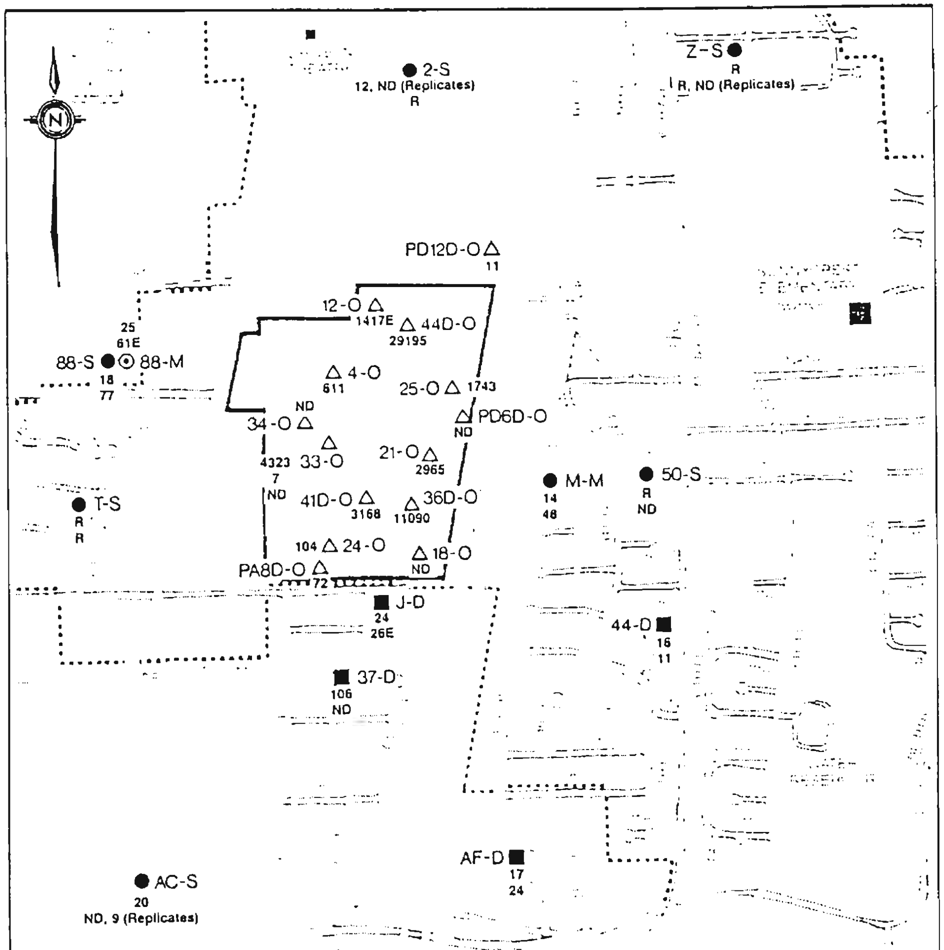
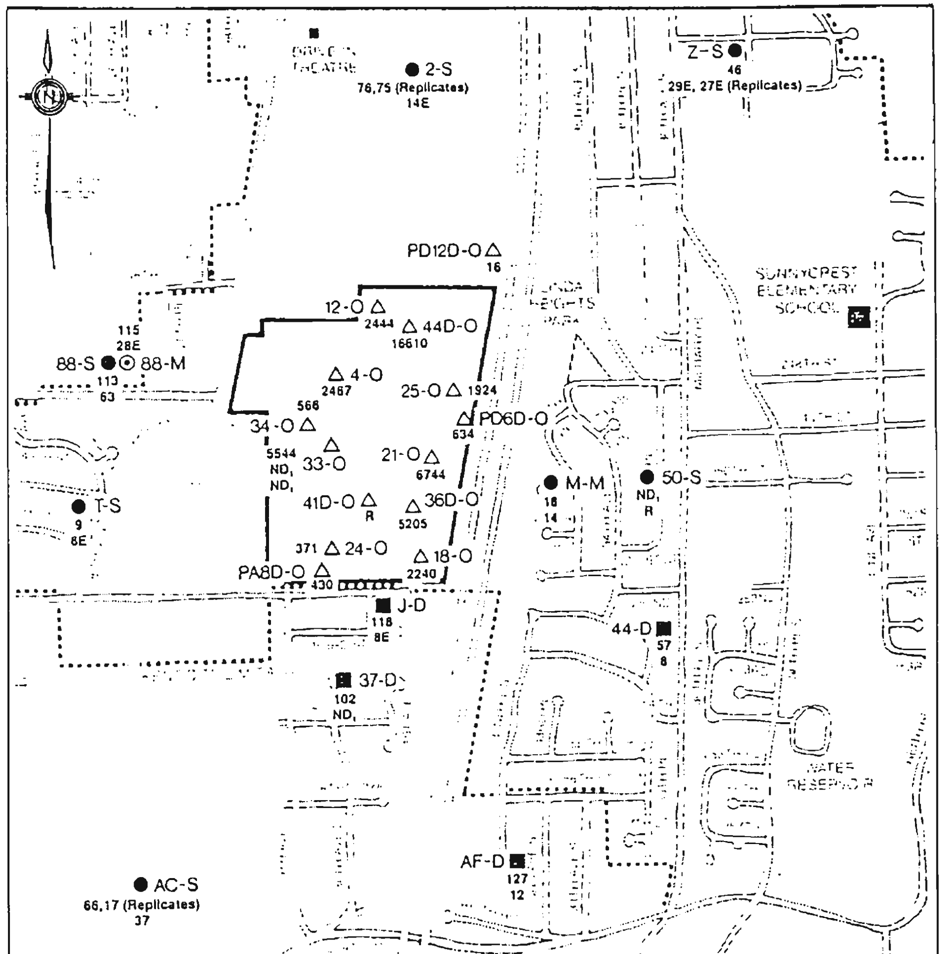
**FIGURE D-20:**
**VOC DISTRIBUTION MEDWAY LANDFILL SITE**
**(Source: Parametrix, 1988)**




Notes: R = Not Reported Present Due to Insufficient Elevation Above Lab Blanks
ND = Below Detection Limit of 113 PPB
E = Estimated Data Value

5

XYLENES




Notes: $ND_1$ = Below Detection Limit of 1.1 PPB
E = Estimated Data Value
R = Not Reported Present Due to Insufficient Elevation Above Lab Blanks

5

ETHYLBENZENE

**LEGEND:**

- ● Shallow Probes
- ⊙ Medium Probes
- ■ Deep Probes
- △ On-Site Control Wells

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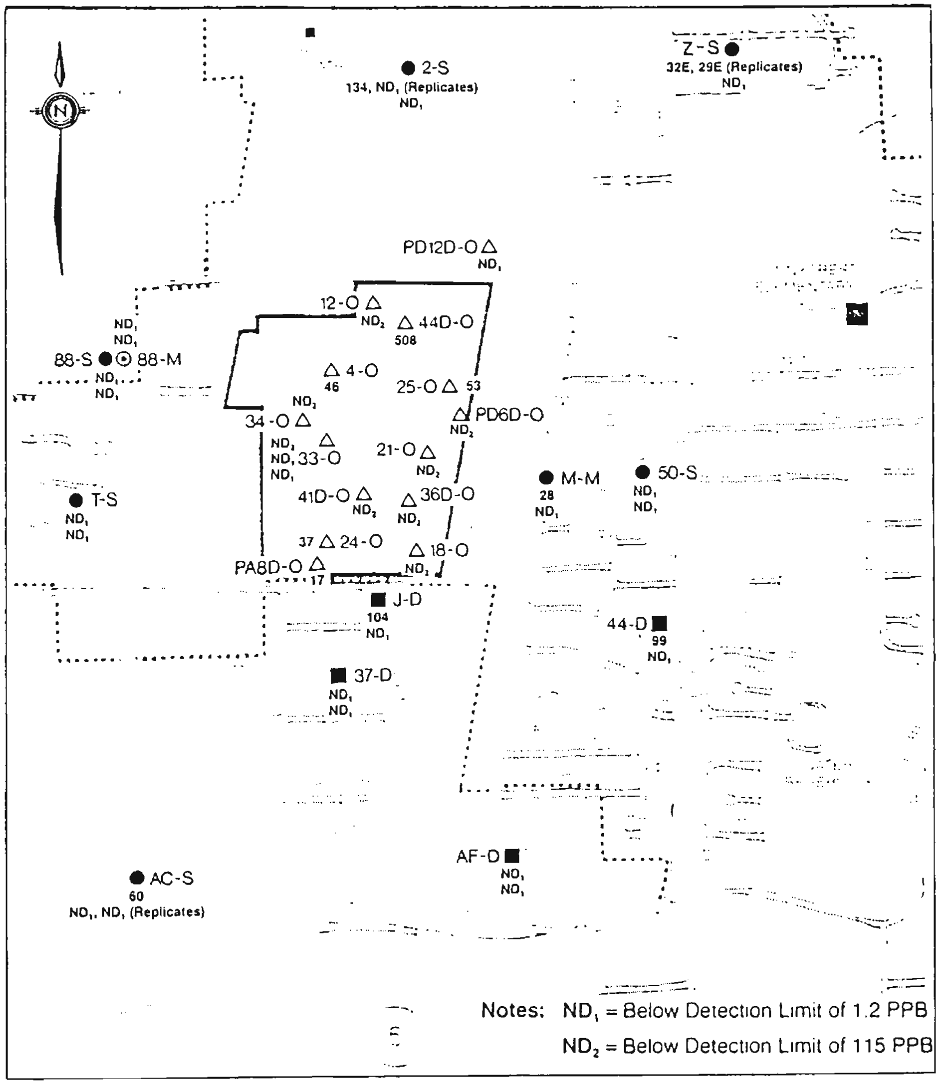
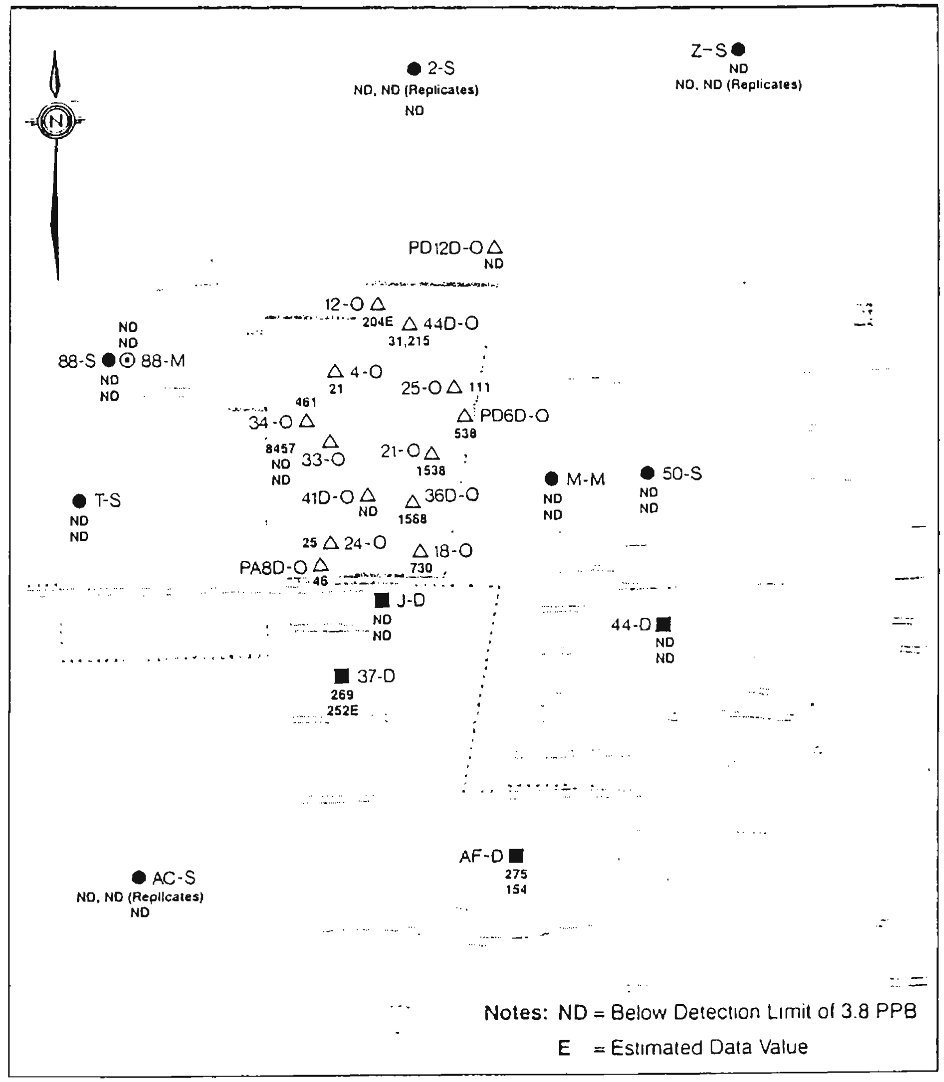
**FIGURE D-21:
VOC DISTRIBUTION MIDWAY LANDFILL SITE
(Source: Parametrix, 1988)**




STYRENE




VINYL CHLORIDE

**LEGEND:**

- ● Shallow Probes
- ⊙ Medium Probes
- ■ Deep Probes
- △ On-Site Control Wells

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# FIGURE D–22: VOC DISTRIBUTION MIDWAY LANDFILL SITE (Source: Parametrix, 1988)

**CMHC SOIL GAS RESEARCH STUDY**
**INVERNATIONAL SECTOR**
**CASE STUDY #4**

**BUILDING TYPE AND LOCATION:** Residential dwellings, Waburn, Massachusetts

**GAS TYPE:** Volatile organic compounds

**SOURCE:** Contaminated groundwater

**TYPE OF CONTROL:**

**CASE STUDY PRÉCIS:**

In April 1989, the Massachusetts Department of Public Health expressed concern that contaminants in the groundwater emanating from the wells G & H Superfund site study area might be affecting a nearby group of homes. ENSR Consultants conducted an indoor air investigation on behalf of two industries identified as potentially responsible parties. The EPA Region I Environmental Services Division planned and conducted a concurrent parallel study. Following an initial survey of homes, EPA selected three homes for sampling by both EPA and ENSR.

**Methods**

Based on previous analytical results of the groundwater in the area, a total of five identifying compounds were chosen for evaluation. Included in this list were: tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1,1-trichloroethane (1,1,1-TCA), t-1,2-dichloroethylene (t-1,2-DCE), and vinyl chloride (VC). Three collection methods were used for the indoor air sampling program including:

- Tenax sorbent tubes Tenax was selected as the primary collection medium for PCE, TCE and 1,1,1-TCA.
- Whole air samples in tedlar bags Approximately 12 litres of air was drawn into tedlar bags via an evacuated drum apparatus. Whole air was selected as the primary method for t-1,2-DCE and VC.
- Passive charcoal organic vapour monitors Monitors were exposed for six to seven weeks in fixed locations, then solvent extracted and analyzed by GC/MS.

In the sampling program, basement and upstairs (first floor) samples were collected simultaneously. On each day, a third sample was collected from the outdoors. Potential background sources of the target compounds were noted in several homes (i.e. paint and solvent cans, dry-cleaned clothes).

Figure D-23 presents the results for three of the five target compounds (PCE, TCE, and 1,1,1-TCA) for air in the basement and upstairs. ENSR only marginally detected t-1,2-DCE by the whole air method in the basement of the Home 1; VC was not detected. In addition, two other bars are shown on the right of each figure representing results of the EPA TEAM VOC study from North Dakota (ND) and North Carolina (NC). Each TEAM bar shows the highest 12-hour "overnight personal air" concentration from 23 or 24 samples in each location.

The ENSR study concluded that the study homes had concentrations within the range of TEAM measurements, and therefore, within the spread of "typical" indoor household exposures (Schatz and Smith, 1990). As such, there was no evidence of groundwater vapours.

**REFERENCE:**

Schatz, A.D. and D.G. Smith, 1990. Detection of Organic Vapors Permeating Buildings from Groundwater. Presented at the 83rd Annual Meeting and Exhibition of the Air and Waste Management Association, June 24-29, 1990.

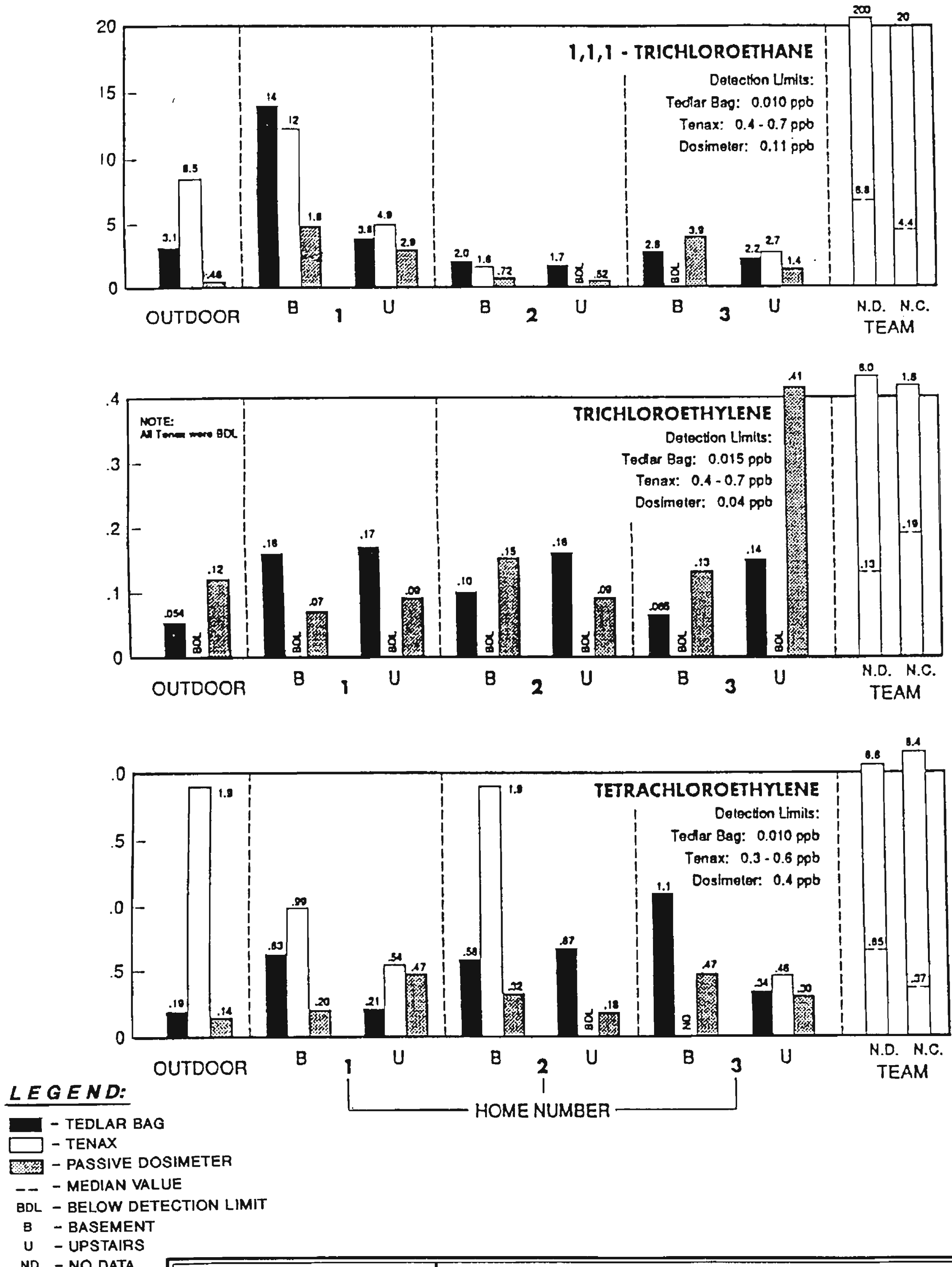


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**FIGURE D-23: RESIDENTIAL INDOOR AIR CONCENTRATIONS WOBURN, MASS. (Source: Schatz and Smith, 1990)**

**CMHC SOIL GAS RESEARCH STUDY**
**INTERNATIONAL SECTOR**
**CASE STUDY #5**

**BUILDING TYPE AND LOCATION:** Six residential dwellings

**GAS TYPE:** Volatile organic compounds

**SOURCE:** Contaminated groundwater

**TYPE OF CONTROL:**

**CASE STUDY PRÉCIS:**

A manufacturing facility was known to have VOC groundwater contamination on its property. A group of six homes was situated across the road, down-gradient in terms of groundwater flow. ENSR conducted indoor air measurements in each of the six homes in March-April 1989. Target compounds included: 1,1-dichloroethylene, 1,1-dichloroethane, 1,2-dichloroethane, tetrachloroethylene (PCE), trichloroethylene (TCE), and 1,1,1-trichloroethane (1,1,1-TCA). Four-hour samples with tenax tubes were collected in the basement and upstairs in each home.

**Results**

All six target compounds were detected in at least four of the six homes. The three compounds found in high concentration in all six homes were PCE, TCE, and 1,1,1-TCA. The results for these three compounds for the basement and upstairs are depicted on Figure D-24. The results are also compared to the results of the EPA TEAM VOC study from North Dakota (ND) and North Carolina (NC). As seen on Figure D-24, the basement concentrations of all three compounds in four or five of the homes exceeded the highest measured concentrations in one or both TEAM locations. Furthermore, the basement concentrations were consistently higher than the first floor concentrations. In Home 6, the observed concentrations of all three compounds were near or below the TEAM median values; there was also no significant difference between upstairs and basement concentrations.

The consultant, ENSR, concluded that groundwater vapours were in fact entering Homes 1 to 5, but not home 6. Immediate steps were taken to mitigate the problem by specifying installation of soil vapour controls in each affected home. (It is uncertain what those controls were.)

**REFERENCE:**

Schatz, A.D. and D.G. Smith, 1990. Detection of Organic Vapors Permeating Buildings from Groundwater. Presented at the 83rd Annual Meeting and Exhibition of the Air and Waste Management Association, June 24-29, 1990.

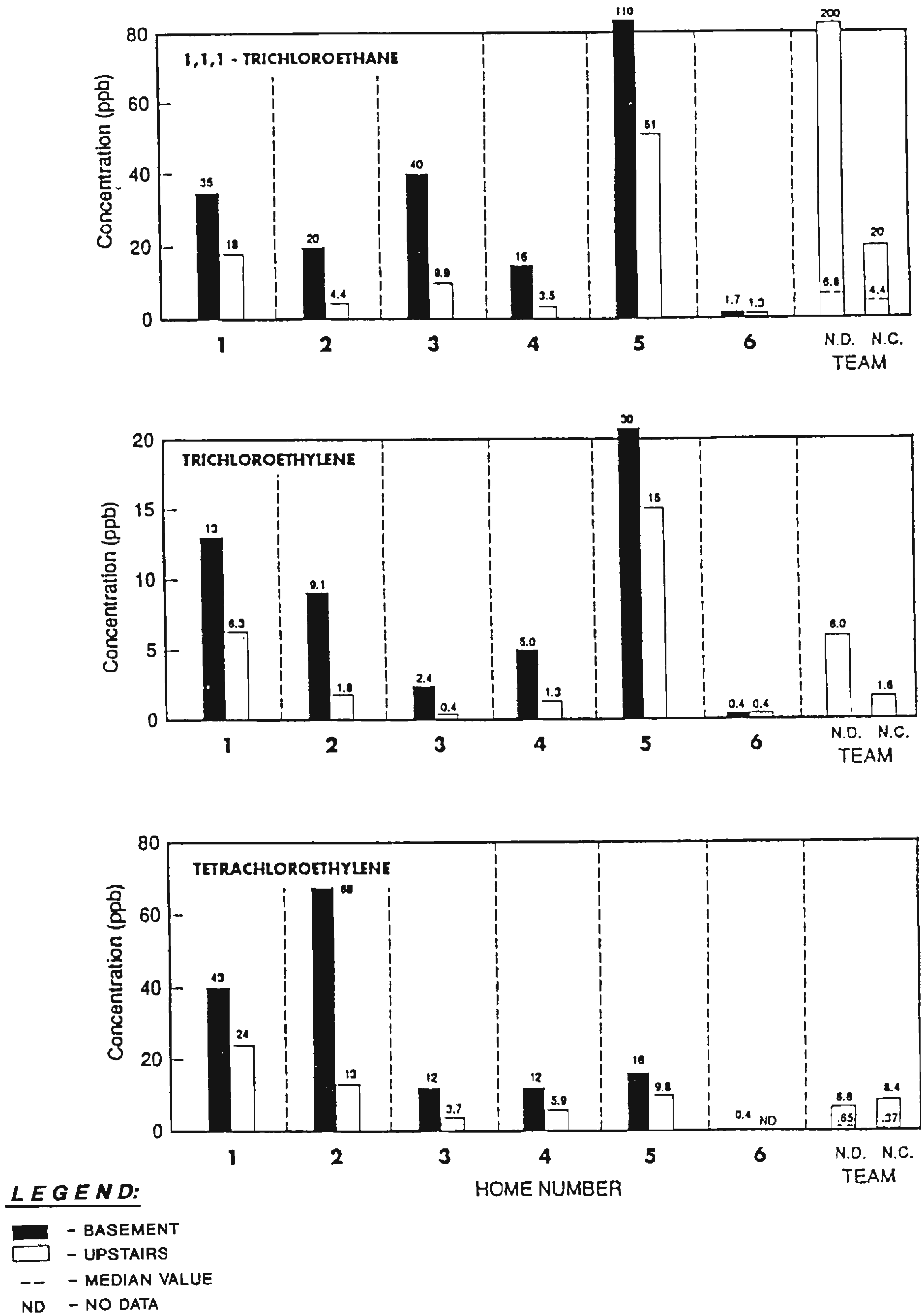


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**FIGURE D–24: INDOOR AIR CONCENTRATIONS IN HOMES NEAR MANUFACTURING FACILITY (Source: Schatz and Smith, 1990)**

**CMHC SOIL GAS RESEARCH STUDY**
**INTERNATIONAL SECTOR**
**CASE STUDY #6**

**BUILDING TYPE AND LOCATION:** Townhouses, Madison, Wisconsin

**GAS TYPE:** Methane

**SOURCE:** Landfill

**TYPE OF CONTROL:** Active/passive venting

**CASE STUDY PRÉCIS:**

The Greentree Landfill was operated by Madison's Street and Sanitation Division for seven years. When the 6 ha site was opened in April 1973, the closest structure was about 150 m northeast from the boundary. Rapid development of the city pushed the corporate limits to approximately 1220 m south and west of the landfill at the time of closure. Residential properties were being developed in the vicinity of the landfill site in 1980. At the time of site closure, on July 3, 1980, 18 residences had already been built within 90 m of the landfill's east berm. This development trend continued and by the spring of 1983, the number of residential properties within 90 m of the site had risen to 26.

The existing landfill gas migration control measures included four passive landfill gas vents and an active landfill gas extraction system on the site's east side. The existing system was installed in 1976.

On November 19, 1983, an explosion ripped through a four unit townhouse, sending two residents to hospital with burns, destroying one unit, and damaging a second. The townhouse was located adjacent to the landfill. The department of public works declared an emergency. A three-part plan was implemented including:

- a technical resolution to the landfill gas migration problem
- regulatory liaison with the Wisconsin Department of Natural Resources (DNR)
- a community relations program

The cause of the explosion was contributed to a set of unfortunate concurrent circumstances (Franklin & Vetter, 1987):

- State plumbing code conditions required two open access hand holes through the basement floor slab to the sanitary sewer lateral's clean out and backflow valve bedded in sand below the structure.

- The sanitary sewer's access hand holes had been identified as possible points of landfill gas infiltration, and city staff had recommended that they be sealed off two days before the explosion.

- Heavy rains for two days before the explosion created an impermeable saturated surface condition, which prohibited vertical gas movement and accelerated horizontal gas migration. Record low barometric pressure readings were also recorded the day before the explosion.

- An undetected landfill gas migration had occurred south and west of the completed landfill site. An expansion of the site's gas monitoring network had been planned, but had not yet been implemented.

- Decreased operating efficiency of the site's existing landfill gas extraction systems, both active and passive.

Soon after the public works emergency plan came into effect, an evaluation of the existing system began. Three probes were installed between two existing extraction wells. The geologic conditions found at this location indicated a sludge-like refuse composition at a depth of 5.5 m. This condition restricted the existing system's ability to extract landfill gas below that depth, thereby decreasing its efficiency.

To remedy the problem, the City and its contractor conducted a series of pumping tests at different locations on the site. Additional extraction wells were installed outside of the waste based on the results of the pumping tests. Having derived the radius of influence from each pumping well, the final system was designed.

System construction began on November 25, 1983. By December 16, 1983, the temporary emergency response blower was activated. The final design was completed by June 1984; construction and assembly of equipment was completed by November 1984.

The final landfill gas extraction system included the following features:

- Complete system back-up included two parallel extraction lines. Each extraction line has been designed with enough capacity to operate independently. Therefore, a second line is always available for back-up in the event of mechanical failure of one line.

- Landfill gas extraction equipment instrumented to provided continuous monitoring of the key operational parameters, including: negative pressure sensing on the landfill collection well on the field side of the blower, pressure switch sensing on the discharge side of the blower, power interruption or failure sensing on the extraction blowers, power interruption or failure sensing on the facility's ventilation system, and an emergency radio alarm system that immediately notifies the responsible city division if a failure occurs in any of the monitored parameters.

In addition, routine monitoring is conducted of all equipment and boundary monitoring probes. Testing of methane, oxygen and soil gas pressure is routinely completed. Whenever the soil gas pressure is equal to or less than zero, it is acceptable (George, P. personal communication, 1990).

**REFERENCES:**

Franklin, J.D. and R.J. Vetter, 1987. Emergency Response to Landfill Gas Migration. Public Works, v. 118, no. 5.

P.W. George, personal communication with M. Adomait, CH2M HILL, 1990.

**CMHC SOIL GAS RESEARCH STUDY**
**INTERNATIONAL SECTOR**
**CASE STUDY #7**

**BUILDING TYPE AND LOCATION:** Residential dwellings, West Covina, California

**GAS TYPE:** Methane, VOCs

**SOURCE:** Landfill

**TYPE OF CONTROL:** Active venting

**CASE STUDY PRÉCIS:**

**Background**

In 1963, the BKK Landfill in West Covina, California began operating as a municipal waste landfill site. From 1972 until December 1984, the BKK Landfill served as the primary commercial hazardous waste disposal site for the Los Angeles area. During the time the landfill has been operating, residential developments have expanded in the vicinity of the site and local citizens have filed numerous complaints. As of 1986, residential housing developments existed immediately adjacent to the southern and western boundaries of the landfill and within 0.3 to 0.8 kilometres of the northern border. Figure D-25 shows the location of housing in the vicinity of the landfill.

The BKK Landfill is located on the western end of the San Jose Hills. The geological structure of the San Jose Hills is characterized by an asymmetrical southwesterly plunging anticline. The principal faults in the area are the San Jose and Walnut Creek Faults. The San Jose fault is nearly vertical and is located to the south of the landfill site, the Walnut Creek fault lies to the northwest of the San Jose Hills.

The geological structure within the BKK Landfill property is quite complex. It consists mainly of shale, medium to coarse conglomerate and sandstone. The geological units have been folded, faulted, and fractured to varying degrees throughout the site. The faults appear to be concentrated on the property's southern and western portions, fracturing is prevalent throughout the landfill site. A cross section of the BKK Landfill is shown on Figure D-26.

BKK Landfill has operated as both a municipal refuse and a hazardous waste disposal site. Waste disposal began at the site in 1963 with the disposal of household wastes and construction debris. In 1972 the landfill began accepting hazardous waste. From 1975 to 1980, waste acids and solutions containing cyanide were also disposed of at this site. Since 1984, the landfill has been closed to the disposal of hazardous wastes.

The BKK Landfill has received more than 17 million tonnes of waste for disposal as of 1984. Of this, 13.7 million were classified as decomposable solid wastes, and 3.4 million were classified as hazardous. Since 1984, BKK has received more than 1 million tonnes of waste per year.

On July 17, 1984, routine monitoring by Southern California Gas Company detected elevated levels of methane gas both inside and around homes along the south-southeast perimeter of the landfill site. As a precautionary measure, 19 homes in the vicinity were evacuated. The EPA issued an order requiring BKK Landfill to improve its gas migration control system, to conduct daily monitoring of the system, and to reimburse evacuated residents for costs incurred.

**Problem Identification**

Extensive surveys were conducted both inside the homes and around structures that break the ground surface using Organic Vapour Analyzers. The methane concentrations inside the homes ranged from 100 to 7000 ppm, samples collected along residential yard retaining walls yielded methane concentrations greater than 5% GAS. These discoveries led to the immediate implementation of major gas control applications. Gas control wells and gas monitoring probes were installed primarily in three locations: the south perimeter (Lynn Court and Leanna Drive area), and the north perimeter (refer to Figure D-25). The south, southeast, and north perimeters of the waste disposal area had historically shown the highest soil-gas concentrations. These parts of the perimeter were the closest to the waste as well as being close to nearby houses. In order to reduce concentrations in these areas, vacuums on individual gas extraction wells were increased at those locations or by installing additional wells. The target was to reduce the concentrations within perimeter probes to less than 1000 ppm.

Since the BKK Landfill had hazardous wastes, sampling for various VOCs was also conducted. Earlier in the spring of 1981, the South Coast Air Quality Management District conducted limited onsite sampling and found elevated concentrations of vinyl chloride, benzene, and toluene. Vinyl chloride, an EPA Class A carcinogen, was detected in the BKK Landfill gas collection system in concentrations up to 500 ppm. Later during testing of two evacuated homes on July 18, 1984, vinyl chloride was found at concentrations of 5 to 990 ppb. Vinyl chloride became the primary landfill gas contaminant of concern.

The extensive monitoring was completed with Organic Vapour Analyzers, and various evacuated flask and bulb samples collected within the evacuated and occupied homes near the site. These collections served to document vinyl chloride and other VOCs, whereas OVA readings indicated the presence of total hydrocarbons.

The offsite indoor air program consisted of:

- Monitoring and sampling with 24-hour samples collected from inside 10 evacuated homes and 1 control home, for the analysis of 10 VOCs, and continuous total hydrocarbon monitoring. These homes were known as Priority I.)
- Monitoring and sampling with 24-hour samples collected from inside 51 occupied homes and 10 control homes, for the analysis of vinyl chloride. (These homes were known as Priority II.)

The Priority II data were not available for this review. The Priority I data, which was collected in October 1984, are summarized in Table D.4. Median values for three VOCs tested were consistently greater in the evacuated homes than the control home: 1,2-dichloroethane, 1,1,1-trichloroethane, and perchloroethylene. Four of the homes (two on Lynn Court, and two on Nanette Street) had elevated median concentrations of several VOCs. However, since these concentrations of VOCs are near the detection limit, there was uncertainty of assigning significance to these slightly elevated levels. CH2M HILL (1988) noted two limitations of the indoor air data collections:

- the use of only one control home, and
- the absence of simultaneous ambient air monitoring near the homes that would allow a determination of the range of background variability.

**Table D.4**
**Summary of the 1984 Priority I Indoor Air Data**

| Compounds | Median Values (ppb) | | | | | |
|---|---|---|---|---|---|---|
| | 2038N | 2041N | 2044N | 2322LC | 2328LC | Control |
| 1,1-Dichloroethylene | 1 | 1 | 1 | 1 | 3 | 1 |
| 1,2-Dichloroethane | 4 | 4 | 1 | 4 | 1 | 1 |
| 1,1,1-Trichloroethane | 6 | 4 | 4 | 5 | 4 | 3 |
| Carbon tetrachloride | 1 | 1 | 1 | 1 | 1 | 1 |
| Chloroform | 1 | 1 | 1 | 1 | 1 | 1 |
| Perchloroethylene | 3 | 6 | 1 | 3 | 3 | 1.5 |
| Trichloroethylene | 5 | 1 | 1 | 1.5 | 1 | 1 |
| Vinyl chloride | 4 | 4 | 4 | 4 | 4 | 4 |

Notes: 2038N indicates #2038 Nanette Street
2322 LC indicates #2322 Lynn Court

After considerable active pumping (as described next), a decreased amount of hydrocarbons were observed around the homes. On August 10, 1984, EPA recommended that nine of the homes could be reoccupied. The exact criteria for reoccupation was not readily available. By December 13, 1984, the remaining homes were reoccupied.

**Remedial Efforts**

The landfill gas migrations and offsite emissions that have occurred along the south and southeast perimeter of the BKK Landfill site are believed to be the result of:

- Permeable subsurface pathways occurring along the southern perimeter of the landfill site.
- Gas generation in the landfill exceeding the sum of the gas collection system capacity and the surface emission rate.

The gas collection system at the BKK Landfill was initially installed in 1975 as a response to complaints from the neighbouring community. It consisted of 15 gas extraction wells and pilot flare with a capacity of 1040 L/s. The system was expanded on a yearly basis to a total capacity of 10,400 L/s.

In response to the detection of elevated methane levels in and around nearby residences in July 1984, an accelerated gas control program was established. It considered of:

- 155 vertical wells installed along the southeast and northern perimeters of the landfill site
- 158 gas migration probes installed around the entire site to monitor gas concentrations
- Installation of 2 flares

The south, southeast, and northern perimeters of the waste disposal area have historically shown the highest methane concentrations in the soil gas. Gas probes were installed in these areas to monitor the effectiveness of the emergency response measures. Gas probes that detected methane concentrations greater than 1000 ppm were targeted for daily monitoring and the monitoring information was used to determine the location for extraction wells. The number of targeted gas probes decreased from 29 to 1 in an 18-month period between November 1984 and April 1986. This is shown graphically on Figure D-27.

The final closure plan for the hazardous waste management area of the BKK Landfill site was approved in December 1989 and was scheduled for completion by March 1989. As of June 1988, the gas collection system consisted of 170 interior vertical gas collection wells, 180 perimeter control wells, 5 horizontal collection systems, 2 flare stations with a total of 10 flares, and a 5 MW Gas Turbine generation plant. The perimeter gas probes are monitored monthly; the methane concentrations in the probes are currently all below 1000 ppm.

**REFERENCE:**

CH2M HILL, 1988. BKK Landfill Environmental Exposure Characterization Report, West Covina, California. Prepared for USEPA, Region IX. EPA Contract No. 68-01-7251.

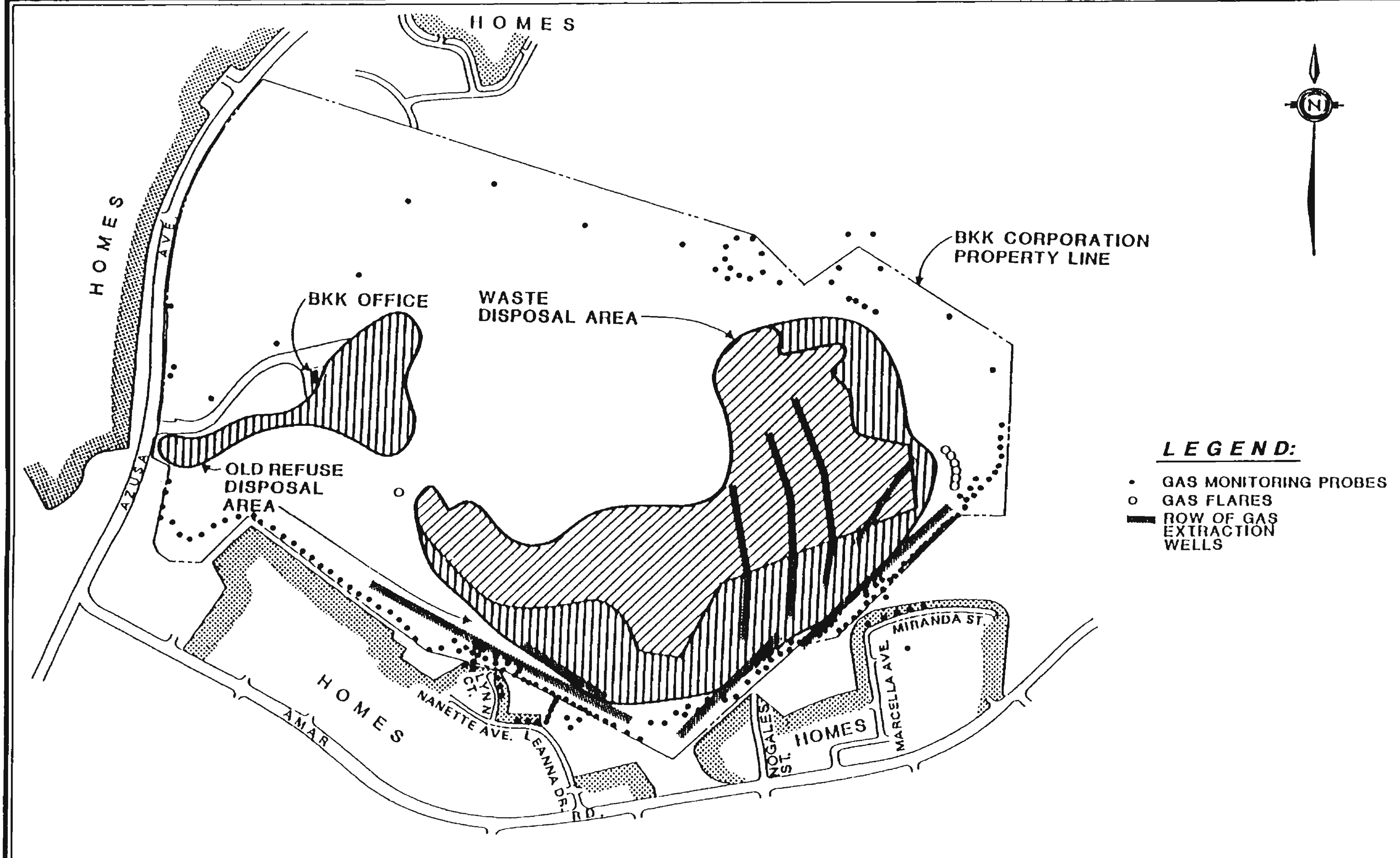


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**FIGURE D–25:**
**BKK LANDFILL GAS RECOVERY AND CONTROL SYSTEM–MARCH 1986**

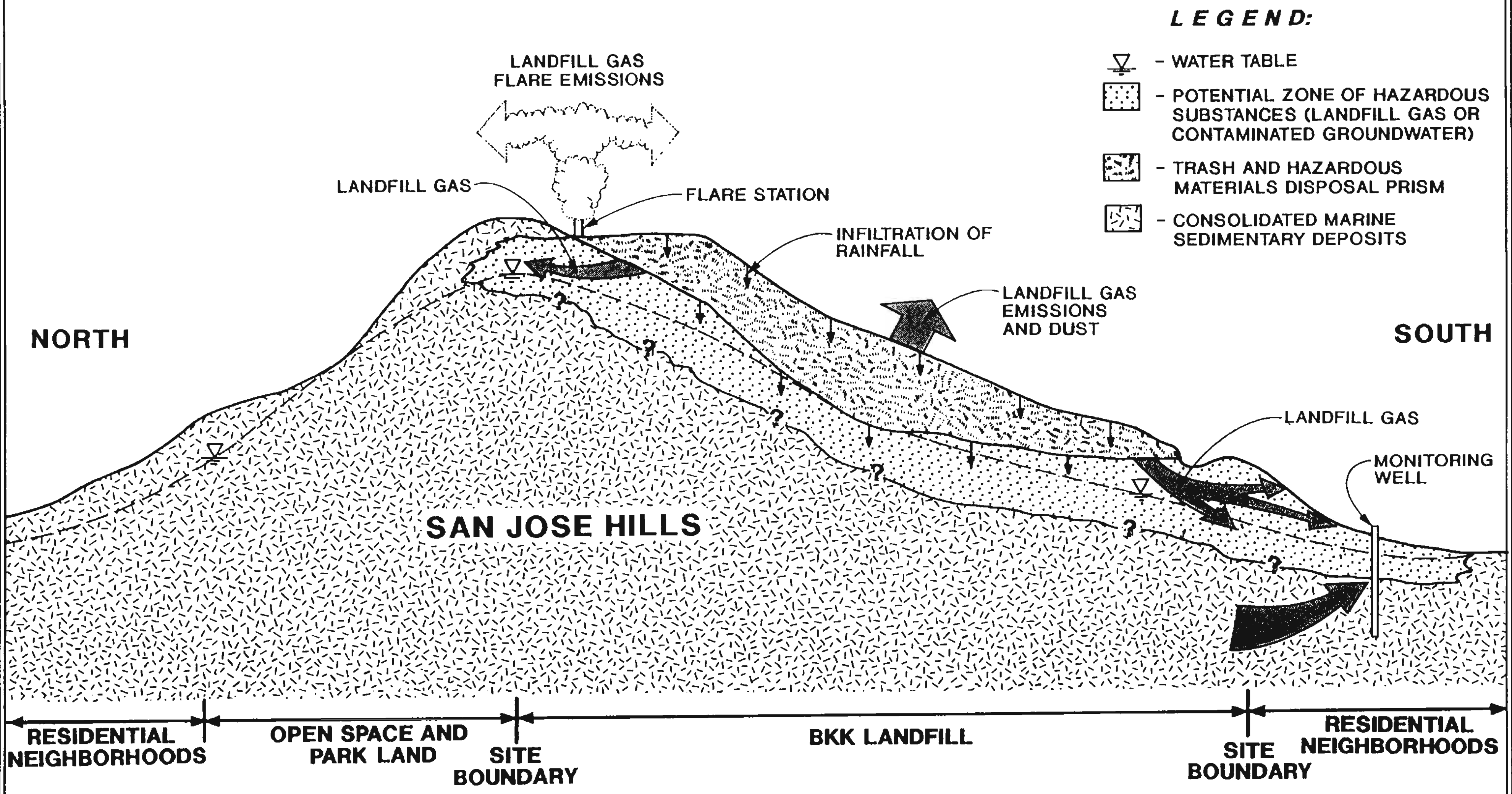


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**FIGURE D-26:**
**SCHEMATIC CROSS-SECTION OF BKK LANDFILL**

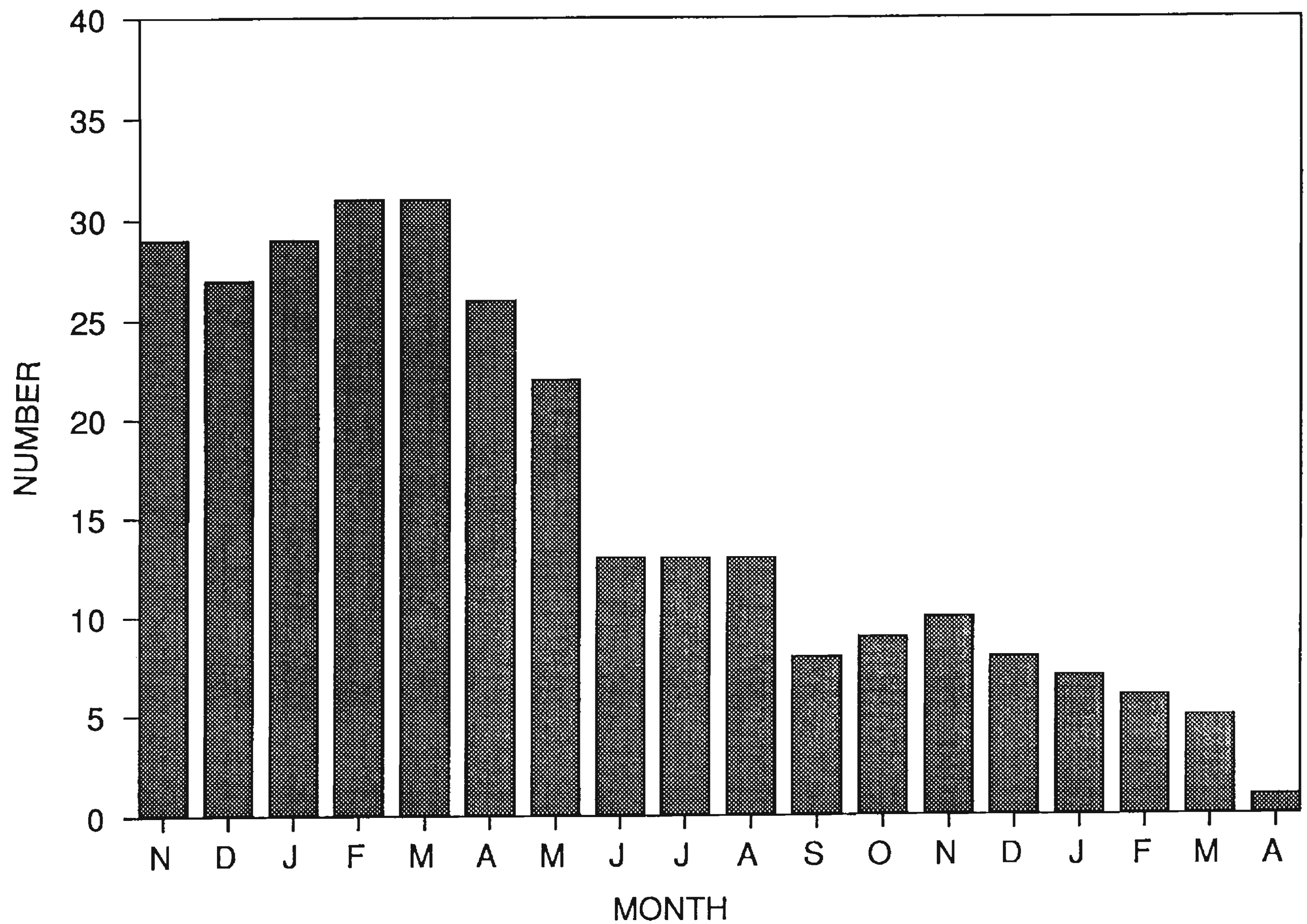


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**FIGURE D–27:**
**GAS PROBES WITH CONCENTRATIONS GREATER THAN 1000 ppm, NOV. 1984–APR. 1986**

## Appendix E

# CONTACTS

# CONTACTS

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**Appendix F**

# COMMENTARY ON THE PROVINCIAL OVERVIEW, TYPES OF SOIL GAS, AND REMEDIATION/PREVENTION TECHNOLOGIES

Appendix F

# COMMENTARY ON THE PROVINCIAL OVERVIEW, TYPES OF SOIL GAS, MONITORING, AND REMEDIATION/ PREVENTION TECHNOLOGIES

## PROVINCIAL OVERVIEW

The types and occurrences of soil gas infiltration and the resulting indoor air quality problems varied across the country. A brief description of the types of soil gas infiltration common to each province and how such problems are handled are given below.

### NEWFOUNDLAND AND LABRADOR

The most common soil gas entry problem encountered in this province is related to the spillage of gasoline. The entry pathway into homes is normally through the sewer network or through the adjacent soil gas. Whenever a petroleum spills occurs, the Department of Environment and Lands will initially investigate. Air monitoring may occur if nearby residences are threatened. This is done by or under the direction of the Department of Environment and Lands with explosimeters, photoionization detectors, and olfactory evidence. If explosive concentrations are encountered, the Fire Marshal will be informed; the fire marshal's office has the jurisdiction to evacuate homeowners. Health concerns are referred to the Department of Health. In the scope of this study, however, no case was identified where health officials actually became involved. The lack of involvement may be due to the fact that many problems tend to be acute rather than chronic.

Solutions to indoor air quality problems typically centre on source control. Source control of a gasoline spill may include soil excavation and installation of drainage ditches. Excavated soil is normally disposed of at a local landfill and used as daily cover. In some cases where remediation is more difficult, such as contaminated soil underneath the building, petroleum companies will consider purchasing the building. This option is viewed as acceptable due to concerns of public pressure and legal considerations.

Another common type of soil gas ingress that occurs in Newfoundland is related to spillage of home heating oil. Investigations tend to be far less analytical in approach. Many times, the spill is not reported. In cases where an odour problem persists, cleanup schemes will normally involve the removal of the contaminated soil. Cleanup standards are normally based on visual or olfactory evidence.

There is only one landfill that was identified as having soil gas migration problems associated with it. A closed landfill site in St. Johns has a methane migration potential. One building, The Regional Taxation Office is located on the site. It has a remediation technique implemented, consisting of crawl space venting. According to Environment and Lands officials, no other landfill site poses a similar problem. Presently in Newfoundland, a 1.6 km buffer zone prohibits development of land for commercial, agricultural or residential purposes in the vicinity of landfill sites.

Other types of soil gas entry problems into homes identified in this study were a result of industrial material being used as backfill around houses, a paint manufacturing process discharging residues on the nearby ground, and a dry cleaning operation discharging perchloroethylene through a hole in the floor (Refer to eastern sector case studies #16, #18, and #19, respectively).

**NOVA SCOTIA**

The most common problem related to hazardous soil gas intrusion into homes is related domestic fuel oil spills. Estimates range between 400 to 500 spills annually across the province (P. Nunn, personal communication 1990). Whenever such spills occur, the Department of the Environment is called to investigate. Other parties such as fuel supplier, and insurance adjuster are contacted and a remedial plan is executed. Remedial plans frequently include excavation for offsite disposal and basement venting. Venting often involves leaving the windows open so that air exchange occurs within the home.

One of the main areas of leakage in domestic fuel storage tanks appears to be along weld joints or along the bottom of the tank. Since the tanks are normally located in an area directly beside the housing structure, any leakage can easily infiltrate through the unfrozen soil adjacent to the house. Fuel normally collects in the weeping tile and consequently produces a persistent odour in the indoor air. Although all new tanks require ULC approval, newer tanks are made of lighter gauge steel compared to older tanks. According to numerous Department of the Environment officials, the lighter gauge steel tanks appear to leak more frequently.

Standards used for effective cleanup appear to be motivated by either olfactory evidence or groundwater issues. In general, very little instrumentation is used. In several cases, environment officials indicated that indoor air quality was not their mandate. Nevertheless, on occasion, Draeger adsorption tubes were used by the Department of the Environment. Health concerns are normally referred to the Department of Health. Consultants, although not commonly consulted in such cases, may use photoionization detectors (PID).

Gasoline spills are the next most common source of hazardous soil gas infiltration problems. Gasoline spills are commonly associated with leaking underground storage tanks, underground piping failures, or accidental spills. Although on an annual assessment there are approximately 100 - 150 gasoline spills in the province, it is rare that housing is affected. This is primarily due to poor soil gas transmission in many of the native soils in Nova Scotia. Much of the province has soil that is indicative of glacial till deposits. Glacial tills generally have poor permeability and consequently do not have good potential for soil gas transmission.

The most common location for soil gas entry into homes resulting from gasoline spills occurs through drain pipe connections. Inadequate plumbing provisions or faulty "p" traps are often a cause for gasoline fumes into basements. Extensive monitoring of indoor air is rarely conducted, normally only with an explosimeter or PID. Specific health concerns and criteria are normally handled by health officials. Monitoring for cleanup is primarily geared to soil criteria. Specific air criteria is not enforced by Department of Environment officials.

Officials from the Department of Health were also contacted in regards to indoor air quality problems. Generally, the Department of Health has had little involvement in soil gas entry problems. Only two gasoline spills were identified. In both cases, vapours were entering through the sewer system. Draeger tubes and the Miran Analyzer was used to make an assessment.

Only one landfill site located in King's Country had possibly affected nearby homes. The problem was investigated and the homes were moved. Other soil gas problems identified include pesticide dumping, and a chemical spill in the sewer system (Refer to case studies #3 and #4, Eastern Canada Sector, Appendix A).

**NEW BRUNSWICK**

Most of the soil gas infiltration problems identified in New Brunswick are associated with gasoline spillage. Whenever a gasoline spill has occurred, the Department of the Environment responds. Nearby homes are checked routinely to identify any adverse indoor air quality problems. Officials from the spill response team, however, indicate that indoor air quality is not in their mandate. Testing is normally done by the potential responsible party or their consultant. Methods of detection of indoor air quality problems is normally done with portable equipment, i.e. photoionization detectors, explosimeters, and Draeger tubes.

Typical avenues for hydrocarbon entry are through sewer drains or utility/sewer trenches. Migration of sewer gases indoors is often erratic in nature, making their detection extremely difficult. At no time was the direction of air flow even specified during investigations concerning hydrocarbon entry. In order to deal with the sewers as an entry pathway, corrections to the plumbing system are often the preferred remediation method. Restoration of "p" traps by means of water addition or mechanical repair is often the simplest method of reducing incoming vapours from the sewers. In cases where excessive concentrations have resulted indoors, ventilation of indoor air is undertaken. On occasion, excessive indoor hydrocarbon vapours have caused extensive damage (refer to eastern sector, case study #26).

At times, hydrocarbon contamination may exit directly adjacent to the structure. In such cases, soil excavation is normally the preferred solution. In other cases, soil vacuum extraction systems are installed to remove hydrocarbon vapours, or bioremediation methods are implemented. Choosing between various remedial technologies is normally based on factors such as: cost, location, and applicability of certain implemented remedial technologies. Regardless of the methods used, based on the findings of this study, it does not appear that any significant air monitoring indoors has been conducted in response to such environmental mishaps.

Another common type of indoor air contamination which occurs is from leaking home oil tanks. Such spillage occurs due to overfilling or by line or tank failure. The level of investigation associated with these spills is often less involved than the minimal monitoring performed during gasoline leaks. Reports completed by the Ministry of the Environment about such activities are normally brief. Cleanup is initiated quickly by the potentially responsible parties and insurance companies (if involved). The main criteria for cleanup is based on olfactory evidence.

Jurisdictional authority over indoor air quality issues may vary depending on the location of the spill. Within cities, the municipality often play a major role since sewer systems are frequently affected. The Department of the Environment are then brought in as advisors (on the environmental issues). In a few cases the Department of Health may be consulted (e.g. eastern sector case study #1); however their involvement is normally minimal. Whenever a mishap occurs in the rural areas, the Department of Environment have acted as consultants to the RCMP who have jurisdictional authority to evacuate homeowners.

**PRINCE EDWARD ISLAND**

Case studies that documented the infiltration of soil gases into homes in PEI appear to be connected primarily to fuel product spills (i.e heating oil or gasoline). Typical entry pathways are through the sewer system. The migration of vapours through of the sewer system is normally due to caps being left off of sewer cleanouts. The degree of indoor air degradation is normally a function of the ventilation rate as well as the source strength. Actual reports of spills where IAQ was affected are limited; normally the only record consists of the official spill report.

Source depletion is the primary objective. Such action may involve excavation of soils, and perhaps installation of a sub-slab vapour barrier.

Gasoline vapours are normally quantified with the use of PIDs. Measurement of heating oil is completed by olfactory evidence. This may be a health problem, however there is a lack of a hand-held meter that is capable of performing the required function.

No landfill problems have been reported. PEI restricts development in the vicinity of landfill sites.

## QUEBEC

In the province of Quebec, cases of hazardous soil gas entry into homes is under the jurisdiction of the Ministry of Environment (MENVIQ), the Ministry of Energy and Resources (MER), and the municipalities. The MENVIQ is responsible for overseeing the management of contaminated soils and landfill sites and is responsible for the enforcement legislation. The MER is responsible for installations on the property of oil refineries, oil depots, and service stations. MER has legislative authority for installations within property boundaries. Large municipalities, such as the City of Montrèal, own landfills and have the required expertise to deal with cases involving soil gas intrusion.

The most common type of soil gas intrusion was related to gasoline spills. Nearly every district MENVIQ office contacted cited several cases where gasoline vapours had migrated into homes. In general, no long standing problems were reported; most problems according to MENVIQ officials would normally be of short duration. Any problems on the fuel oil depot, gasoline station etc. would be handled by the MER.

Only a few well documented cases of indoor air contamination were reported related to landfill activity. Although there are many more known problems, limited information was retrieved. A few cases: the Miron landfill, the Ville Lasalle Municipal Dump, and the Père Marquette Highschool are described in Appendix A (Eastern Canada Sector) as case studies #20, #21, and #22. Other smaller landfills in the City of Montrèal also have remedial measures installed (case studies 23-25); however, limited information was retrieved on the scope of the original problem or the effectiveness of the solution.

## ONTARIO

As with other provinces, problems identified with respect to soil gas influx into the indoor environment are handled by several jurisdictional parties in Ontario. Whenever soil gas entry near hazardous lands is encountered, the Ministry of Environment is normally the first to be notified. Although the Ministry of Environment does not have jurisdiction over indoor air quality standards, frequently field personnel will inspect these cases. Primarily, the Ministry of Environment is interested in the mitigation of the source of the problem and focus on the contamination of outside soil, water or air. In some cases where health or safety concerns are encountered, fire department officials or health officers are contacted. Within municipalities, municipal authorities also play a major role. Whenever soil gas entry into homes is encountered (e.g. gasoline spills, or landfill derived gases) the municipalities will investigate. Measurements conducted by municipal officials are performed for the primary purpose of evaluating explosive gas levels. The Ministry of Natural Resources also may have jurisdiction especially when natural gas migrates from natural deposits.

Ontario has a wide assortment of soil gas entry problems. There are hundreds of gasoline spills yearly, and numerous cases of landfill gas entry have been documented in the province. Gasoline or fuel spills are handled in similar fashion as across the country.

Typical source control measures such as soil gas venting, bioremediation, and excavation of contaminated soil are routinely practised. On occasion, homes are purchased when gasoline contamination of indoor air has occurred. Although this solution is expensive, the petroleum company then has the option of completing the remediation in a more systematic fashion, and avoids potential legal concerns.

Several municipalities within Ontario have been reported to have inner-city landfill sites including: Toronto, London, Tillsonburg, Barrie, Brantford, Kitchener, Hamilton, Ottawa, Sault Ste. Marie, Mississauga, Woodstock, and Oshawa. Several of these centres have implemented source control measures (i.e. landfill gas extraction systems), and other centres have controls (remedial measures) implemented at the point of impingement. Several well-documented cases exist; however, many more poorly documented cases are also in existence.

Ontario also has a large industrial base. Soil gas problems associated with industry are poorly documented, likely for legal concerns, and actually are not well-known. Other incidents of radioactive gases (i.e. radon) have been identified within the province. Several houses in Deloro had radioactive fill placed around the buildings. This case has been described. Since radon was not a focus of this study, no further substantial effort was undertaken to identify more cases.

**MANITOBA**

Landfill gas migration and petrochemical spills are the most common soil gas problems in Manitoba. Although the Manitoba Department of the Environment takes the lead role in environmental matters in the province, the City of Winnipeg has developed substantial expertise in dealing with a considerable landfill gas problem. The City of Winnipeg's landfill situation merits an entire description itself.

The majority of soil gas problems each year in Manitoba deal with petrochemical spills. There are approximately 125 hydrocarbon spills and 50 underground storage tank leaks per year in Manitoba. The Province of Manitoba is continuing to update the regulations and procedures that govern the underground storage of petrochemical products. In Manitoba, a gasoline spill typically involves the local fire departments and the Provincial Environmental Emergency Response Team. In many cases, spills are first detected by fumes emanating from sewers, drains, and outlets. Typically the fire department flushes the local sewer or land drainage systems to prevent any explosive build up in buildings adjacent to the spill site. After flushing of the systems is complete, active remediation is undertaken. Typically remediation plans in Manitoba are developed by consultants, implemented by the owner, and monitored by the Manitoba Department of the Environment. Underground storage tank leaks in Manitoba typically have proven to be a problem due to frost in the soil and cold climatic conditions within the province.

In Manitoba, the need for remediation is governed by the measurable contamination levels in the soil. These values are typically measured under laboratory conditions.

During field operations, levels of contamination are measured by use of photoionization detectors, explosimeters or Draeger tubes all of which measure the character of the soil gas.

The City of Winnipeg has recognized the problem of methane gas generation and migration from abandoned and active landfill sites since the mid-1970s. As a result, the City has actively studied, monitored, and attempted to moderate some of the potential effects of this problem. In total, more than 38 sites in the immediate vicinity of Winnipeg, two of which are currently active, have been examined over the last decade.

Experience has shown that the local surficial geology, which is predominantly glaciolacustrine clay and silt, has greatly affected the patterns of methane migration. Methods of predicting the extent of methane migration pursued in other North American cities often fail in the Winnipeg region because of the nature of the overburden and the extreme variation in climate experienced in Winnipeg. Most of the landfills in Winnipeg are less than 7 metres deep and were often placed in former clay borrow pits. Methane production from shallow landfill sites can be affected (slowed and prolonged) by the cold Winnipeg winters. Measured temperatures in abandoned landfill cells reflect groundwater temperatures and typically range from 8 to 10 degrees Celsius.

Landfills placed in abandoned clay borrow pits often intersect irregular silt seams that occur randomly throughout the Winnipeg area. When dry, these silt seams can serve as pathways for methane migration. As well, when soils in the Winnipeg area become extremely dry, large desiccation or shrinkage cracks form in the clay. These cracks promote highly unpredictable methane migration. Utility corridors have also been found to serve as pathways for methane gas migration from landfill sites.

Prior to the appreciation of the methane problem, the City of Winnipeg allowed construction either immediately on or adjacent to these sites. Because of methane migration and differential settlement, the City was forced to purchase and demolish some buildings. Other measures implemented by the City include: the creation of a 4-man team to monitor the long-term impacts and effects of landfill methane, the establishment of a zone of control around each landfill site, and gas control measures at several landfill areas. Results of current indoor monitoring have been reported to be well below the action threshold measurements of one percent in air.

**SASKATCHEWAN**

Soil gas influx into homes in Saskatchewan are dominated by hydrocarbon spills. Of approximately 250 environmental spills which occur annually, half of these spills are related to hydrocarbon products. A concern regarding the presence of radon gas in northern Saskatchewan has been the subject of a recent study and is dealt with in a report by Saskatchewan Department of Environment and Public Safety.

Petroleum spills which have the greatest impact on neighbouring buildings typically result from underground gasoline or diesel storage tanks. Leaks from such underground facilities often are first observed emanating from sewers or lift stations. Gasoline vapours entering homes migrate through weeping tile systems, or cracks in basement floors and wells. Within Saskatchewan, typical methods of remediation for these situations include: excavation, vapour extraction, passive venting, sealing or plugging vapour entry, or relocation of a home.

In order to combat the increase of underground storage tank leaks, Saskatchewan has made an active policy statement whereby all underground storage tanks must be replaced by April 1994. Stringent leak detection criteria will be applied to each facility. It is hoped that with this policy, the frequency of underground storage tank leaks can be minimized and the impacts can be moderated.

Concern of gas leakage from producing well sites was also addressed in this study. Fugitive emissions from gas wells has been specifically identified as a problem in the Lloydminster area of Saskatchewan. Some vegetation stress has been noted in this area. To date however, cases identifying migration from such facilities has been found only in the immediate vicinity of the well bore. No cases of affected neighbouring buildings were found.

Saskatchewan has not observed significant problems associated with offsite migration of landfill gas. This problem has been moderated by keeping most abandoned landfills as "green space".

**ALBERTA**

In Alberta, as in many parts of Canada, procedures and policies for dealing with soil gas problems have changed considerably in recent years. With increased public concern in these issues, and better methods of detection being employed, the frequency of claims of soil gas related fire hazards and air quality problems in buildings has risen dramatically though it seems now to have peaked. The most common type of soil gas problem is related to petroleum hydrocarbons.

Most claims are handled confidentially by private consulting firms whose involvement is commissioned by petroleum companies dealing with underground fuel storage tanks. Many of the problem situations stem from poor connections made in storage tanks, as well as subsidence of soils causing movement of tanks and damage to lines. Client confidentiality in most of these cases is usually maintained making detailed information privileged and usually not available to the public. Until recent years, the Alberta Department of Environment (AE) had handled most public complaints about groundwater contamination and air quality effects of soil gas transmission.

Today most calls are channelled to the municipal Fire Departments. The Fire Department, working together with the Pollution Control Division (PCD) and Pollution Emergency Response Team (PERT), will ensure that the situation is regulated to a safe condition. Fire Department officials will arrive at a site with gas detection equipment, usually a Gastec sampling pump and low-range gas detection tube system, and decide on the level of caution required. When the site is deemed to be out of immediate danger, the Fire Department will then insist that the client or owner of the site hire an engineering consultant with specific knowledge of soil contamination and remediation. Consultants will supply the Fire Department with summary reports outlining their findings, recommendations and remediation procedures. In this way the Fire Department can ensure that clean up is effective. The PCD is a lead contact group for the AE in follow-up investigations and assessment of the problem cases. The Fire Department serves each municipality as an extension of the Alberta Department of Labour (AL).

Remediation techniques typically employed by engineering firms involved with soil gas problems include: vapour extraction and management systems, construction of intercepting drainage systems, placement of soil gas barriers below sites, and excavation and removal of contaminated soils from affected areas. In the case of excavation, soils are replaced with less compacted, easier draining soils that can be aerated properly.

Some unusual situations include a case in Kingmen, southeast Alberta, presently under investigation, where usually methane gases suspected to have entered a house through a non-vented water-well resulted in a violent explosion. Another unusual case was where a housing development in south western Alberta was built on a site that a farmer had dumped leftover herbicides into a pit for many years. The herbicide contaminants had to be removed later by excavation.

**BRITISH COLUMBIA**

The jurisdictional authority for handling soil gas problems is divided among several jurisdictions. This is because the responsibilities for hazards control, air pollution, waste management in this province has evolved out of expediency rather than on a planned basis. The municipality of the District of Burnaby, for example, has established an Environmental Control section within the Environmental Health Division which is under the Health Department. Duty officers are called to investigate reports of petrochemical odours, spills or other suspicious events. If a problem such as a leaking petroleum storage tank is identified, they have the authority under a new municipal bylaw to cause the owner to remediate the problem. If, however, the problem is air emissions, the inter-municipal authority known as the Greater Vancouver, Regional District (GVRD) is alerted. If the problem is a result of a natural gas leak, it must be referred to the provincial Department of Labour, Gas Safety Branch. On the other hand, if the problem is subsequently identified as natural in origin, as in marsh gas, there is no defined authority to enforce correction. The municipality can withhold new building permits on land which may have a potential soils gas hazard. But there is no specific action to enforce remediation on land which is already developed and occupied. Methane control is left to the discretion of the owner to correct. Potentially the problem could be dealt with by the Municipal Fire Marshal if the gas presents a fire hazard, but to date, they have been reluctant to take action.

Investigations have been undertaken by municipal environmental control groups which have resulted in remediation by owners. Most often this involved leaking fuel tanks.

Residential and industrial cases frequently have involved property owners who apparently were not aware of abandoned storage tanks on their property. Mitigations were undertaken by the owner or, in the case of more complex conditions, with the assistance of consultants.

A number of site projects have been undertaken to control methane migration in British Columbia. The remedial actions have been enforced through the buildings permits division and in some cases the control systems were installed at municipally owned landfills. When there are requests by owners to change the usage zoning of a specific property and if there is a reason to suspect soils contamination, municipal council can demand that a soils audit be conducted. Investigations of this type are normally undertaken by specialists retained by the owner. This can result in extensive borehole investigations together with soils sample analyses.

With the exception of some high profile case studies most of the hazardous soils gas problems, investigations and remedial works which impact at the residential level are initiated by the Municipal Authorities. The notable exception is the treatment of the lands once occupied by Expo 86. These lands (approximately 82.5 ha) have long been used for industrial purposes. Following Expo 86 the site has been slated for high density residential, commercial and open space development (refer to western sector case #19).

The responsibilities for control of hazards and the supporting legislation is in the evolutionary stage. Some people support the concept of strengthening the Regional jurisdictions in British Columbia in order to provide a consistent basis for measurement and throughout the province. Until additional regional guidelines are established, municipal environmental and health bodies will likely remain the primary instrument through which soil gas hazards are monitored and controlled.

## SUMMARY OF TYPES OF SOIL GAS ENTRY

A summary of the various soil gas infiltration problems which were documented in this study were detailed previously on Tables 2, 3, 4 and 5 in the text for the eastern, central, western Canada and international sectors, respectively. Essentially there were three predominant groups of problems encountered including those related to petroleum hydrocarbons, methane sources, and miscellaneous volatile organic compounds. Although there were similarities in how such gases may enter homes, the measurement of the problem, the frequency of occurrence, and solutions implemented were slightly different. Each of these different groups of compounds will be discussed below.

### PETROLEUM HYDROCARBONS

Petroleum spills represent the greatest number of reported cases of soil gas entry. The degree of analytical effort involved in most hydrocarbon infiltration studies was found to be generally minimal, stressing the identification of entry pathways and to a minor degree source concentrations. Influx of petroleum fumes occurred either from leaks of underground storage facilities or from home heating fuels. Infiltration from leaks of underground storage tanks (UST) will be discussed first.

The method of entry of soil gases from UST typically travels from the source to the home through the path of least resistance. One of the most significant entry points was through the sewer system. Eastern case studies #12, #25, and central case studies #11, #15 are only a few of many of the cases across Canada which typically go undocumented and in many cases likely unreported. Many of these problems were cited as being due to non-existent or inoperable "P" traps before the house. Although occasional plumbing problems do occur, as in eastern case #25, the likelihood of such conditions occurring at all times is questionable. For example, in central sector case #15, when gasoline entered the sewer, a large number of adjacent homes experienced fumes indoors. Although plumbing problems were cited, failure of a large number of "P" traps is remote. Similarly, eastern sector case #9 in Moncton, N.B. was cited as having plumbing problems when indoor contamination occurred after solvents were spilled in the sewers. After drainage connections were checked and found to be operating effectively, soil gas influx still occurred. This may suggest that although vapours will travel through sewers through inoperable "P" traps, operating "P" traps will not necessarily restrict vapours from entering the indoor environment. It may be that vapours could enter the fill surrounding the sewer connections and migrate into the buildings through floor cracks or through the concrete pore space. Another slower pathway of infiltration could also include diffusion through the water in an operating trap and into the indoor air.

Despite the frequent intrusion of gasoline fumes by this pathway, such occurrences were typically short in duration before discovery. Nevertheless, such occurrences may be quite dangerous especially when explosive concentrations are reached such as encountered in eastern sector case study #25.

The other pathway of soil gas entry for gasoline vapours is through higher permeable soil, sand or gravel. Many of the case studies where infiltration of gasoline vapours has been identified have, as expected, been located in higher permeable geologic formations: eastern sector case studies #1, #2; central sector case studies #7, #18, #32, #35, #49, #51; and western case studies #23, #24. Once such gases have entered the building envelope, entry can occur either through cracks (such as floor/wall joints), through the pore space in the concrete, locations where no wall, floor or foundation exists (as in a dug-out basement), or through the weeping tile system (especially when it is terminated at a sump pump indoors). These various entry points (with the exception of entry through the concrete pore space) were cited in many of the gasoline entry investigations. In some cases, the exact point of entry may not have been known or went undocumented.

Despite the generally limited descriptions of petroleum source concentrations, one trend was nevertheless apparent from the data that was collected. Of the various case studies involving gasoline vapour transport through soil and into the indoor environment (excluding those related to the sewer pathways), most of the studies had either a source of pure-phase product or a severely contaminated groundwater plume near or underneath the building affected by soil gas infiltration. Four of the five eastern sector petroleum hydrocarbon case studies had some form of plume underneath the building whenever indoor air contamination was identified. The one case study where such a comparison was not evident did not have sufficient information for comparison. Of the eight central sector cases studies where vapours had migrated through the soil, five case studies showed similar results. Central cases #18, #35, probably #49 and #51 had either pure-phase products or severely contaminated groundwater under the building. Central sector case #50 was the only case where it appeared that vapour transport exceeded the zone of liquid contamination. Three other reported problems (case studies #7, #8, and #32) had insufficient data. In the western sector, three of the four gasoline contamination studies had similar conditions. One western case study, #23, also noted that the greatest indoor contamination resulted in homes where gasoline was present directly below the building. Only one case (#24), had insufficient data to make this evaluation.

Another distinctive feature about the gasoline investigations was the lack of consideration of the soil gas driving force. Of all of the studies which were reviewed, on no occasion was the soil gas pressure recorded during the investigative phases of the program. Similarly, influences on the soil gas pressure such as barometric effects, rainfall events, fluctuating water-tables, stack effect, etc. were never documented (or even mentioned).

Another major source of hazardous soil gas influx which occurs across the country is due to spillage from home heating oil. Since most fuel tanks used for home heating fuel supply are located near the building structure, any product leaks normally cause a problem of contaminated soil and groundwater in the immediate vicinity of the building. Frequently fumes enter the indoor living space either through cracks or the weeping tile system. Although there are hundreds of such incidences yearly, only a few cases are documented here: eastern sector cases #7, #11 and central sector cases #41 and #42. The most abundant cases are found in Atlantic Canada. Investigations typically are not very analytical in approach. Olfactory evidence of contamination normally is the only analytical approach used. In most cases remediation by excavation is begun almost immediately.

## METHANE

The most documented cases of soil gas entry across Canada deal with methane intrusion. Methane intrusion has long been recognized as a safety problem, and consequently has been the subject of many investigations. Two main sources of methane have been known to cause problems for buildings. These include man-made sources such as mining activities or landfill sites, and natural sources such as degassing of natural peat deposits or petroliferous bedrock formations.

Throughout this survey, it was discovered there were essentially three types of methane studies carried out. The first type of study was a general audit. Such a study, usually conducted by municipalities, was aimed at documenting any zones of potential methane hazards, and/or investigating homes/businesses where such hazards existed. Typically, such investigations were restricted to areas within jurisdictional boundaries. If problem areas were discovered, the municipality would in turn restrict building permits or implement action plans to remediate the problem. Central sector case studies #5, #6, #24, and #26 describe the general audits conducted in the Thorold, Kitchener, Winnipeg, and Ottawa. The two other types of studies were typically carried out when a potential problem had been identified. The second type of methane study, carried out by or for developers, was conducted on lands where previously methane had been suspected or confirmed. The objectives of such studies normally centred around determining the potential for subsequent methane build-up, and recommending appropriate preventative technologies to ensure safety of future occupants. The developer was normally forced to satisfy the concerns of other municipal or environment officials before building permits were issued. The third type of study was conducted whenever homes/businesses were affected by some methane source. If the methane discovered was due to natural conditions, the owner normally was faced with remediation costs, whereas if man-made actions had caused the problem, the owner of landfill sites was normally held responsible.

The majority of landfill based methane problems was encountered in the more populated centres such as Montreal, Ottawa, Toronto, London, Kitchener, Winnipeg and Vancouver. Previous indiscriminant dumping, and/or the high demand for developable land has resulted in buildings being constructed on or near lands affected by methane gas. Conversely, methane problems related to natural sources such as degassing of peat or petroliferous bedrock is found in both rural and urban settings. Such settings are common in low-lying lands or where gas producing bedrock exists. Central sector cases #1, #2, #3, #4, western cases #1, #2, #3, #4, #8, #10, and #18 describe situations where methane has infiltrated homes from natural sources.

As with all soil gases, methane will follow the path of least resistance from the source to the point of impingement. The results of this survey suggested that the length of this pathway could be anywhere from several metres up to 914 m as in the case of Seattle, Washington (international sector case study #3). A significant number of homes in this study were identified as being built directly on/adjacent to refuse or organic matter (eastern sector cases #16, #20, #23, #24; central sector cases #1, #2, #5, #6, #10, #12, #14, #21, #23-#25, #28, #31, #34, #37, #40, #46; western sector cases #1-#4, #6-#11, #13, #14, #17-#19; international sector case #2). Refer to Tables 2 to 5 in the text for the summary. Some homes which were located away from the source were nevertheless connected by permeable pathways. Such pathways included fractured rock (eastern sector cases #6, #19, #21, #22; international sector case #7), fractured till (central sector cases #3, #4, #27), utility corridors (central sector cases #24-#26; international case #1), and sand and gravel deposits (eastern sector case #8, central sector cases #13, #19, #29, #38, #39, #43, #45, #48; western sector cases #5, #12; international sector cases #3, #6). Providing that the building envelope intersected such pathways, methane was detected at the most common entry points including sewer or utility lines, cracks in the floor, through the concrete pore space, through open holes, and the weeping tile network.

In contrast to gasoline spill investigations (discussed previously), more effort is typically aimed at understanding soil gas source concentrations. In most cases, this quantification consisted of methane concentrations in the soil air. Typically, such values were derived from field measurements on portable equipment.

Despite the detailed description of soil gas concentrations, significantly less studies documented the soil gas driving force. Although such information as gathered in this survey may have been occasionally been missed or was unavailable, it is still apparent that many investigations have not included such information. Several studies also chose to calculate gas production rates (e.g. central sector cases #24, #38) to define the mass balance for methane production. In general, however, such data was not gathered as part of investigative studies.

## MISCELLANEOUS VOLATILE ORGANIC COMPOUNDS

The last class of compounds to be reported on here are a group of compounds which was referred to as miscellaneous VOCs, those VOCs derived from landfills or any other non-petroleum source. With the exception of one case study (western sector case #19), all problems were identified after the buildings were in place.

Of the cases reported, spillage into the sewer was implicated in 4 investigations (eastern sector cases #4, #9, #17; central sector case #47). Some of these investigations utilized limited analytical effort; evaluations were primarily based on olfactory evidence (e.g. eastern sector case #4). Other investigations included chemical evaluation of numerous sewer water samples (eastern sector case #9; central sector case #47), or chemical evaluation of numerous indoor air samples (eastern sector case #17).

Seven case studies implicated nearby commercial/industrial activity including eastern sector cases #3, #18, central sector #7, #9, #22 and international sector cases #4 and #5. Indoor air contamination from these cases resulted from either contaminated soil near the homes (eastern sector case #3, central sector case #9, #22), or from de-gassing of contaminated groundwater. Analytical evaluations included soil sampling and analysis (eastern sector case #3, central sector case #9), indoor air analysis (eastern sector cases #3, #18; central sector case #9; international sector cases #4, #5) and laboratory analysis of groundwater (eastern sector case #18; central sector case #7; international sector cases #4, #5).

Municipal landfills which accepted some industrial wastes, potentially caused indoor contamination in 5 cases. These cases included the Miron Landfill (eastern sector case #19), the St. Julien Park Landfill, and the Ottawa Street Landfill (central sector cases #19 and #46) and the Midway Landfill, and BKK Landfill (international sector cases #3 and #7). Considerable analytical effort including groundwater sampling and analysis (all cases) soil gas sampling and laboratory analysis (central sector cases #19, #46; international sector cases #3, #7), and indoor air sampling and analysis has been completed (central sector #46; international sector case #7).

Three landfills which accepted a significant quantity of industrial wastes are reported here. These cases include LaSalle landfill (eastern sector case #20), the former Expo 86 site (western sector case #19), and the Love Canal (international sector case #1). Analytical effort included indoor air sampling and analyses (with the exception of the former Expo 86 site), groundwater and soil sampling with laboratory analysis. With the exception of the former Expo 86 site, all homes on the affected lands were subsequently demolished.

As can be seen by the above descriptions, the analytical effort involved is substantially greater than for a typically comparable gasoline spill which may have similar compounds. Since the cases discussed here typically were of high public profile, the increased effort for a more thorough analytical protocol was warranted. Analytical methods usually included both portable equipment for screening purposes (e.g. photoionization detectors, flume ionization detectors, explosimeters, solid adsorption tubes, etc.) and sampling pumps, cartridges, evacuated canisters for more precise laboratory measurements. Investigations involving other types of gases, i.e. hydrocarbons and methane, rarely included such comprehensive methods.

## REMEDIATION / PREVENTION TECHNOLOGIES

The term remedial technology, as referred to in the text, refers specifically to a technology which was implemented for the purpose of correcting a situation where soil gas influx was occurring. Such solutions are typically retrofit techniques implemented on houses which have been constructed without consideration for soil gas entry. Prevention technologies, on the other hand, perform similar functions but are normally installed as part of the original structure. Prevention technologies are incorporated either where soil gas had been previously identified or suspected prior to construction.

The various remedial or preventative technologies may be summarized under two strategies:

- Source control
- House based control

In some cases, however, the control of the above parameters has not been used. In some cases, the demolition or the physical removal of homes has taken place. Other technologies such as the ventilation of indoor air (e.g. western sector case #23) or monitoring as a stand alone tool have been used. Such strategies are typically used only as stop gap measures and are not recognized as methodologies for limiting soil gas entry. Furthermore, the climatic conditions in Canada do not make the widespread use of indoor venting economically feasible.

### TECHNOLOGY DESCRIPTIONS

#### *Source Control Strategies*

Source control strategies essentially attempt to eliminate the origin of the problem. Depending on the type of source and local conditions, either active or passive venting, liners, pressurized air curtains, groundwater pumping, bioremediation, steam extraction, or soil excavation have been implemented.

**Active Venting.** Active venting is referred to in the literature under many titles such as gas extraction, soil vacuum extraction, soil venting and other terms. Active venting has been applied in numerous situations to remove methane, gasoline, and various VOCs from the subsurface. Providing that well screens are installed in permeable formations where soil gas is travelling, and the negative pressure induced by the system is configured to encompass the zone of migration/contamination, proper control of the subsurface gas can be achieved. Several cases (central sector cases #3, #13, #38, #43; western sector cases #12, #15, #23), as shown on Tables 10 and 11, have demonstrated that active venting can successfully reduce methane or gasoline vapours in soils and buildings. Several other case studies documented on Tables 9 to 11 had insufficient data to determine the effectiveness of the installations.

Active venting installations have for the most part been installed in areas where the gas generation rate has been high. Gas generation rates has been determined by pump testing (e.g. central sector case #38) or by using indicator parameters such as pressure (e.g. central sector case #25).

Some difficulties associated with active venting can occur when wells are improperly placed relative to the porous gas transmission zone (e.g. central sector case #3; international sector cases #3, and #6). Active pumping has also been known to cause aerobic conditions within landfills by introducing large amounts of oxygen. As a result, landfill temperatures may be elevated (e.g. central sector case #38) such that plastic header pipes and wells may deform. Deformations of this sort can cause sagging of header pipes which would allow water to pond in pipes, or allow a place for microbial build-up. This may lead to inoperable wells due to clogging or even subsurface fires (e.g. international sector case #3). Active systems require proper and consistent monitoring/maintenance to ensure all designed operating conditions are being met.

**Passive Venting.** Passive venting technologies have been applied to soil gas problems involving mainly methane and, to a limited extent, petroleum hydrocarbons. Construction of typical systems include simple ventilation trenches filled with gravel (e.g. central sector case #16), gravel filled ventilation trenches with a header pipe assembly connected to exterior risers equipped with wind turbines (eastern sector case #22), ventilation header pipes connected to deep well pipes and surface risers, and gravel filled ventilation trenches combined with liner systems (e.g. central sector case #25).

Passive venting is a preferred method of remediation of subsurface methane in several situations. Passive venting is utilized when the migration pathway heading towards buildings is shallow. In such cases, gravel filled trenches can easily be constructed to intersect methane migration. Whenever gas production rates are low, or situations where designers were concerned about vandalism to exposed active systems, passive systems have been deemed adequate. On occasion, passive venting has been applied as a precautionary measure (central sector case #33).

Although in theory, passive venting should limit horizontal methane migration for the most part, especially when the water table is sufficiently high, some passive systems installed where the water table is deeper have failed (e.g. central sector case #38; western sector case #5). Replacement with active systems is normally the preferred alternative. In some cases where gas production is high or where occasional environmental conditions have caused considerable migration, some municipalities are forced to use a mobile venting unit to reduce surface methane levels (e.g. London, Winnipeg).

Limited data was actually collected in this study to evaluate the performance of passive systems. Firstly, monitoring data was non-existent for such systems, and secondly, data of this sort was often confidential. Typical responses to requests for data indicated that the systems were functioning well; no or limited methane was recorded in houses. Results summarized on Tables 9 through 12 for eastern sector cases (#22, #23), and central sector cases (#4, #16, #19, #25, #33 and #48) reflect this lack of data. Many of these case studies, however, appear to have limited methane generation potential.

Only one case was identified where passive venting was used to remediate petroleum hydrocarbon vapours (western sector case #22). In this particular case, the procedure was augmented by other methods such as groundwater extraction.

**Liners.** Liners have been used as a protective measure to impede the progress of subsurface gas in shallow soils. Primarily, liners have been installed in a vertical fashion near landfills in conjunction with passive venting (central sector cases #4, #25) or with pressurized air curtains (central sector Case #39). On occasion, natural clay barriers may separate the source from the zone of transmission as in western sector case #17. Although short-term testing has revealed the integrity of these liners, no long-term monitoring information was obtained. Liners have also been used to limit short-term vapours from petroleum hydrocarbons from migrating to nearby homes. No such case study identified in this survey had sufficient data for documentation.

**Pressurized Air Curtain.** Pressurized air curtains have been used to impede the flow of methane gas from landfills. Pressurized air curtains were used in central sector case #39 in conjunction with a liner, a passive venting trench (western sector case #5, #15), and active venting (western sector case #12). Initial results of operation have proven successful; no long-term performance was obtained in this survey.

**Groundwater Pumping, Etc.** A number of source depletion technologies such as groundwater pumping, bioremediation, steam extraction, and soil excavation are used to remediate sites contaminated with petroleum hydrocarbons or VOCs. Such technologies are widely used and are effective means of reducing source concentrations. Although source depletion will affect indoor air concentrations, such methodologies cannot be considered as vapour management controls.

*House Based Control Strategies*

House based control strategies may fall into several categories: sub-slab venting, active venting, passive venting, pressurized air curtains, crawl space venting, liners, sealing, and plumbing corrections. The technologies described here are specifically those which have been applied within the building envelope.

**Sub-slab Venting.** Sub-slab ventilation is a method used to remove contaminants from below the basement floor slab in a building. Although sub-slab venting has primarily been applied to cases involving methane intrusion, control of petroleum hydrocarbons by this method has also been documented (Brown and Tribe, 1990). The venting process takes place primarily in the high permeability sub-slab gravel layer. Ventilation is accomplished either by straight suction below the slab as in central sector cases #2, #14, #44, and western sector cases #4, #7. Sub-slab venting may be accompanied by passive supplies (western sector case #6; international sector case #2) or with air-injection techniques (western sector case #14). Some sub-slab venting designs have incorporated the additional use of a sub-slab liner (central sector case #2). Sub-slab ventilation has been used as a designed preventative measure (e.g. central sector case #14) or as a retrofit measure (e.g. international sector case #2).

All of the case studies reviewed have shown excellent performance of the sub-slab ventilation systems, at reducing indoor methane concentrations (refer to Tables 10 and 11). Stearns and Petoyan (1984) however document the occurrence of a landfill fire due to overpumping.

**Active Venting.** Active venting within the building envelope has been undertaken for indoor air problems caused by methane and petroleum hydrocarbons. Physical arrangements for the active venting of methane have included vertical wells installed beside buildings (central sector cases #5, #28; western sector case #15; international sector case #3), large diameter perforated collection pipes installed at footings (central sector case #10, #46), and horizontal perforated header pipes installed below the surface adjacent to a building (central sector case #37). Soil vacuum extraction, a term used to describe active venting of petroleum hydrocarbons, typically has used vertical perforated wells installed near buildings to accomplish the task. Central sector cases #18, #41, #49, #50, #51, and western sector case #24 have applied soil vacuum extraction. On occasion when indoor air has been severely affected, some practitioners have also implemented pressurization of the basement ambient air (e.g. central sector case #18). This would have the added effect of forcing the indoor air outwards and establishing a positive gradient towards the soil. Cold winter conditions may restrict such activity.

Active venting has had both favourable and somewhat favourable results. Whenever active venting systems were started up, a measurable decline in indoor contaminant concentrations was normally observed. This decline did not necessarily always eliminate the problems but reduced concentrations to acceptable levels. One problem commonly cited for the lack of complete elimination of all indoor concentrations is the poor transmissivity frequently encountered in some subsurface geologic materials. Because of transmission problems, the contaminant source is not always affected by the cone of influence exerted by the pumping well. Such an occurrence was found in a trial program in central sector case #46. (In central case #46, sub-slab venting was ultimately chosen as the preferred remediation alternative.)

**Passive Venting.** Passive venting within the building envelope has been undertaken for both methane and petroleum hydrocarbon vapours. Various designs of passive systems for methane removal have been implemented including a bell-shaped concrete sub-floor connected to a stationary riser (eastern sector case #24), a three-metre gravel filled trench around the building connected to several risers (central sector case #5), the use of drainage pipes connected to stationary vertical risers (central sector cases #6, #21), a series of perforated pipes installed under a plastic (or CPE) liner under the basement floor slab (central sector case #31, #34), and the installation of a vertical well connected to a stationary vertical riser pipe (western sector case #3). Only one case was identified where a single vertical pipe was used to passively dispel petroleum hydrocarbon vapours from the subsurface (central sector case #32).

When comparing the results of the passive venting measures installed in the individual case studies as seen in the text on Tables 9 to 11, it is apparent that no indoor methane levels were ever detected. This fact may be due to: limited monitoring or a depressurized subsurface soil zone. Soil gases with no or negligible subsurface soil gas pressure, may lack a driving force to enter the indoor air space.

**Pressurized Air Curtain.** A limited number of cases documented in this study have applied a pressurized air curtain within the building envelope. Various designs have included the use of horizontal perforated pipe installed within a CPE membrane pillow (central sector case #40), a series of horizontal perforated pipes installed prior to the pouring of the slab (western sector cases #8, #16), pressurized pipes on one side of a building with passive venting on the other (western sector case #10), and active injection wells outside of the building with sub-slab wells inside the building (western sector case #14). Limited long-term performance data exists.

**Crawl Space Venting.** Crawl space venting has been implemented when buildings have been installed on or directly adjacent to landfills. A small crawl space is constructed underneath the building and gases are actively vented. Buildings where such technology has been applied are typically used for public or commercial purposes. Three cases were documented in this study. Although no performance data was available, all operating systems are reported to be performing well.

**Liners.** One of the most common methods to reduce the leakage area is through the use of liners. Two types of liner material are available including polyvinyl chloride (PVC) and chlorinated polyethylene (CPE). For landfill or methane applications, CPE liners are the preferred choice because of their low permeability (central sector case #25) and their resistance to hydrocarbons (central sector case #40). A single 30 mil CPE liner has been used in numerous installations: central sector cases #2, #34, #40; western sector cases #1, #2, and #18. A double CPE liner separated by a sand layer was installed at a sports complex as described in western sector case #11.

Monitoring results for many of these installations has shown that the CPE liners are working effectively. Several case studies (e.g. western sector cases #1 and #2) have been installed fairly recently and therefore long-term results are as of yet unavailable. Nevertheless, the initial results are encouraging. In one case (western sector case #11), despite massive cracking of the floor slab, the double CPE liner has remained intact.

**Sealing, Caulking.** Sealing or caulking of cracks and/or floor surfaces, and utility conduits is often used as a stop gap measure to limit soil gases from entering homes. In several cases (e.g. eastern sector case #3 and other undocumented cases), sealing of openings has been attempted; however, limited data supporting the performance is available. Sealing of utility conduits (as in central sector case #6) likely would be effective. In central sector case #49, door jams and cracks were sealed; no discernable effect was observed.

Sealing of concrete floors was attempted in two cases: international sector case #2, and central sector case #46. (Case #46 does not document sealing.) Investigations of international sector case #2 discovered that even with the use of an approved sealant, methane entry was not retarded. On the other hand, in central sector case #46, a home owner had applied a coating of paint on a concrete floor. During an energy study of the building, as the home was being depressurized, a noticeable change of methane entry was observed over the unpainted vs the painted portion of the floor. This suggested that some increased resistance through the painted floor had occurred.

In some municipalities (e.g. Madison, Wisconsin), it is a City ordinance to apply foundation sealant on all walls, and penetrations.

**Plumbing Corrections.** Plumbing corrections are one of the simplest ways to remediate soil gas entry problems providing that they are the sole pathway. Improper sewer connections have been cited for gasoline vapour entry (and explosions; eastern sector case #25), and entry of perchloroethylene (eastern sector case #4). Inadequate weeping tile connections have been cited in central sector case #6 where methane entered the indoor living space unrestricted.

The most common remedial measure recommended has been the repair of "p" traps. This is especially true for the influx of gasoline vapours. This procedure has on occasion met with marginal success (e.g. eastern sector case #9; also refer to discussion on petroleum hydrocarbons on page 19). In other cases, flushing of sewers has proven adequate (e.g. central sector case #15).

Several methods have been implemented to limit methane through the weeping tile system and utility systems. Western sector case #1 describes the use of bentonite to seal utility entrances into the basement. Central sector case #6 describes a system by which the weeping tile was to be hooked into the storm sewer system before the water trap. In addition, the weeping tile was also vented passively to the atmosphere.

Other plumbing corrections/requirements have also been imposed through building codes, as in the case of Madison, Wisconsin. According to Substitute Ordinance No. 8487 under Section 29.20 of the Madison General Ordinances, any building within 150 metres of a landfill equipped with a mechanically ventilated gas system, or within 300 metres of a landfill site not equipped with a mechanically ventilated system should include the following construction practices:

- A clay cut-off shall be installed as near to the property line as feasible in utility trenches which emanate from the direction of the zoning lot of the current or former disposal site.
- All basement floor openings, such as boxouts for backflow devices, cleanouts, and sump pump systems shall be sealed or fitted with a cover or a gasket.

Although no data exists on the success of individual plumbing corrections requirements, such procedures are apt to help restrict soil gas build-up.

## REFERENCES

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