# BMR Record 1992/61

# Light hydrocarbon geochemistry of the WA-28-P area, Dampier Sub-Basin, Western Australia: *Rig Seismic* Survey 97

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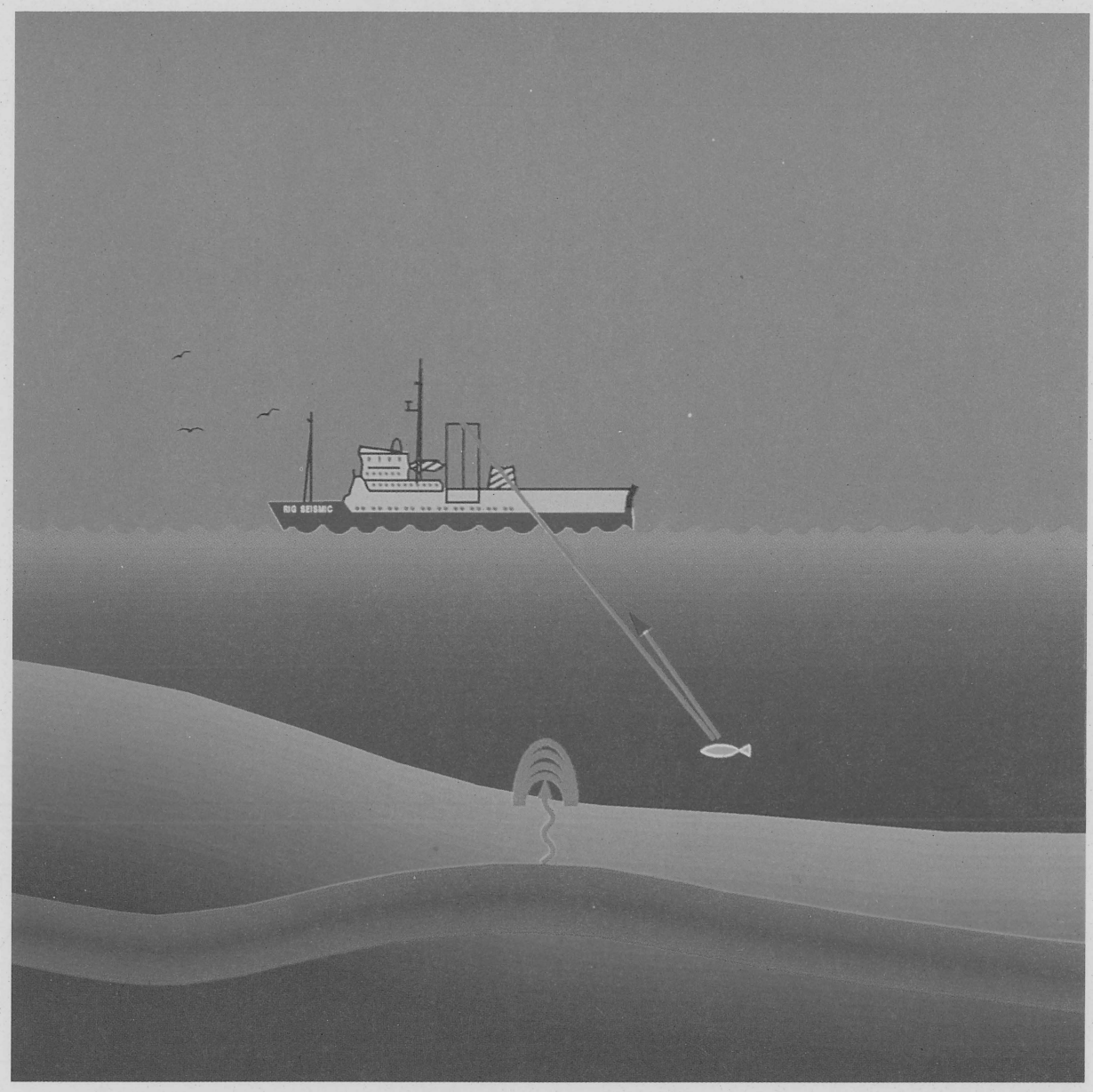


**Project 121.19**

**G.W.O'Brien, G. P. Bickford, J. Bishop & J.F. Marshall**

1992/61
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MARINE GEOSCIENCE AND PETROLEUM GEOLOGY PROGRAM

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# LIGHT HYDROCARBON GEOCHEMISTRY OF THE WA-28-P AREA, DAMPIER SUB-BASIN, WESTERN AUSTRALIA: RIG SEISMIC SURVEY 97

# PROJECT 121.19

G.W.O'Brien, G. P. Bickford, J. Bishop & J.F. Marshall

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS, AUSTRALIA

DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY
Minister: The Hon. Simon Crean
Secretary: G.L. Miller

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Executive Director: R.W.R. Rutland AO



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# EXECUTIVE SUMMARY

As part of its geochemical research program, the Marine Geoscience and Petroleum Geology Group (Australian Bureau Of Mineral Resources) is evaluating the usefulness of the Direct Hydrocarbon Detection (DHD) method. The data for this DHD program were acquired during a co-operative high resolution seismic reflection program with Woodside Petroleum Pty Ltd in the Dampier Sub-Basin. The data acquisition phase took place between October 22-28, 1990, with a total of 531 km (25 lines) of DHD data being collected between the Angel gas field in the north-east and the Madeleine 1 well in the south-west of Woodside Petroleum exploration permit WA-28-P in the Dampier Sub-Basin, on the North-West shelf, Australia.

No significant hydrocarbon anomalies were detected on any of the lines, in spite of the fact that many lines traversed known oil and gas accumulations, such as the Wanaea, Cossack and Angel accumulations. The lack of anomalies indicates that the major reservoir horizons in this part of the Dampier Sub-Basin are well-sealed, and that little opportunity for the vertical migration of hydrocarbons exists.

While no significant anomalies were detected, very minor increases in total hydrocarbon were, however, observed over some of the wells/fields. The largest increase in THC was observed over the Montague 1 well location, where the value increased from a background level of 16ppm to a high of 22.8ppm. There was no increase in any of the light hydrocarbon gases.

# INTRODUCTION

## Surface geochemistry and offshore exploration for hydrocarbons

The aims of surface geochemical techniques in offshore petroleum exploration are: (a) to detect direct evidence for thermogenic generation of hydrocarbons in a sedimentary basin, (b) to assist in locating sub-surface hydrocarbon accumulations, and (c) to provide information on the likely composition of hydrocarbon accumulations within a given geologic province. The most common technique used to detect hydrocarbon seepage offshore involves towing a submerged 'fish' close to the seafloor which continuously pumps seawater into a geochemical laboratory in the tow-vessel. There, hydrocarbons are extracted and measured by gas chromatography. The equipment, commonly known as a geochemical 'sniffer' (Schink et al. 1971; Sigalove and Pearlman 1975), or what we refer to as Direct Hydrocarbon Detection (DHD), has been widely used overseas for offshore petroleum exploration. InterOcean Systems Inc., a US-based corporation, has collected over 1.5 million line kilometres of data from about 140 surveys around the world. However, most of the data gathered by contractors for clients remain proprietary and the opinions expressed publicly, about surface 'sniffer' geochemical techniques, by the petroleum exploration community remain divided. Scheiner et al. (1985) have reviewed about the use of the geochemical 'sniffer' in the North Sea.

Within Australia, the 'sniffer' has been a relatively under-utilised tool in offshore hydrocarbon exploration, with only four surveys being carried out prior to 1988. Consequently, since 1989, the Bureau Of Mineral Resources (BMR) has, as part of its Continental Margins Program (and under the auspices of a Joint Agreement with Transglobal Environmental Geoscience (TEG) of Leucadia California (Heggie et al., 1990), been conducting bottom-water DHD programs around the Australian continental margin to better evaluate the usefulness of this technique. Part of this work includes research into:

- the origins (biogenic or thermogenic?) of bottom-water light hydrocarbons
- light hydrocarbon 'sources' (liquids, condensate or gas?)
- bottom-water and seafloor expressions of seepage
- the relationships of seepage to the surface and sub-seafloor geology, including hydrocarbon accumulations and source rock types and distributions.

# BMR Surface Geochemistry: Overall Program Objectives

The overall objective of the BMR offshore surface geochemistry program is to evaluate the application of surface geochemical techniques (both direct hydrocarbon detection (DHD) and sediment [hydrocarbon-headspace] techniques) to hydrocarbon exploration around the Australian continental margin. Specific objectives include:

- To collect, via reconnaissance surveys, new information on the thermal generation of hydrocarbons in under-explored Australian basins.
- To test the application of both bottom-water DHD and sediment geochemical techniques to hydrocarbon prospect ('target') evaluations in both known hydrocarbon provinces and frontier basins.
- To test, develop and refine criteria to recognise thermally-generated migrated hydrocarbons from background biogenic hydrocarbons in both seawater and sediments.
- To examine the relationship between hydrocarbon generation and migration by relating the surface and sub-seafloor expressions of hydrocarbon seeps to the sub-seafloor geology and probable locations and type(s) of source rocks.
- To relate the chemical and isotopic compositions of seeps to 'source' characteristics, i.e. gas, condensate, liquids, and to predictions from geohistory and maturation modelling of different source rock types.
- To test bottom-water DHD and sediment geochemistry techniques in the search for hydrocarbons sealed by stratigraphic traps.
- To examine the biogenic processes influencing the concentrations, distributions and chemical compositions of hydrocarbon seeps in bottom-waters and the near surface sediments.
- To examine oceanographic dispersal processes of seeps.

To achieve this, multi-disciplinary programs involving the simultaneous collection of bottom-water DHD, seismic reflection, gravity, magnetic and side-scan sonar data have been carried out by the BMR's research vessel *Rig Seismic* around the Australian continental margin.

The geochemical analysis system (Direct Hydrocarbon Detection or DHD) that has been installed aboard the *Rig Seismic* as part of the Agreement is shown schematically in Figure II-1 of Appendix II. The laboratory system analyses a variety of gases extracted from seawater, including $C_1$-$C_8$ hydrocarbons with facilities to collect gases for shore-based

isotopic analyses. Complete details of both the DHD system and the interpretative methodologies used are given in Appendices II and III.

This BMR Record provides both the basic data and a preliminary interpretation of the bottom-water hydrocarbon data which were collected by the R.V. *Rig Seismic* in the Dampier Sub-Basin during Survey 97 in October 1990.

# Survey Objectives

A joint BMR-Woodside Offshore Petroleum Pty Ltd scientific research program was carried out between October the 22nd and 28th, 1990, to investigate the shallow sub-surface structure of part of Woodside's permit WA-28-P in the northern Dampier Sub-Basin (Figure 1). Independently of this study, BMR carried out a DHD study of the hydrocarbon gas compositions of the seawater in the area (Figure 2). Most of these DHD data were collected simultaneously with seismic acquisition. The principal objective of this DHD program was to carry out a 'calibration' survey over the known oil and gas accumulations within the Dampier Sub-Basin, and thereby determine the applicability of the DHD technique within this region.

# DHD Results: Dampier Sub-Basin

The program in the northern Dampier Sub-Basin consisted of 25 lines with a total survey length of 531 kilometres (see Tables 1 & 2). The location of the DHD survey lines are shown in Figure 2 and Enclosure 1. Composite summary plots of the DHD data, showing the distribution of an assortment of hydrocarbon concentrations and parameters along all of the survey lines from the Dampier Sub-Basin, are presented in Figures 3-13.

The complete set of results for the entire survey (on a line-by-line basis) are given in Appendix I, which includes:

- Line summary sheets, which present the light hydrocarbon statistics and characteristics of each survey line, the locations of the start and end of each line, as well as brief statements about data for that line.
- Charts showing the distribution along each survey line of:
  - total hydrocarbons (THC) and methane;
  - methane, ethane and ethylene;
  - methane, propane and propylene;

❑❑DHD fish depth, altitude and water depth.

Full details of the acquisition methods used and the interpretative methodologies employed are given in Appendices II and III. Floppy diskette(s) containing geochemical and navigation data in an ASCII format are included in Enclosure 2.

Direct hydrocarbon detection data were acquired in two phases. The first phase consisted of eight lines on which only DHD data were acquired. A list of these lines is given in Table 1. The second phase of DHD data collection was carried out simultaneously with high resolution seismic acquisition and consisted of 17 lines (Table 2), yielding a total number of 25 survey lines.

No significant hydrocarbon anomalies were detected on any of the lines, in spite of the fact that many of the lines ran over major hydrocarbon accumulations, such as the Wanaea and Cossack oil accumulations, and the Angel gas field. The lack of anomalies suggests that the major reservoir horizons are well-sealed and that little opportunity exists for significant vertical hydrocarbon migration to shallow depths.

Minor increases in total hydrocarbon were, however, observed over some of the wells/fields. The largest increases in THC was observed on Line 97/022 (approximately over the Montague 1 well location), where THC increased from a background concentration of 16ppm to a high of 22.8ppm. There was no accompanying increase in any of the light hydrocarbon gases.

The DHD 'fish' was towed between 10 and 20 metres above the seafloor, with the exception of in the immediate vicinity of the well-heads. There, the fish was towed approximately 20 to 25m above the seafloor.

In order to better characterise the vertical structure of the water column within the northern Dampier Sub-Basin, three vertical profiles were carried out. These were on lines AB (at 19$^{o}$ 24'S; 116$^{o}$ 35'E), 4 (at 19$^{o}$ 40'S; 116$^{o}$ 21'E) and 24 (19$^{o}$ 25'S; 116$^{o}$ 39'E). The results were fairly consistent over all three profiles, and indicate that the water column typically shows little vertical structure in terms of temperature and conductivity (Figure 14a), the THC and methane concentrations (Figure 14b), the ethane and propane concentrations, and the biologically-produced hydrocarbons (ethylene; Figure 14d).

# SUMMARY

The BMR conducted a bottom water DHD program in the northern Dampier Sub-Basin in October 1990. The program acquired 531 line km of DHD data between the Angel gas field and the Madeleine 1 well (Figure 2).

No significant hydrocarbon anomalies were detected, even though many lines traversed the Wanaea, Cossack and Angel accumulations. Minor increases in total hydrocarbons were, however, found on some of the survey lines. Over the Montague 1 well, for example, THC increased to 50% above background, although there were no corresponding increases in individual $C_1$-$C_4$ hydrocarbons.

The lack of hydrocarbon seepage in the northern Dampier Sub-Basin contrasts with our DHD observations in the eastern Barrow Sub-Basin, where natural hydrocarbon seepage appears to be common (Heggie et al., 1991). This contrast is probably directly related to the differences in the geology of the respective regions. In the Dampier Sub-Basin, the oil reservoirs are typically deep [2797 m at Wanaea 1; 2864 m at Cossack 1; see Bint 1991)] with the overlying Cretaceous and Tertiary sediments being thick, largely impermeable and unfaulted, thereby providing a significant barrier to the vertical hydrocarbon migration.

In contrast, in the eastern Barrow Sub-Basin, the oil reservoirs are shallow [e.g. 1102 m at Saladin 1], the sealing Cretaceous/Tertiary units are thin, and faulting extends close to the seafloor (Tait et al., 1989). In fact, residual oil columns in the Saladin wells, when combined with the lack of an associated gas cap, has been cited as evidence that the Saladin Fault has leaked hydrocarbons (Tait et al., 1989).

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**Tait, A.M., Bartlett, R.M., Sayers, M.J., McLerie, M.K. & McKay, D.M. (1989),** The Saladin Oil Field. *APEA Journal* 29:212-219.

# ACKNOWLEDGMENTS

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## SURVEY PERSONNEL

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**Systems Officers**:-F. Brassil & E. Chudyk

**Technical Staff**:- J. Bedford, R. Curtis, B. Dickinson, S. Davey, P. Davies, C. Green, L. Hatch, T. McNamara, S. Milnes, J. Pittar, D. Pryce, A. Radley, D. Sewter, C. Tindall, J. Whatman & P. Vujovic,

**D.O.T.**

**Master**:- A. Codrington

**Chief Officer**:- W. McKay

**Second Officer**:- M. Gusterson

# LIST OF ENCLOSURES

**Enclosure 1.** Map showing DHD survey lines.

**Enclosure 2.** Floppy disk with geochemical data in ASCII format. Data has been made available as a separate download file.

# LIST OF TABLES

**Table 1.** Direct hydrocarbon detection survey lines, Dampier Sub-Basin.

| Line Number | Latitude Start | Long. Start | J. Day Start | GMT Start | Line Length |
|---|---|---|---|---|---|
| | Latitude Finish | Long. Finish | J. Day Finish | GMT Finish | nM/km |
| | | | | | |
| **97/AB** | 19 25.165 | 116 35.058 | 295 | 0850 | 12.00/22.24 |
| | 19 34.559 | 116 43.470 | 295 | 1234 | |
| | | | | | |
| **97/CD** | 19 35.542 | 116 41.164 | 295 | 1349 | 12.9/23.9 |
| | 19 25.675 | 116 32.153 | 295 | 1626 | |
| | | | | | |
| **97/QR** | 19 34.500 | 116 18.868 | 296 | 0125 | 13.0/24.09 |
| | 19 44.826 | 116 27.212 | 296 | 0408 | |
| | | | | | |
| **97/OP** | 19 44.980 | 116 27.729 | 296 | 0414 | 16.0/29.65 |
| | 19 33.041 | 116 20.454 | 296 | 0712 | |
| | | | | | |
| **97/ ON2** | 19 34.8 | 116 24.4 | 296 | 0837 | 15.0/27.80 |
| | 19 42.1 | 116 29.8 | 296 | 1030 | |
| | | | | | |
| **970 /KL** | 19 31.1 | 116 23.3 | 296 | 1045 | 13.0/24.09 |
| | 19 41.7 | 116 31.6 | 296 | 1617 | |
| | | | | | |
| **97/IJ** | 19 29.880 | 116 25.853 | 296 | 1713 | 13.0/24.09 |
| | 19 40.537 | 116 34.328 | 296 | 2045 | |
| | | | | | |
| **97/GH** | 19 40.652 | 116 35.59 | 296 | 2046 | 13.6/25.2 |
| | 19 32.527 | 116 32.628 | 296 | 2259 | |
| | | | | | |

**Table 2.** Geochemical data collected simultaneously with seismic data: Dampier Sub-Basin.

| Line Number | Latitude Start<br>Latitude Finish | Long. Start<br>Long. Finish | J. Day Start<br>J. Day Finish | GMT Start<br>GMT Finish | Line Length<br>(nm)<br>[km] |
|---|---|---|---|---|---|
| | | | | | |
| **97/001** | 19 31.599<br>19 39.667 | 116 30.397<br>116 20.8 | 297<br>297 | 0000<br>0253 | 12.0<br>22.24 |
| **97/002** | 19 37.251<br>19 29.81 | 116 21.863<br>116 36.75 | 297<br>297 | 0408<br>0731 | 17.2<br>31.87 |
| **97/003** | 19 27.212 | 116 40.530 | 297 | 1006 | 21.0 |
| | 19 37.800 | 116 22.100 | 297 | 1637 | 38.91 |
| **97/004** | 19 39.345 | 116 25.281 | 297 | 1910 | 5.53 |
| | 19 35.628 | 116 20.623 | 297 | 2200 | 10.25 |
| **97/005A** | 19 34.538 | 116 21.911 | 297 | 2200 | 6.5 |
| | 19 38.505 | 116 27.014 | 297 | 2318 | 12.04 |
| **97/006** | 19 38.467 | 116 29.904 | 298 | 0110 | 11.7 |
| | 19 30.919 | 116 20.282 | 298 | 0328 | 21.68 |
| **97/007** | 19 31.958 | 116 23.646 | 298 | 0538 | 5.4 |
| | 19 36.906 | 116 29.718 | 298 | 0835 | 10.01 |
| **97/008** | 19 35.548 | 116 30.175 | 298 | 1021 | 5.0 |
| | 19 31.523 | 116 25.988 | 298 | 1129 | 9.27 |
| **97/009** | 19 31.474 | 116 28.026 | 298 | 1239 | 4.9 |
| | 19 35.219 | 116 31.774 | 298 | 1341 | 9.08 |
| **97/010** | 19 38.894 | 116 30.187 | 298 | 1554 | 12.2 |
| | 19 26.170 | 116 29.396 | 298 | 1824 | 22.61 |
| **97/011** | 19 27.132 | 116 28.505 | 298 | 2017 | 5.5 |
| | 19 28.002 | 116 33.511 | 298 | 2124 | 10.19 |
| **97/012** | 19 28.197 | 116 34.072 | 298 | 2310 | 6.92 |
| | 19 33.476 | 116 38.692 | 299 | 0030 | 12.82 |
| **97/013** | 19 33.286 | 116 38.025 | 299 | 0210 | 6.0 |
| | 19 27.671 | 116 36.468 | 299 | 0320 | 11.12 |
| **97/021** | 19 30.482 | 116 30.625 | 300 | 1309 | 11.0 |
| | 19 37.639 | 116 21.548 | 300 | 1522 | 20.38 |
| **97/022** | 19 39.197 | 116 22.870 | 300 | 1710 | 10.5 |
| | 19 28.995 | 116 20.659 | 300 | 1914 | 19.46 |
| **97/023** | 19 33.883 | 116 24.037 | 300 | 2126 | 14.1 |
| | 19 32.354 | 116 38.880 | 301 | 0014 | 26.13 |
| **97/024** | 19 33.136 | 116 37.541 | 301 | 0220 | 7.0 |
| | 19 26.784 | 116 39.920 | 301 | 0342 | 12.97 |
| | | | | | |

# LIST OF FIGURES

## Text



# Appendix I

**Hydrocarbon compositions on individual survey lines**

The following charts were prepared for all of the survey lines. They are in Appendix I.

- THC and methane concentration versus shot-point number.
- Methane, ethane and ethylene concentration versus shot-point number.
- Methane, propane and propylene concentration versus shot-point number.
- DHD fish depth and altitude versus shot-point number.

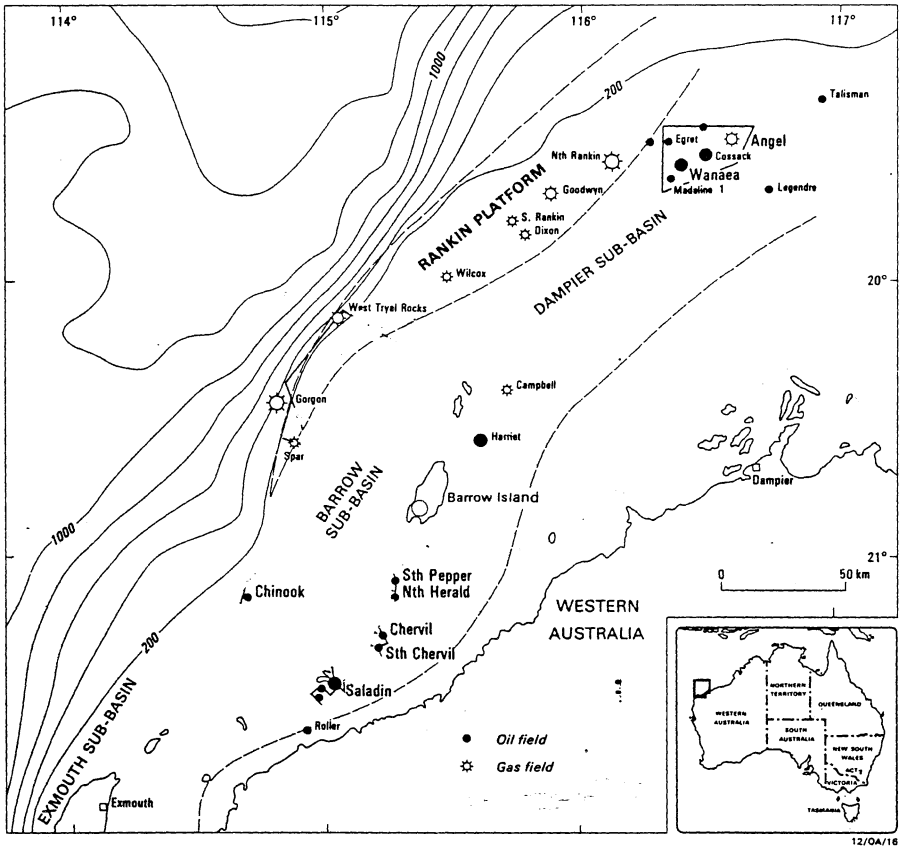



**Figure 1.** Location map showing the position of the Dampier Sub-Basin, North-west Shelf, Western Australia.

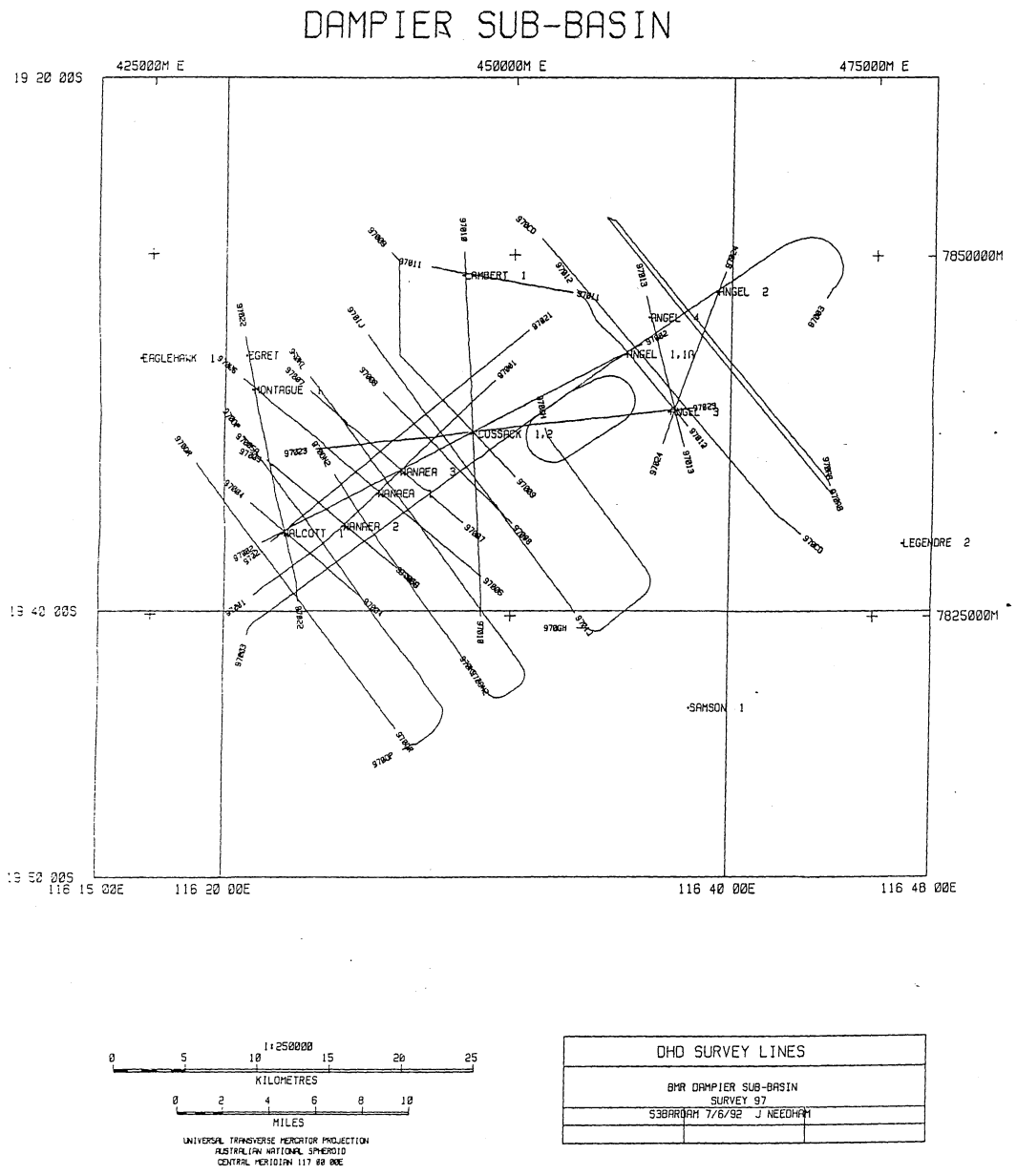



**Figure 2.** Location map showing the position DHD lines which were acquired within the Dampier Sub-Basin during Survey 97.

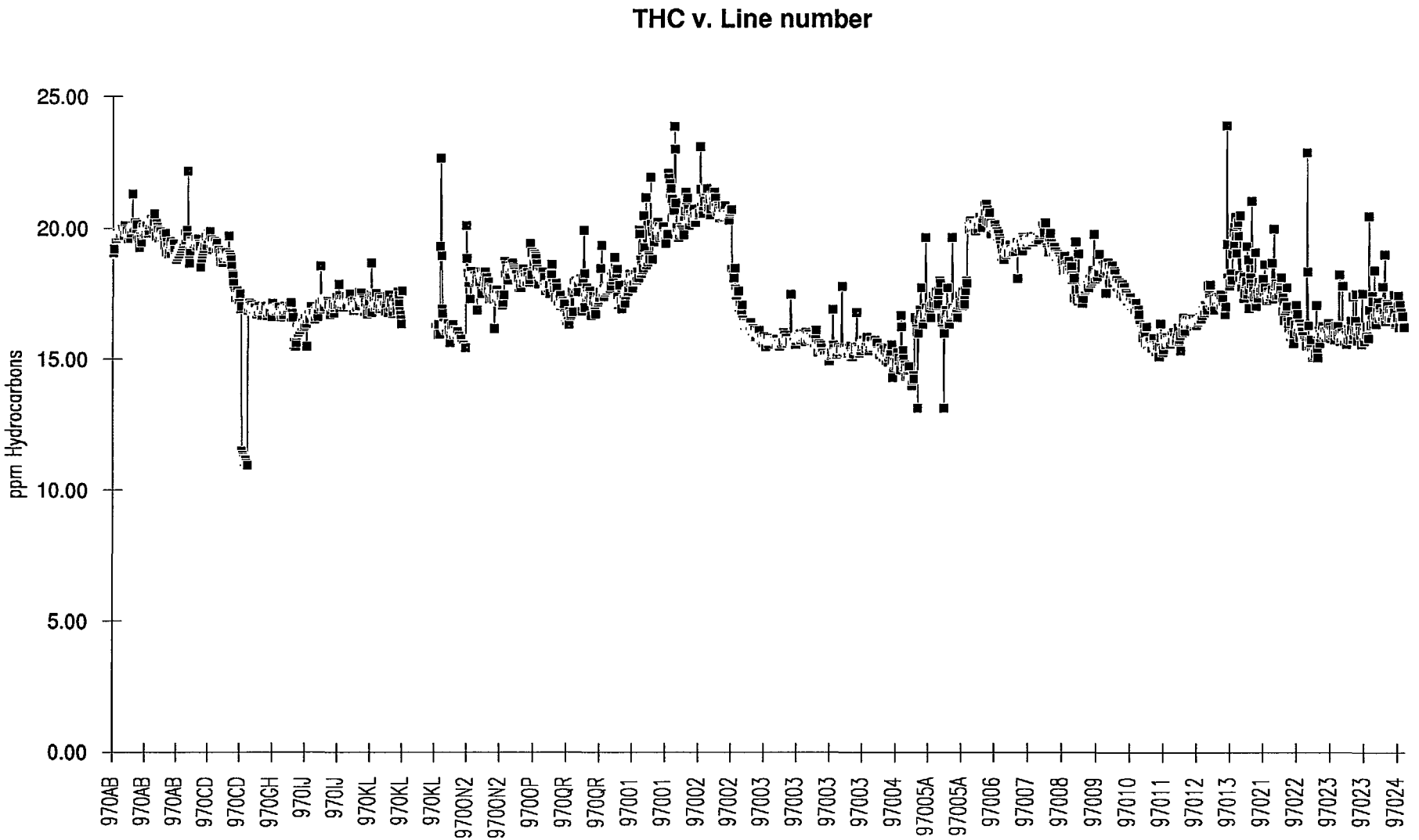



**Figure 3.** Total hydrocarbons (THC) versus line number (Dampier Sub-Basin).

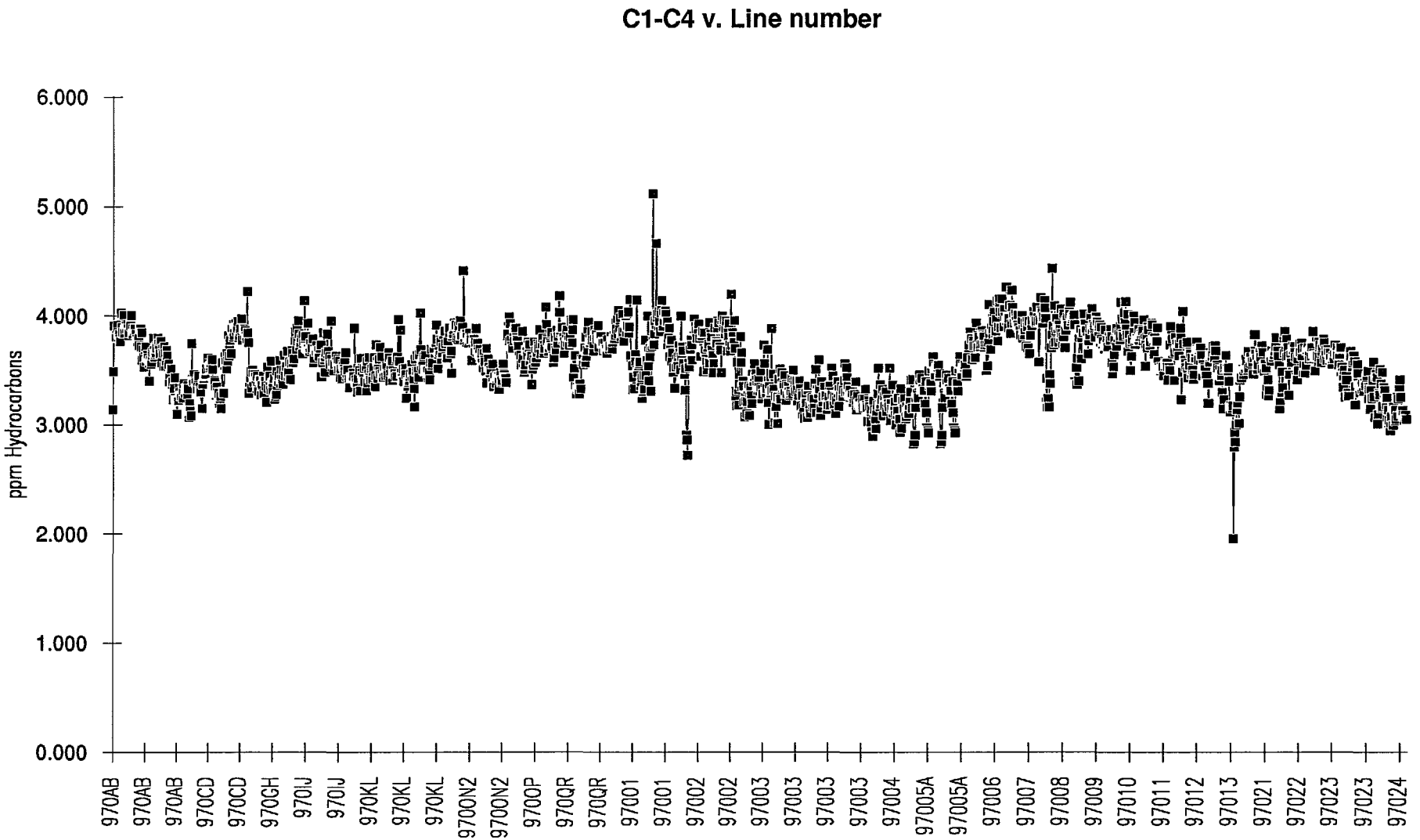



**Figure 4.** Sum of $C_1$-$C_4$ hydrocarbons (Dampier Sub-Basin).

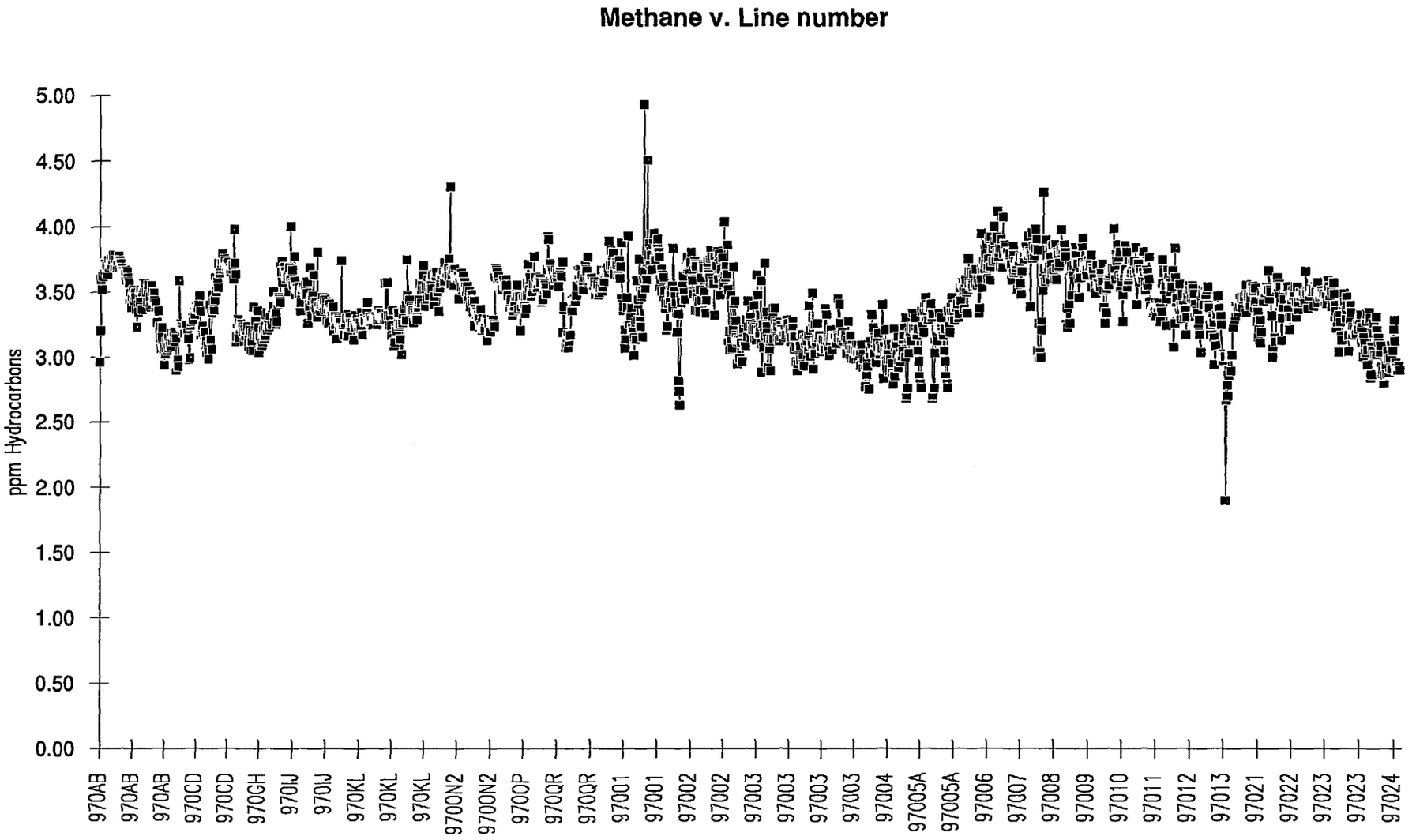



**Figure 5.** Methane versus line number (Dampier Sub-Basin).

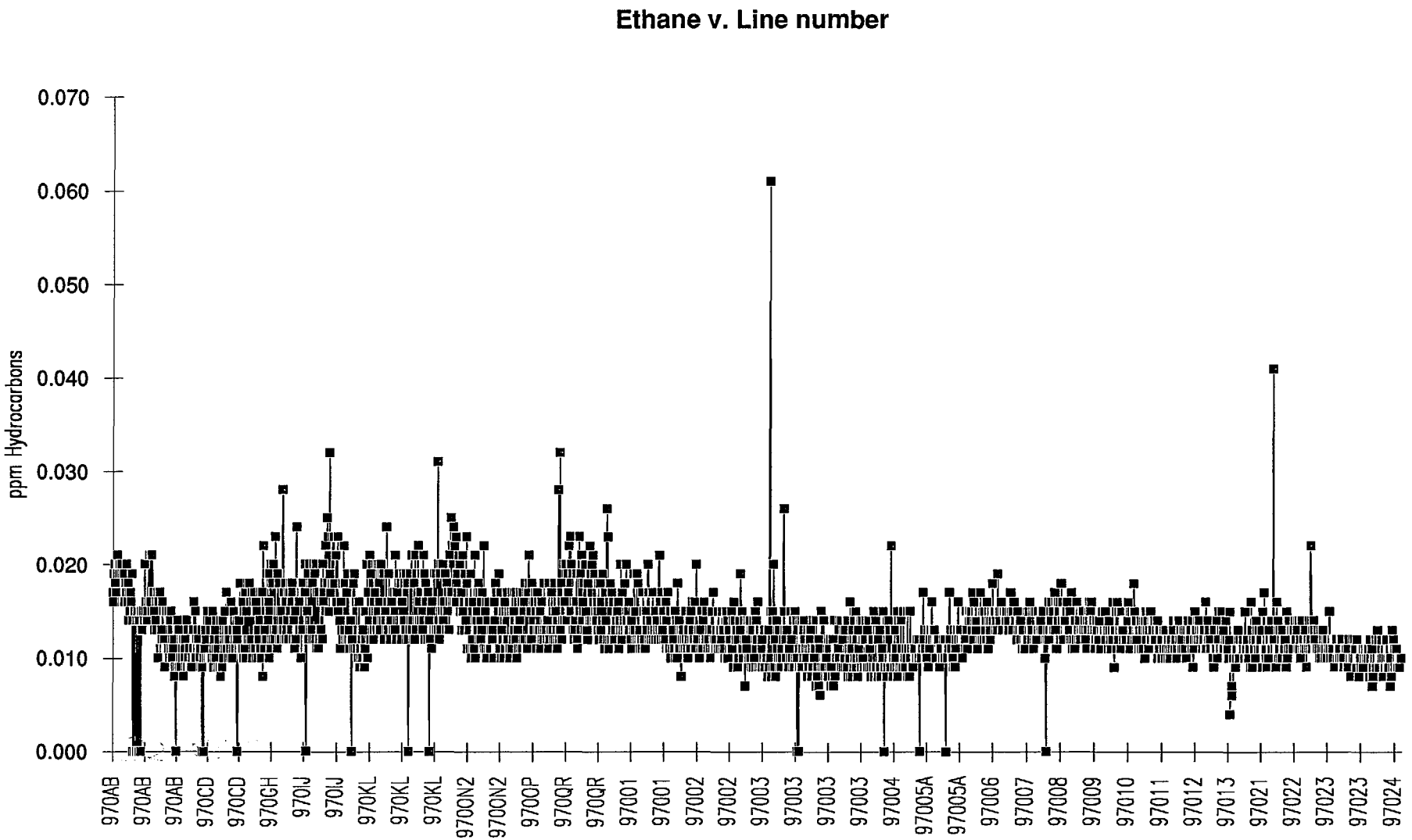



**Figure 6.** Ethane versus line number (Dampier Sub-Basin).


**Figure 7.** Ethylene versus line number (Dampier Sub-Basin).

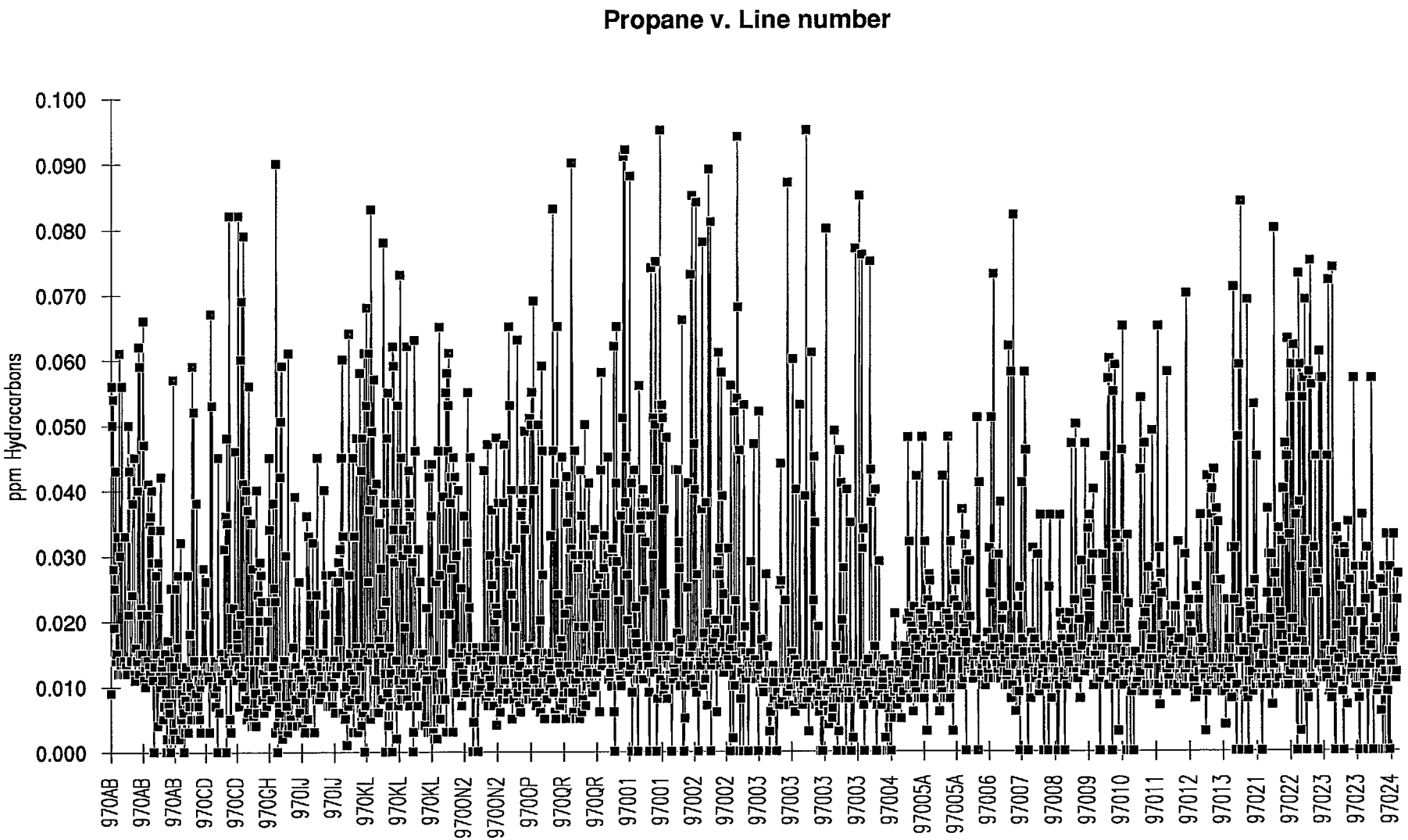



**Figure 8.** Propane versus line number (Dampier Sub-Basin).

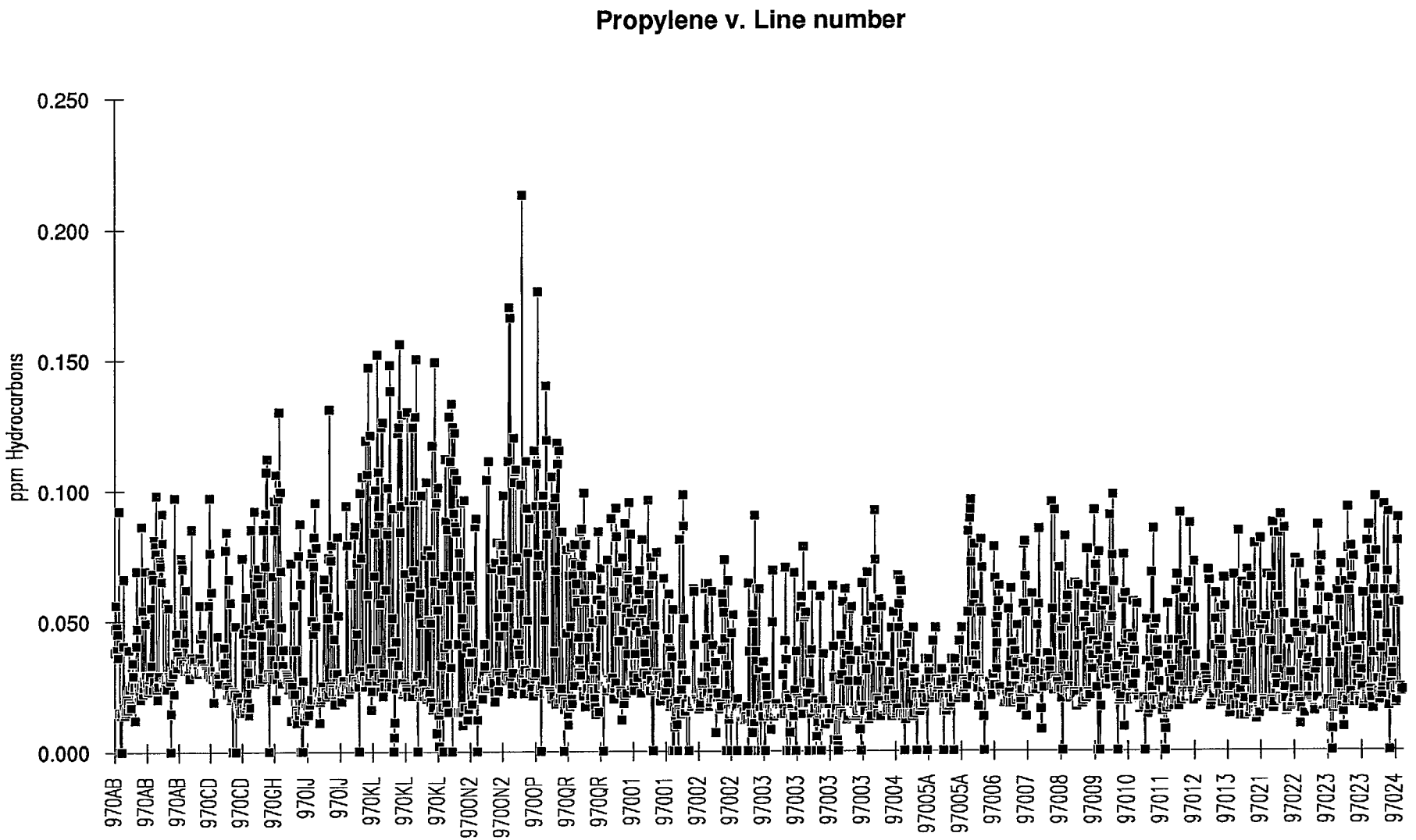



**Figure 9.** Propylene versus line number (Dampier Sub-Basin).

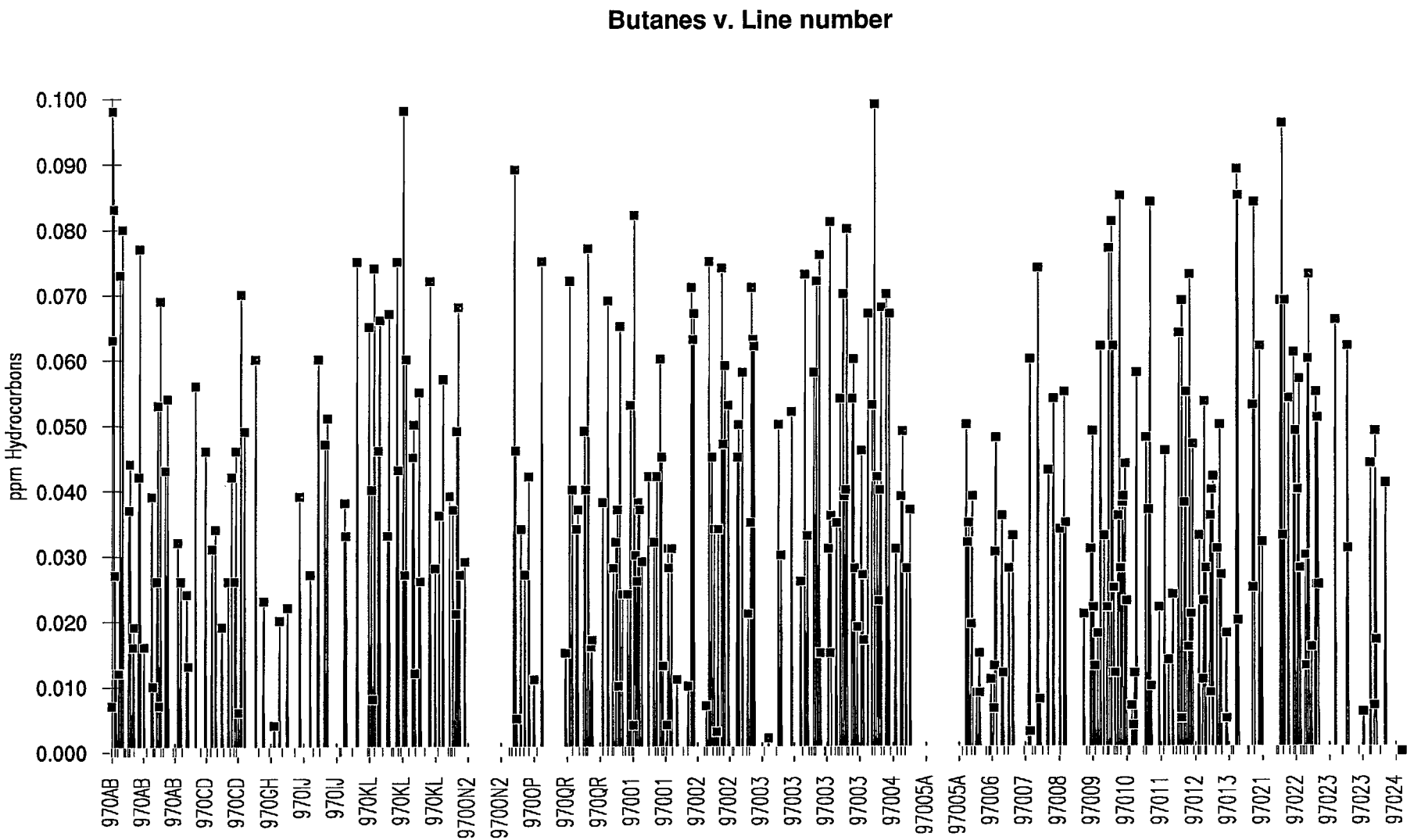



**Figure 10.** Butane versus line number (Dampier Sub-Basin).

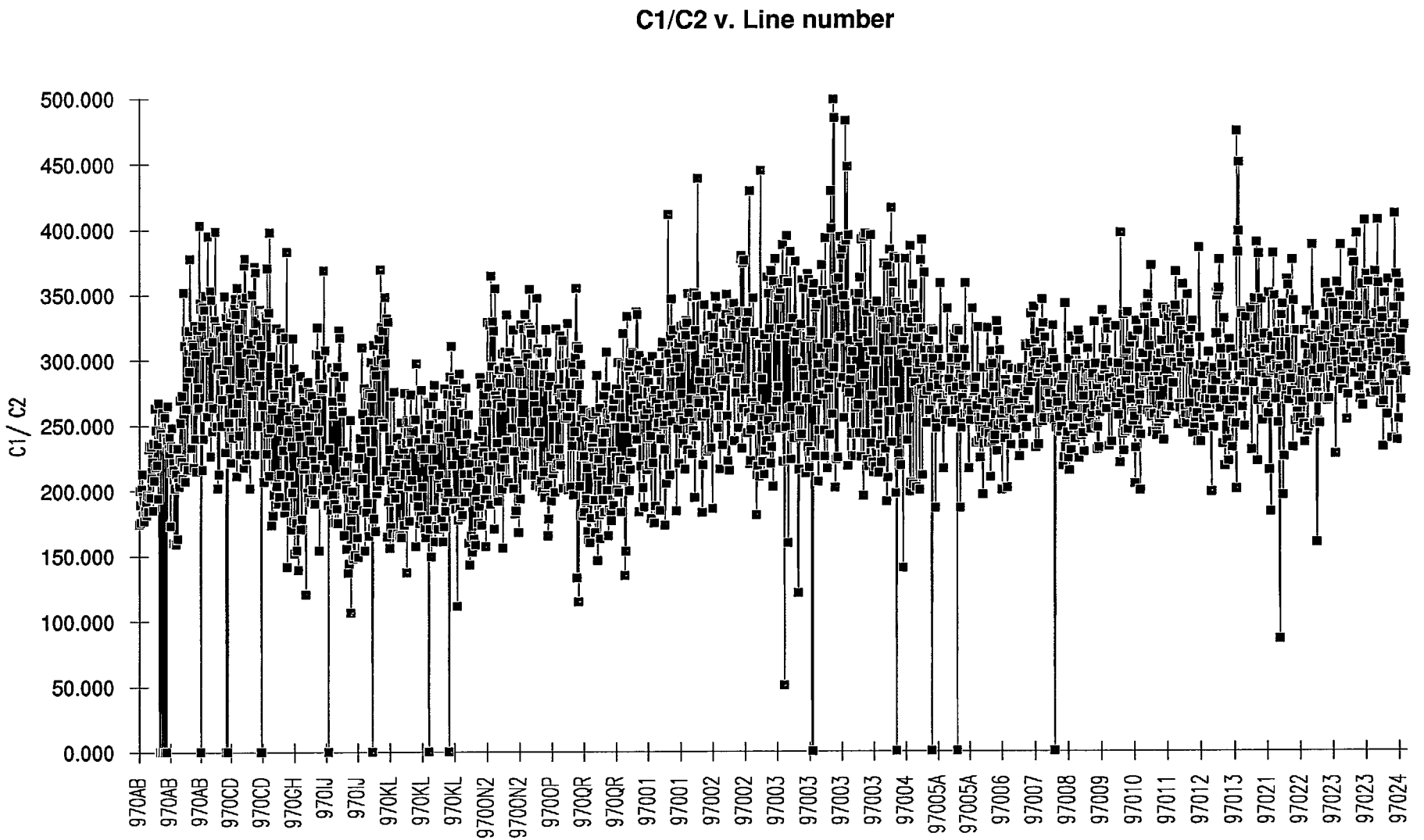



**Figure 11.** Ratio of C1/C2 versus line number (Dampier Sub-Basin).

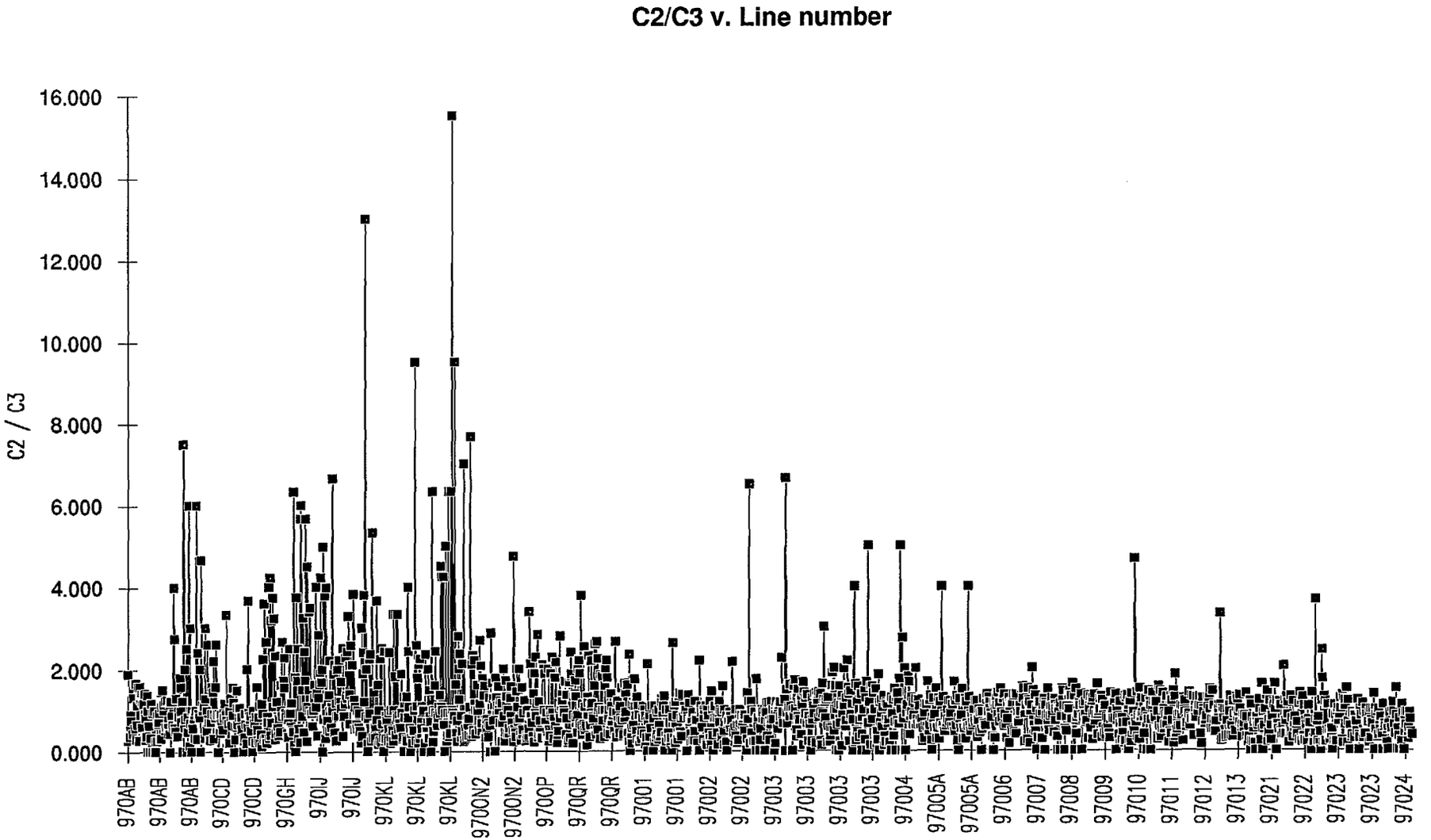



**Figure 12.** Ratio of C2/C3 versus line number (Dampier Sub-Basin).

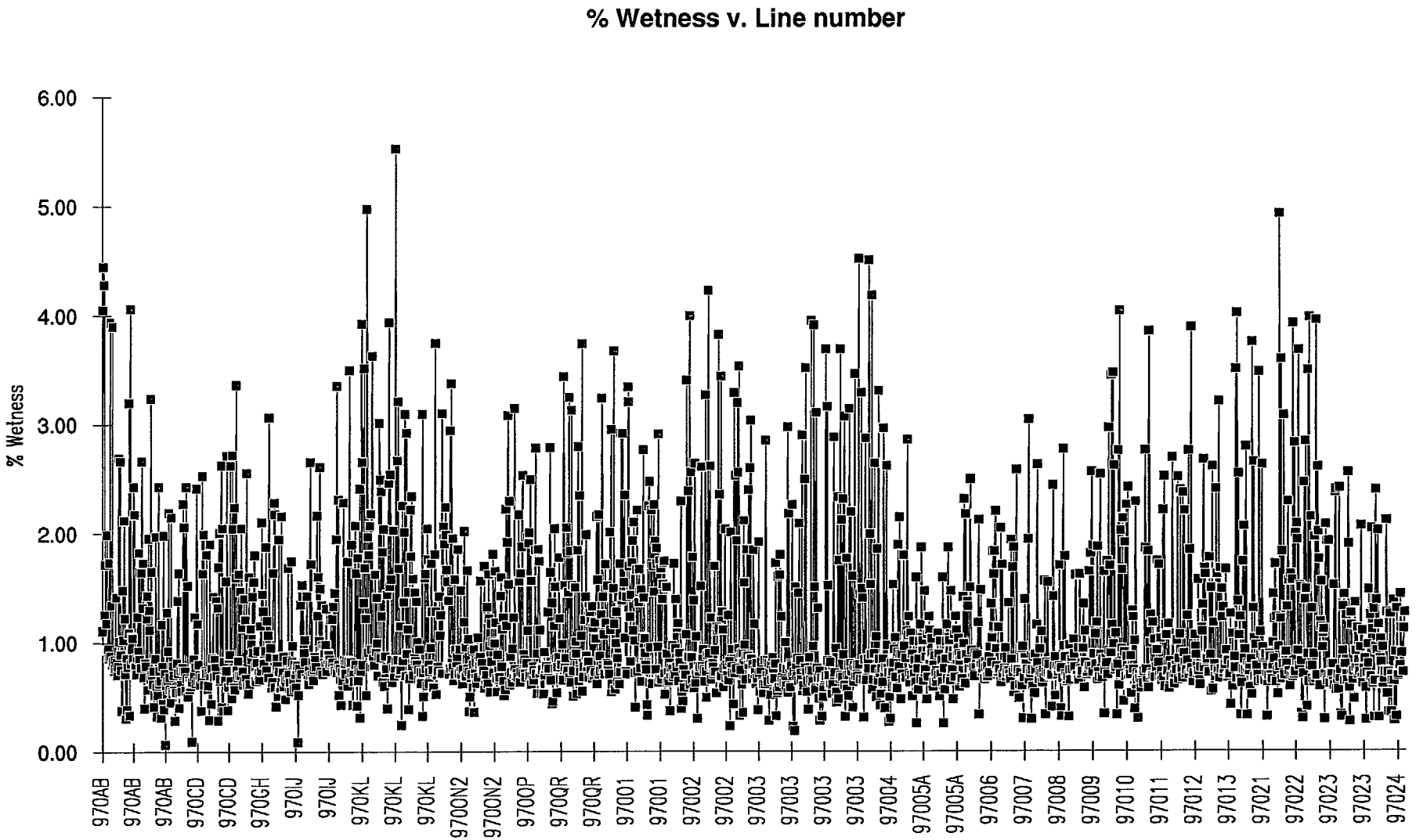



**Figure 13.** Percent hydrocarbon wetness versus line number (Dampier Sub-Basin).

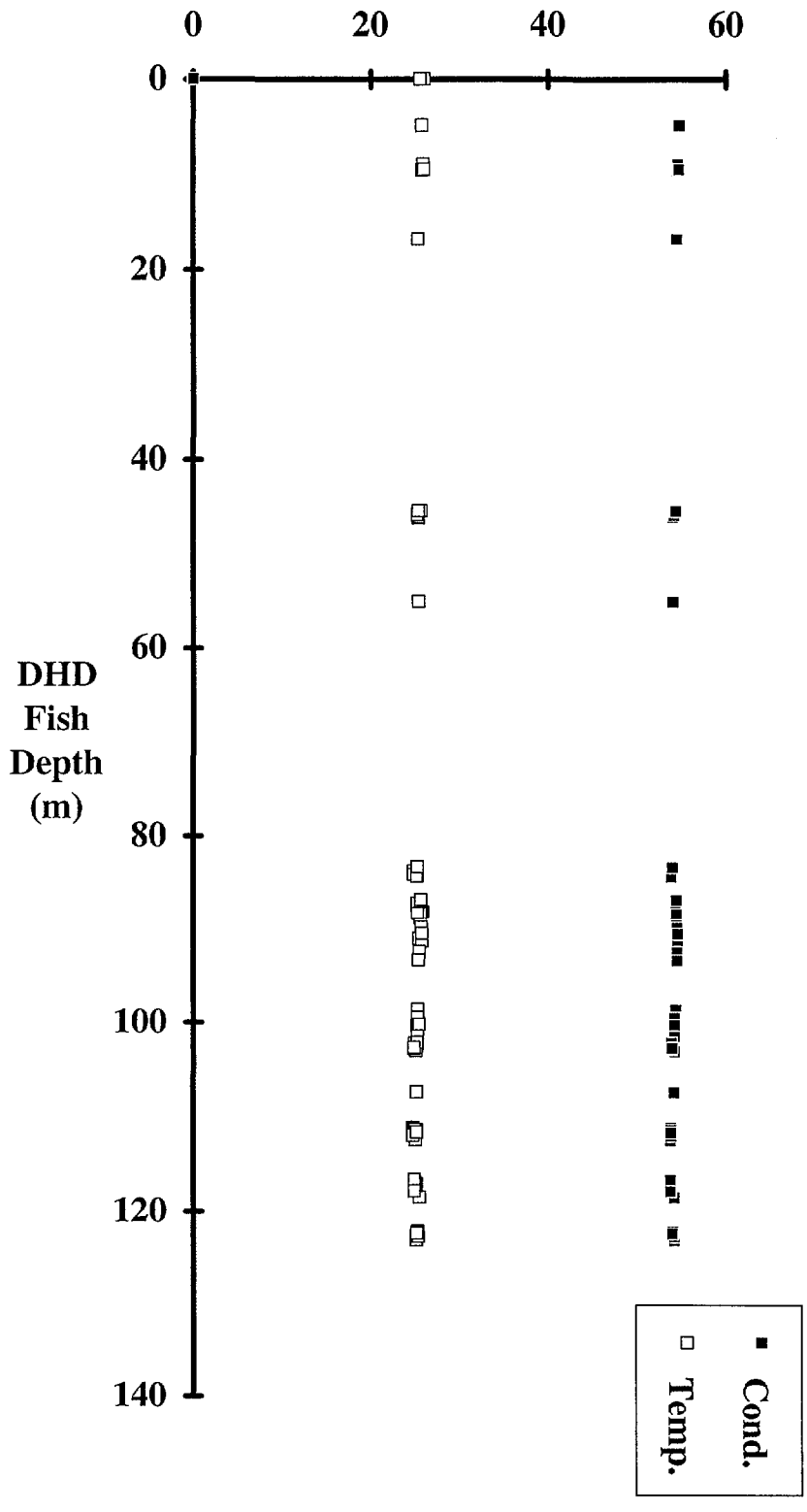



**Figure 14a.** Vertical profile on line 97/024 (at 19° 25'S; 116° 39'E), showing the relationship between depth and the water column's temperature and conductivity.

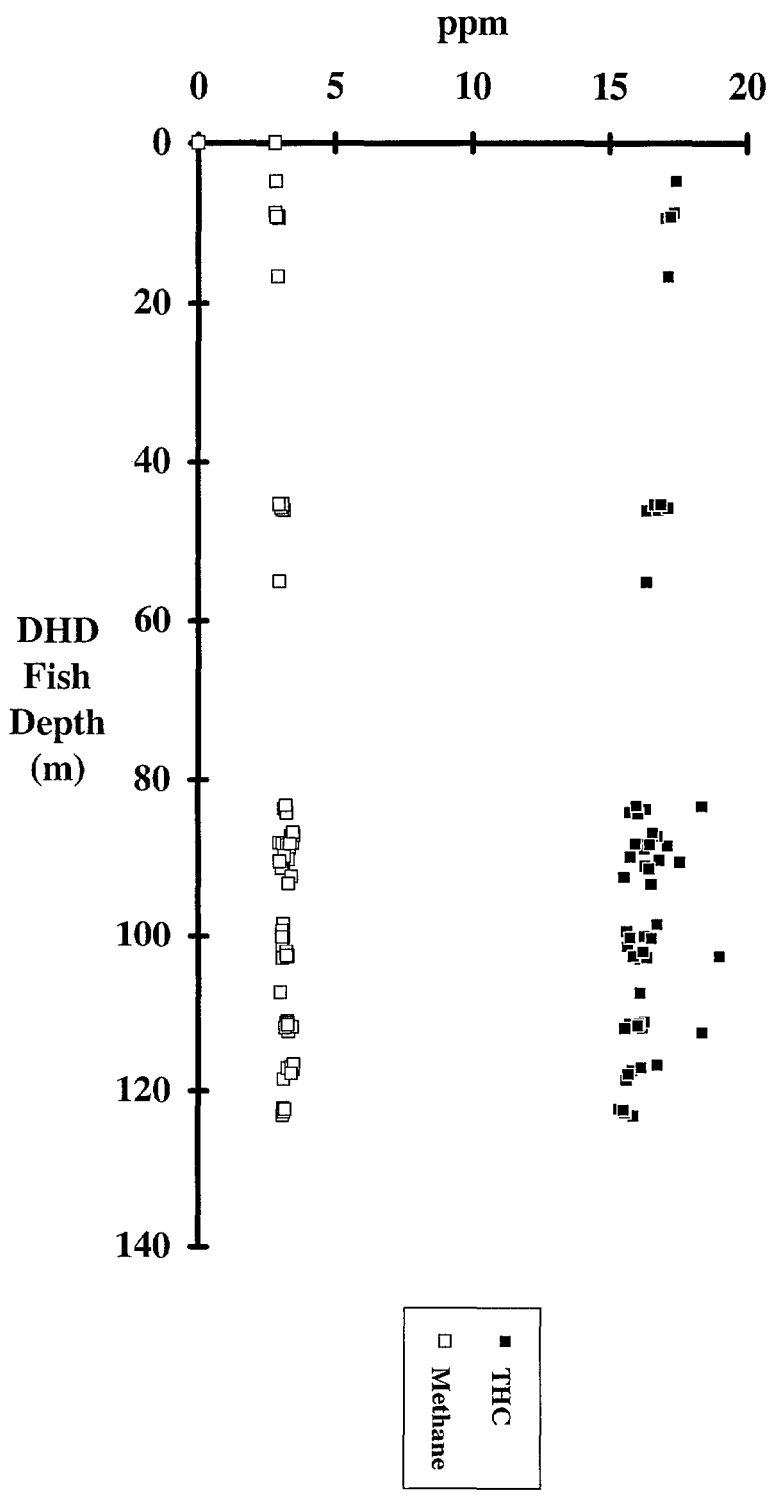



**Figure 14b.** Vertical profile on line 97/024 (at 19° 25'S; 116° 39'E), showing the relationship between depth and the water column's THC and methane concentrations.

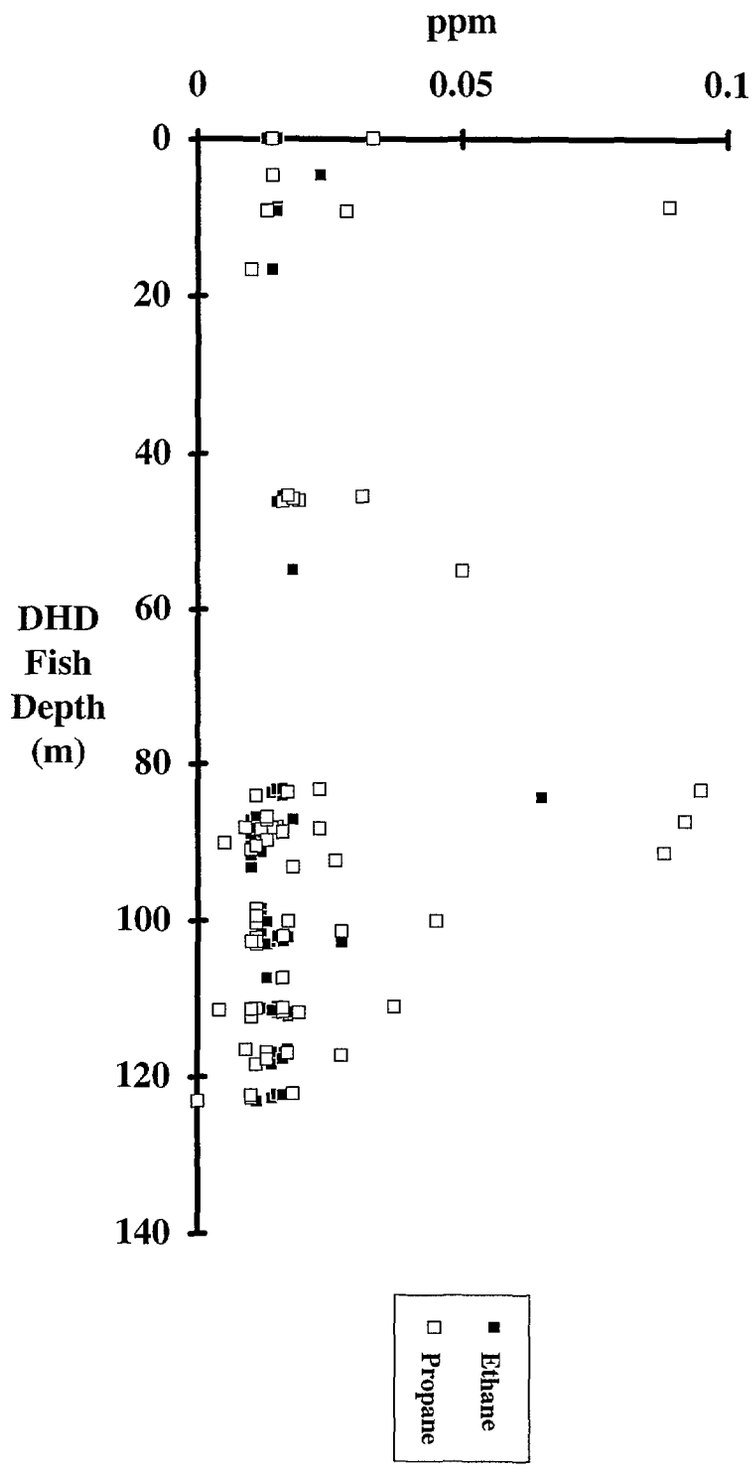



**Figure 14c.** Vertical profile on line 97/024 (at 19° 25'S; 116° 39'E), showing the relationship between depth and the water column's ethane and propane concentrations.

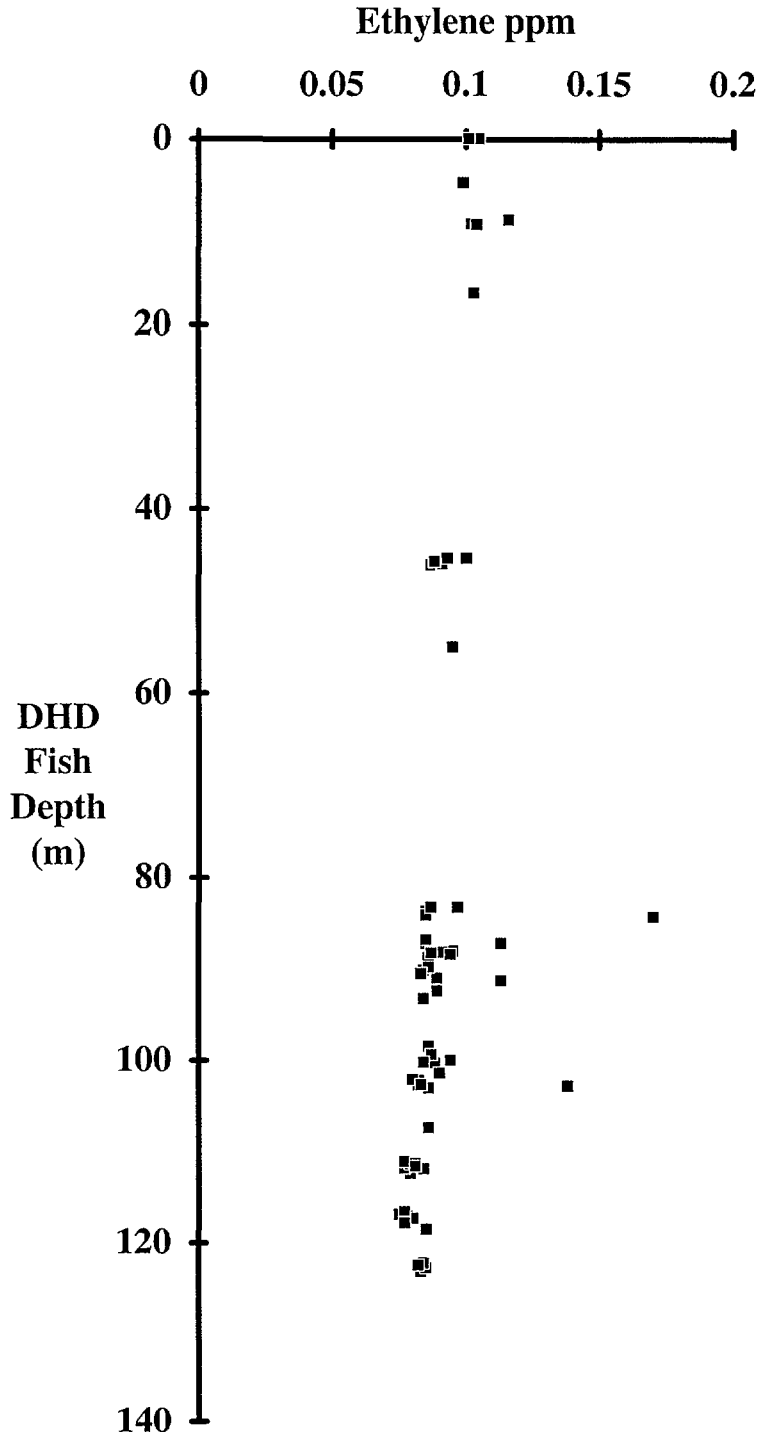



**Figure 14d.** Vertical profile on line 97/024 (at 19° 25'S; 116° 39'E), showing the relationship between depth and the water column's ethylene concentration.

# APPENDIX I

## DATA SUMMARY SHEETS

## GRAPHS OF HYDROCARBON CONCENTRATIONS VERSUS SHOTPOINT

Line Summary

| | |
|---|---|
| Line Number | 970AB |
| No. of Shotpoints | 120 |

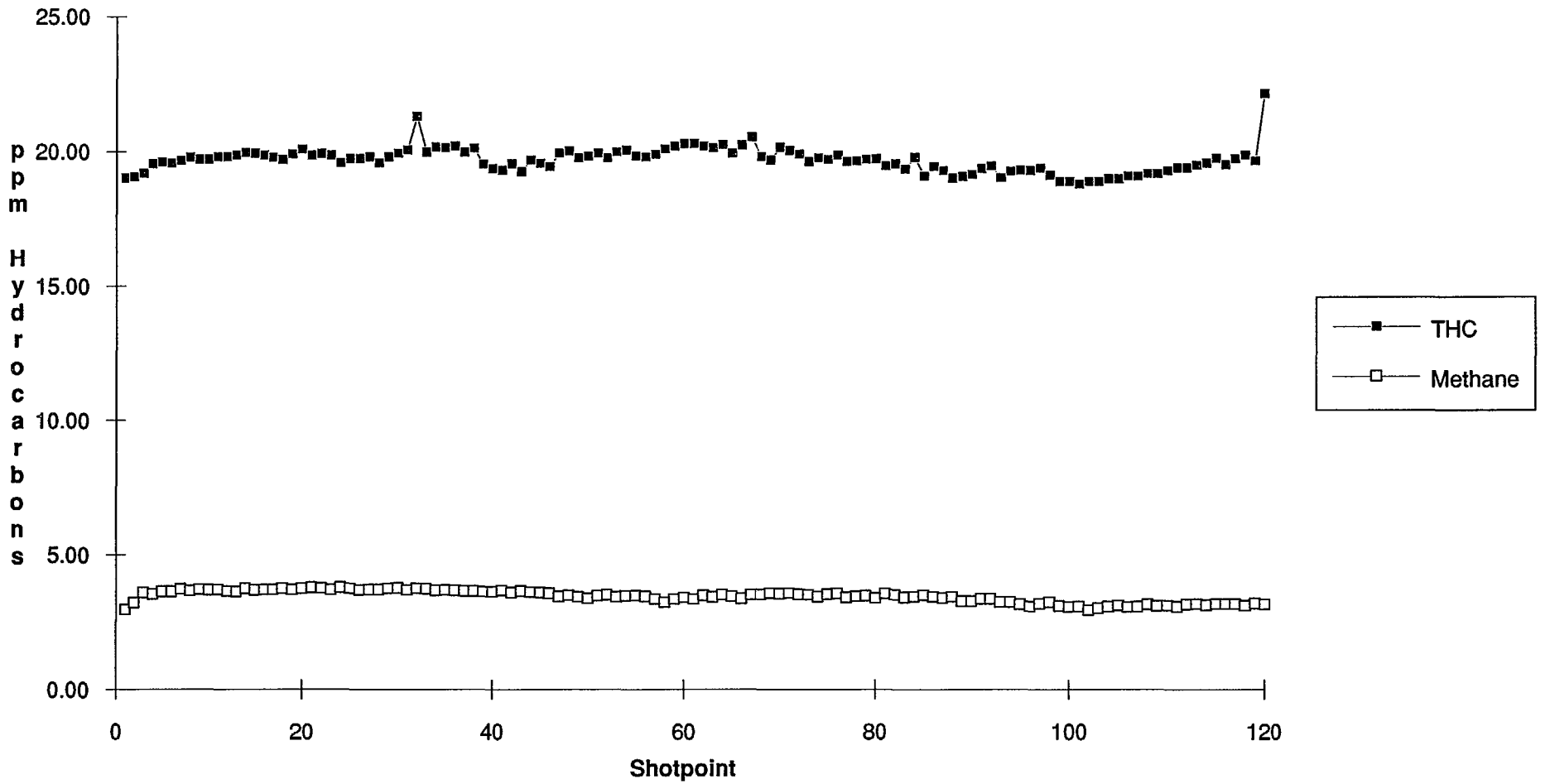
| | Shotpoint | Date | Time | Latitude | | Longitude | |
|---|---|---|---|---|---|---|---|
| Start | 4 | 22-Oct-90 | 08:50:57 | 19 | 25.224 | 116 | 35.099 |
| End | 2 | 22-Oct-90 | 12:53:38 | 19 | 36.132 | 116 | 44.055 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 19.683 | 3.446 | 0.014 | 0.098 | 0.020 | 0.038 | 0.009 | 0.000 | 0.001 | 0.121 | 0.044 | 0.000 | 1.210 |
| Std. Dev. | 0.463 | 0.228 | 0.005 | 0.008 | 0.016 | 0.022 | 0.020 | 0.003 | 0.004 | 0.034 | 0.021 | 0.000 | 0.915 |
| Minimum | 18.800 | 2.936 | 0.000 | 0.081 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.065 |
| Maximum | 22.155 | 3.781 | 0.021 | 0.119 | 0.066 | 0.098 | 0.083 | 0.033 | 0.019 | 0.159 | 0.089 | 0.000 | 4.444 |

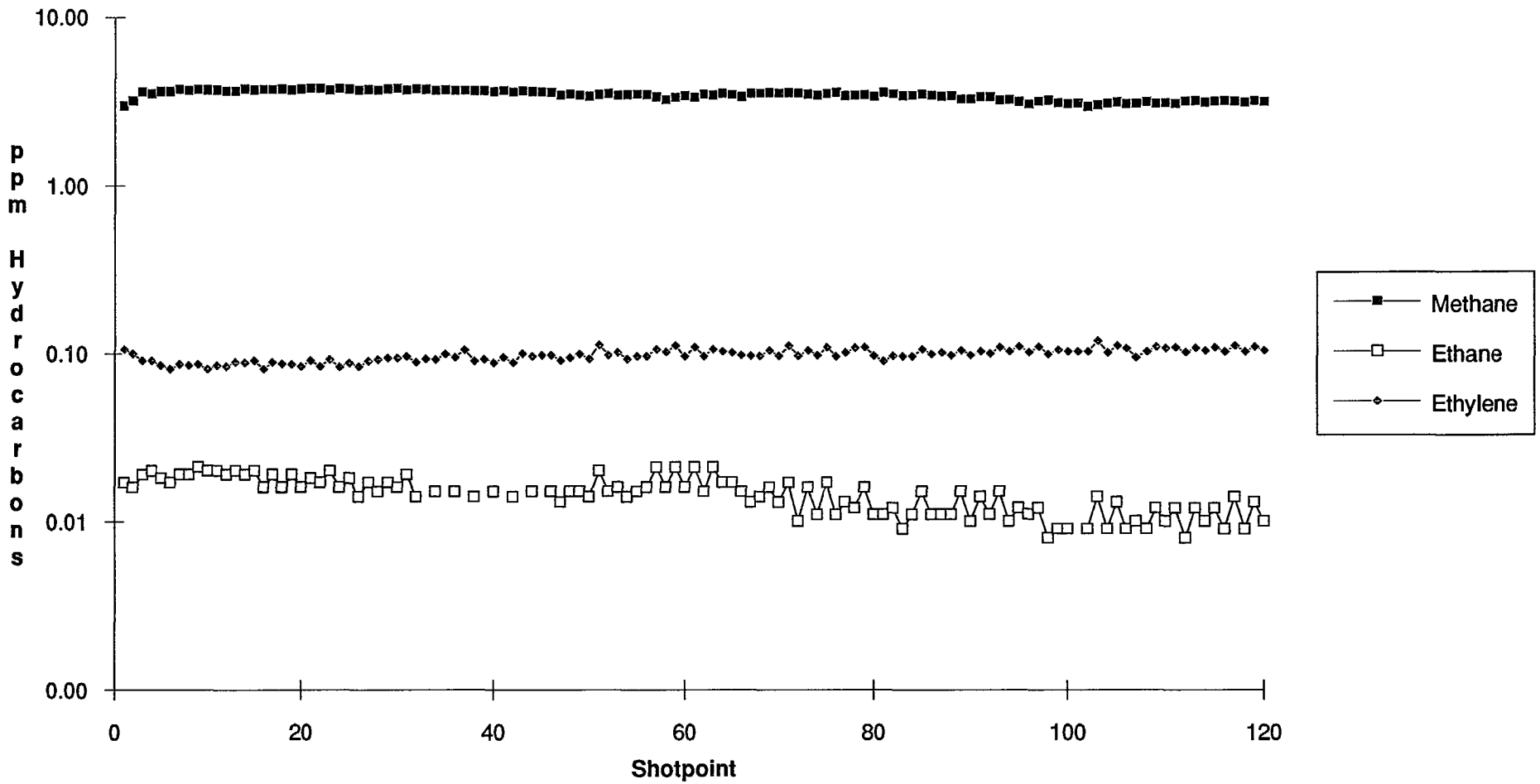
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 53.565 | 26.752 | 61.378 | 82.219 | 20.842 |
| Std. Dev. | 0.301 | 2.092 | 23.012 | 26.643 | 4.434 |
| Minimum | 53.320 | 25.720 | 31.500 | 47.000 | 14.000 |
| Maximum | 55.330 | 36.790 | 99.500 | 126.500 | 29.000 |

Notes No anomalies.

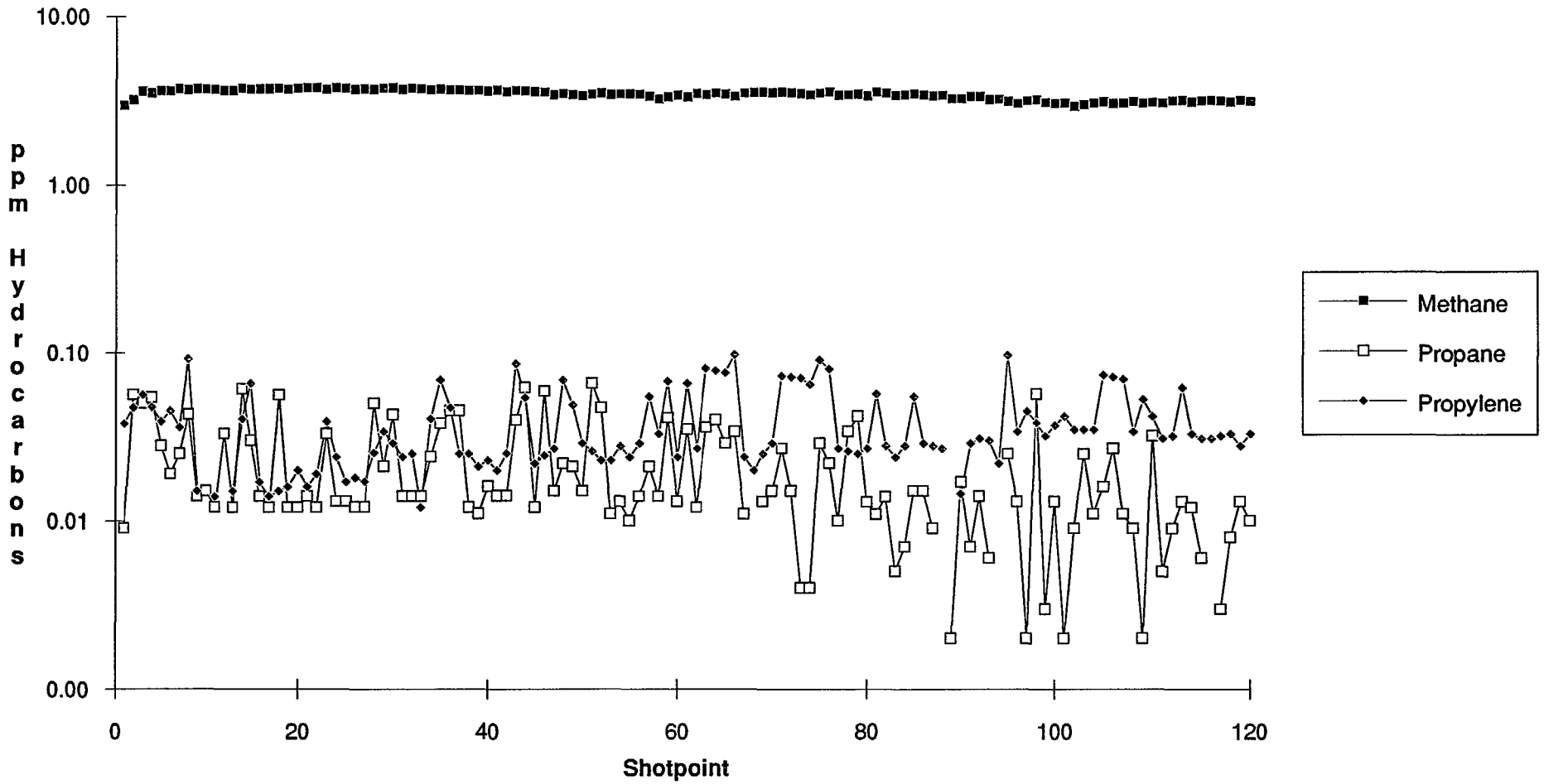
# Line 970AB THC, Methane



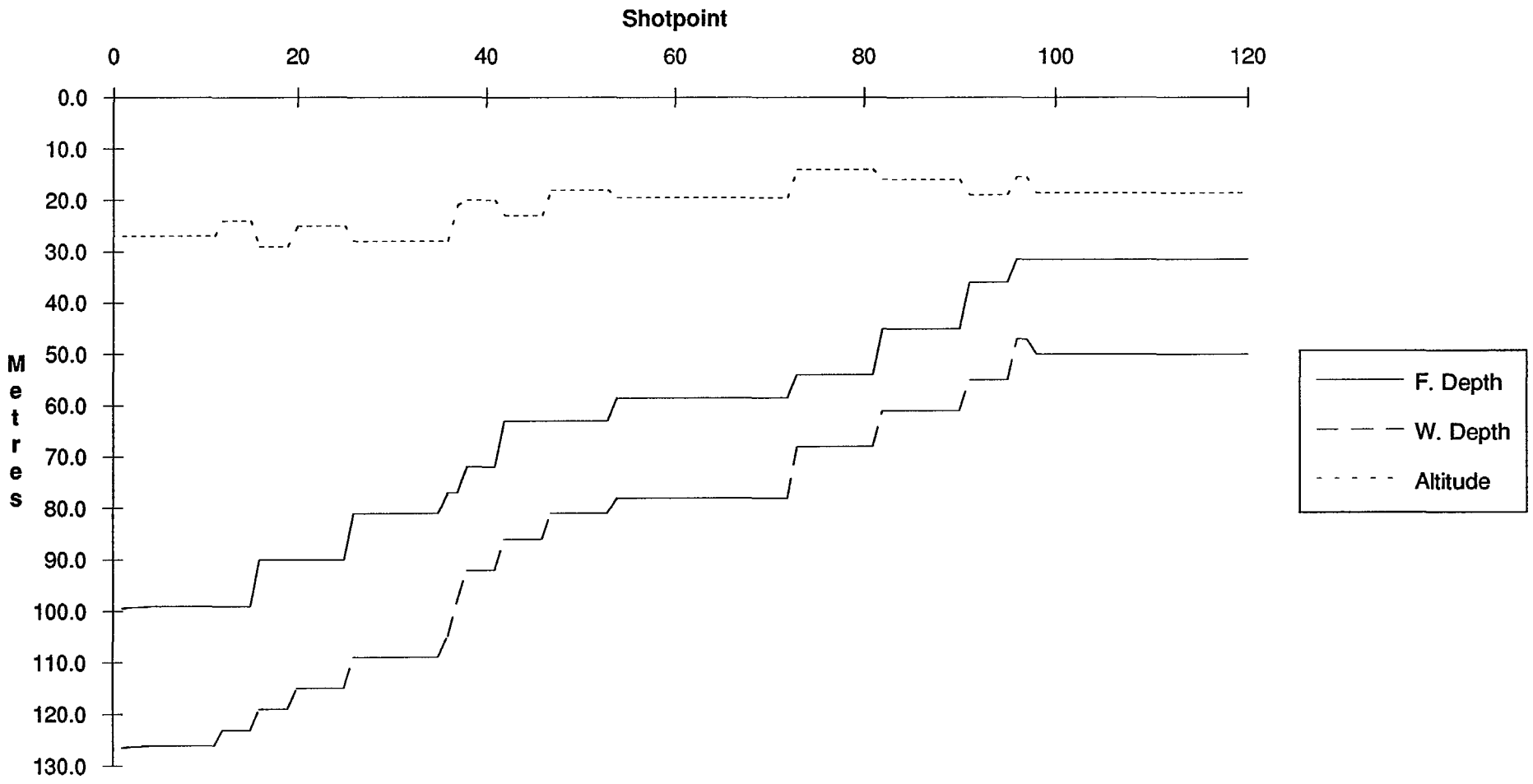
## Line 970AB Methane, Ethane, Ethylene



## Line 970AB Methane, Propane, Propylene



# Line 970AB Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 970CD |
| No. of Shotpoints | 94 |

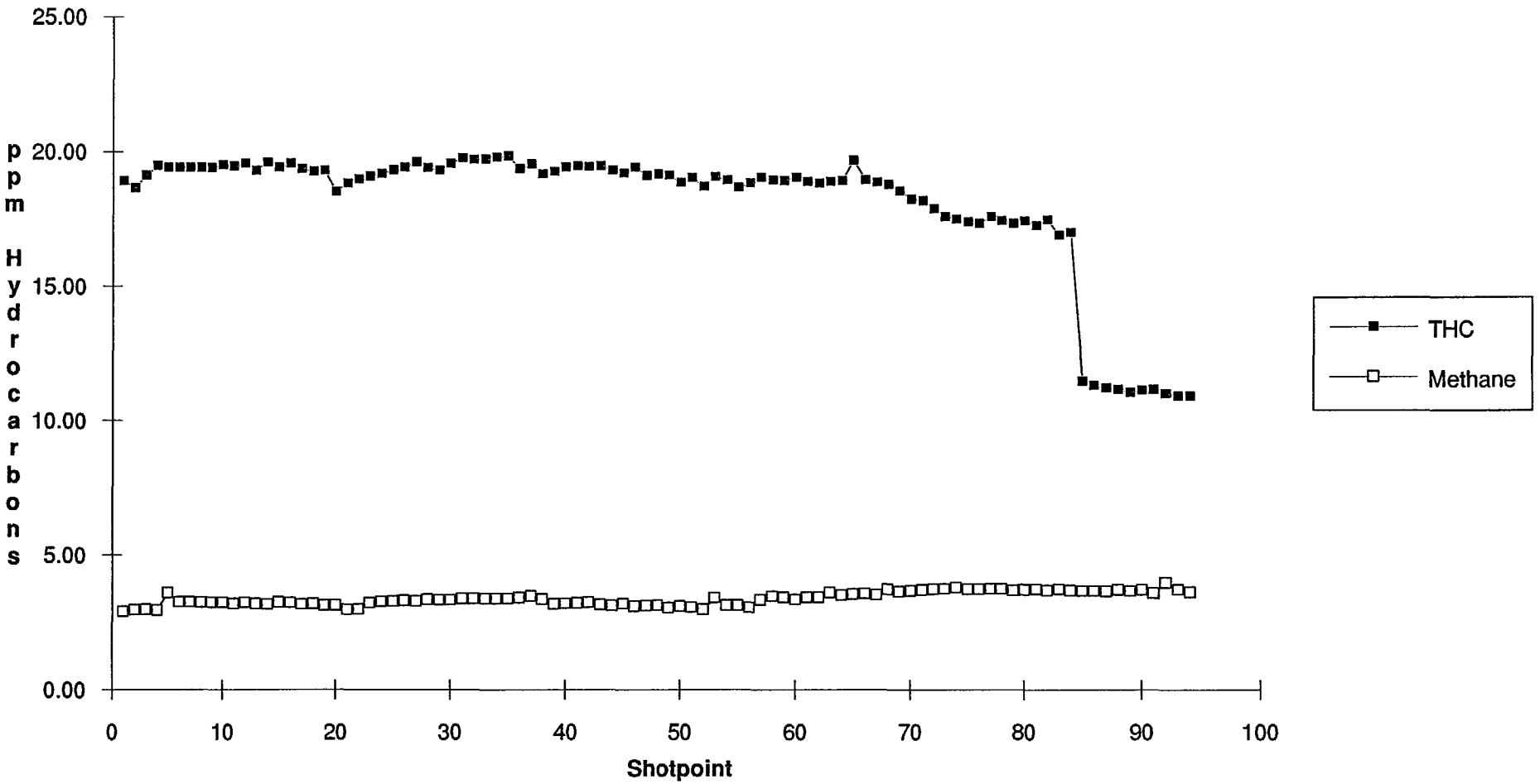
| | Shotpoint | Date | Time | Latitude | | Longitude | |
|---|---|---|---|---|---|---|---|
| Start | 1 | 22-Oct-90 | 13:20:07 | 19 | 36.929 | 116 | 42.603 |
| End | 94 | 22-Oct-90 | 16:26:03 | 19 | 25.675 | 116 | 32.153 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 18.093 | 3.378 | 0.011 | 0.098 | 0.020 | 0.033 | 0.004 | 0.001 | 0.000 | 0.124 | 0.039 | 0.000 | 1.040 |
| Std. Dev. | 2.514 | 0.255 | 0.003 | 0.010 | 0.018 | 0.017 | 0.012 | 0.006 | 0.000 | 0.041 | 0.018 | 0.000 | 0.701 |
| Minimum | 10.919 | 2.899 | 0.000 | 0.072 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.093 |
| Maximum | 19.852 | 3.974 | 0.018 | 0.122 | 0.082 | 0.097 | 0.070 | 0.042 | 0.000 | 0.186 | 0.084 | 0.000 | 3.356 |

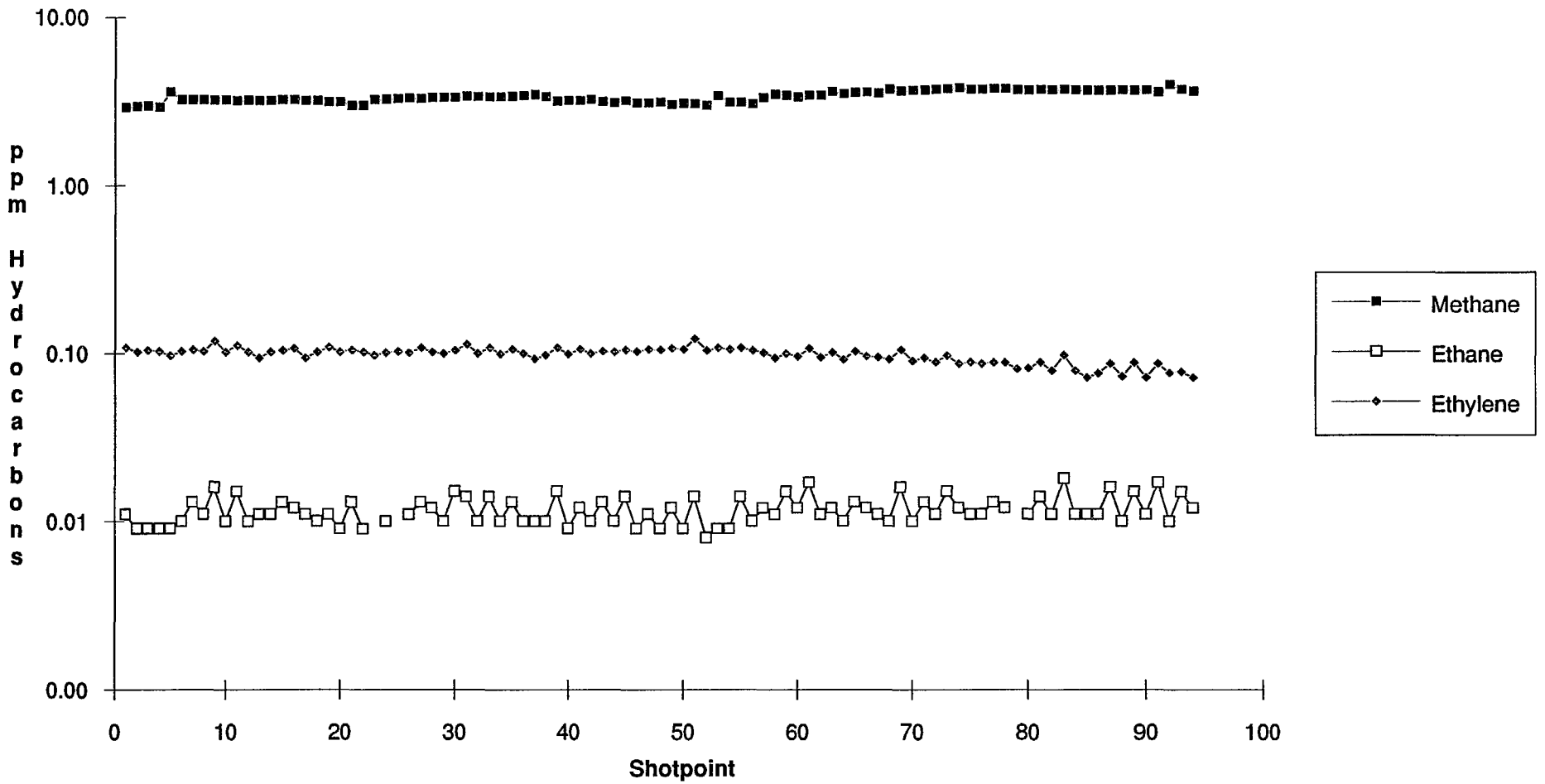
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 53.036 | 25.333 | 54.739 | 71.904 | 17.213 |
| Std. Dev. | 0.446 | 0.480 | 25.495 | 22.345 | 3.447 |
| Minimum | 52.040 | 24.320 | 31.500 | 52.000 | 10.000 |
| Maximum | 53.600 | 26.180 | 108.000 | 118.000 | 21.000 |

Notes No anomalies.

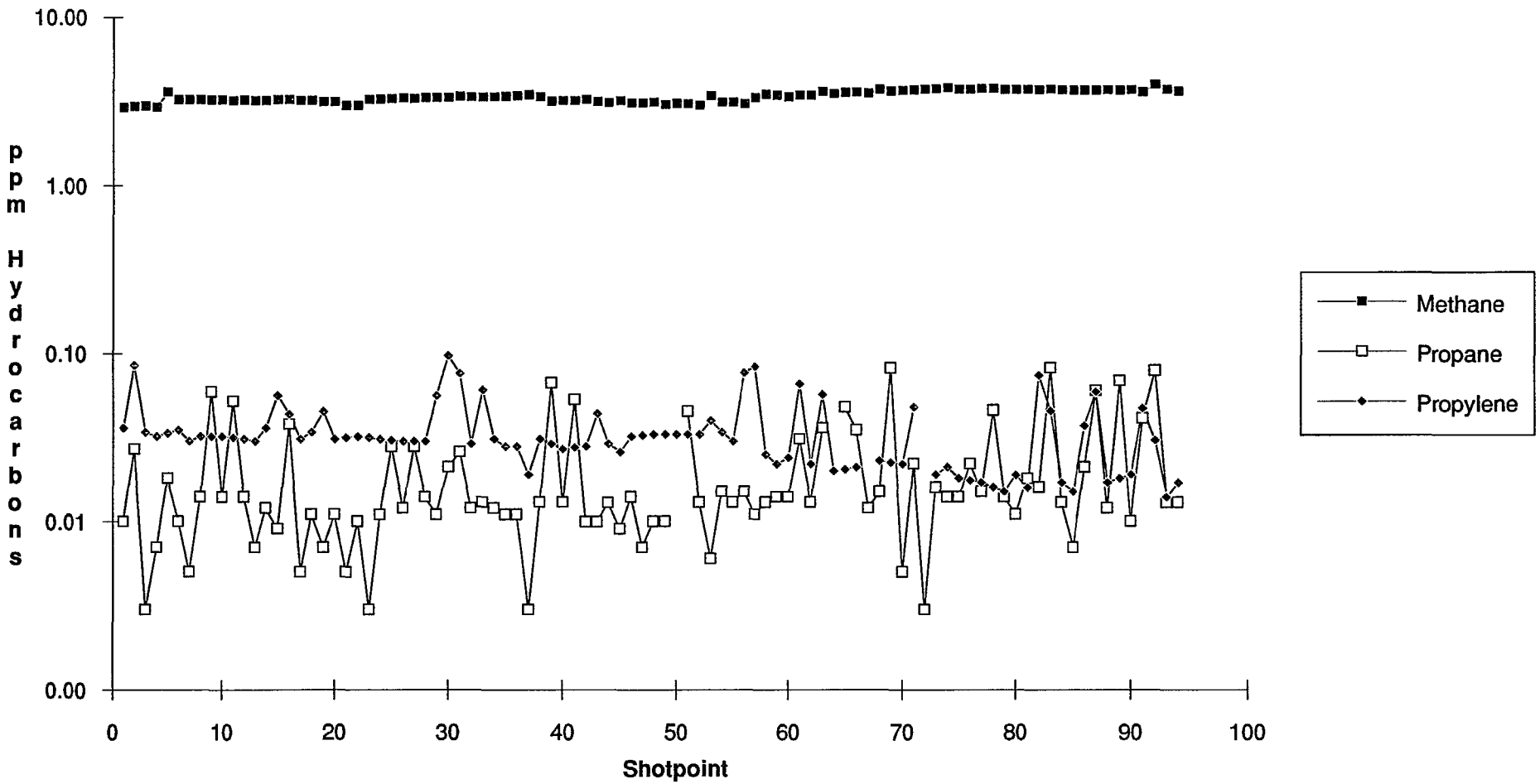
# Line 970CD THC, Methane



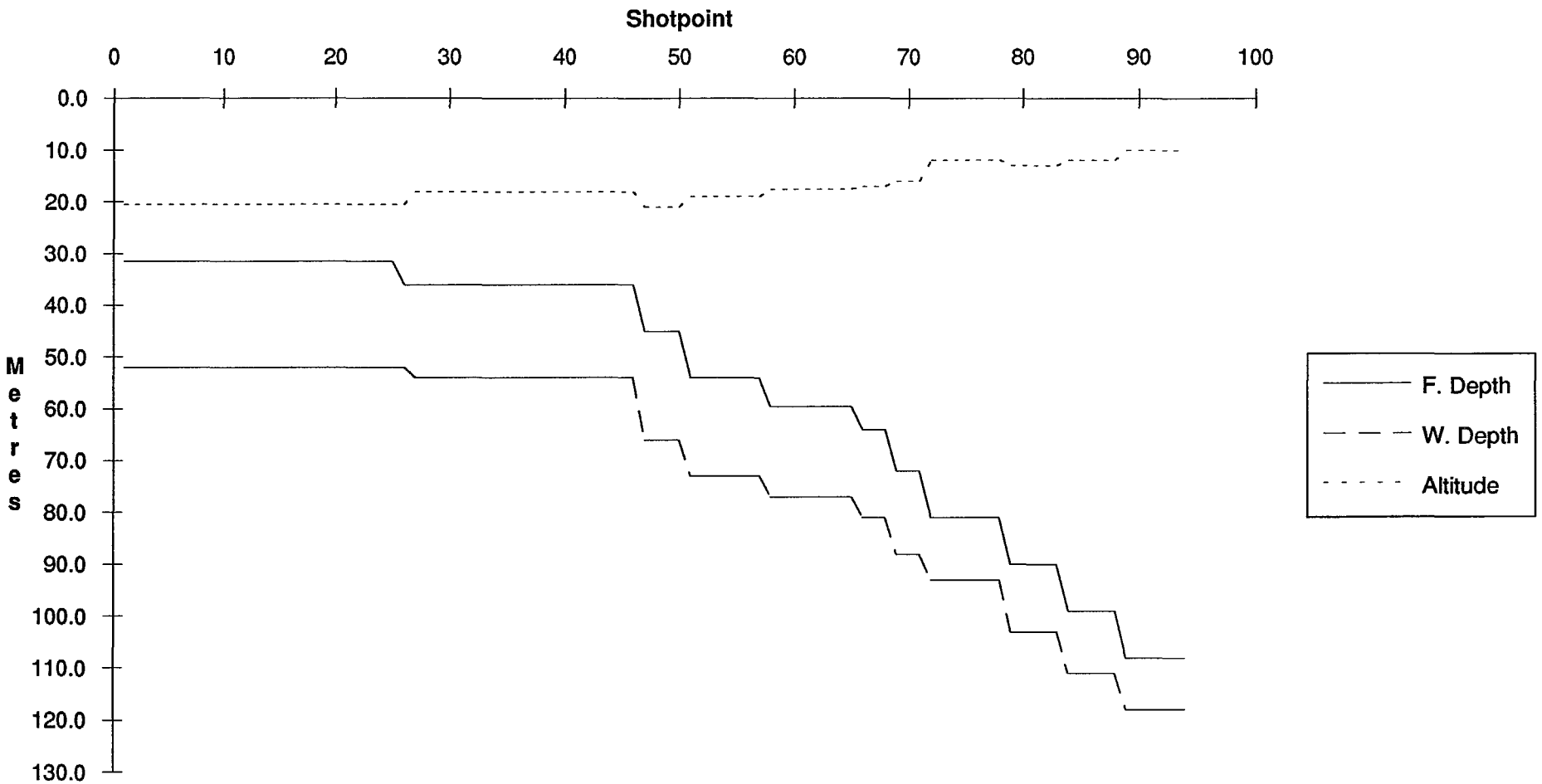
# Line 970CD Methane, Ethane, Ethylene



# Line 970CD Methane, Propane, Propylene



# Line 970CD Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 970GH |
| No. of Shotpoints | 69 |

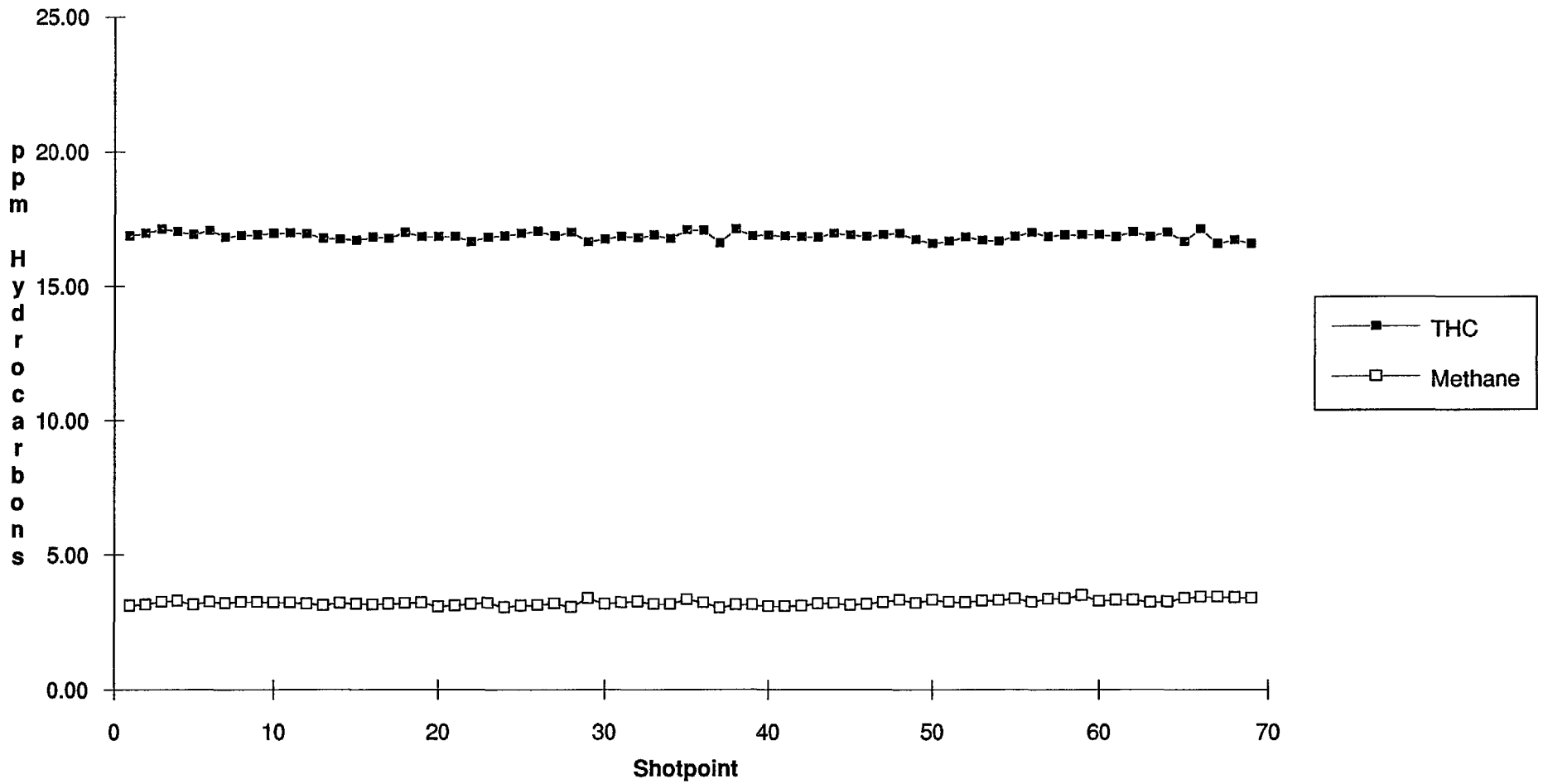
| | Shotpoint | Date | Time | Latitude | | Longitude | |
|---|---|---|---|---|---|---|---|
| Start | 1 | 23-Oct-90 | 20:45:28 | 19 | 40.652 | 116 | 34.424 |
| End | 69 | 23-Oct-90 | 23:01:26 | 19 | 32.686 | 116 | 32.636 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 16.862 | 3.232 | 0.015 | 0.107 | 0.019 | 0.049 | 0.002 | 0.000 | 0.000 | 0.109 | 0.000 | 0.000 | 1.069 |
| Std. Dev. | 0.135 | 0.105 | 0.004 | 0.012 | 0.017 | 0.028 | 0.008 | 0.000 | 0.000 | 0.021 | 0.003 | 0.000 | 0.568 |
| Minimum | 16.576 | 3.033 | 0.008 | 0.091 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.411 |
| Maximum | 17.140 | 3.503 | 0.028 | 0.148 | 0.090 | 0.130 | 0.060 | 0.000 | 0.000 | 0.127 | 0.022 | 0.000 | 3.061 |

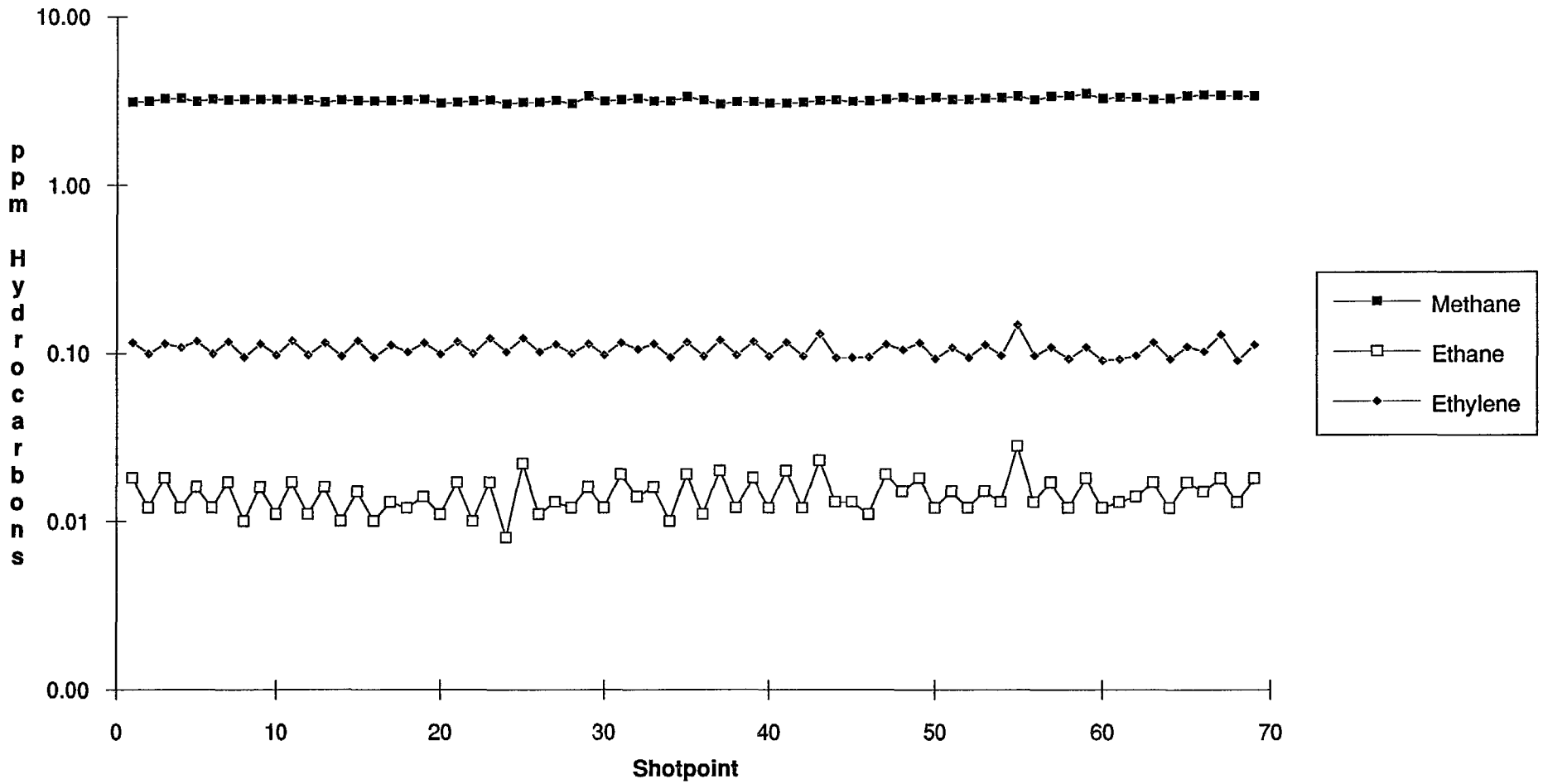
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 53.257 | 24.776 | 48.113 | 61.925 | 13.812 |
| Std. Dev. | 0.102 | 0.162 | 8.113 | 8.186 | 1.865 |
| Minimum | 53.120 | 24.430 | 39.576 | 53.576 | 12.000 |
| Maximum | 53.480 | 25.090 | 62.934 | 82.730 | 20.000 |

Notes No anomalies.

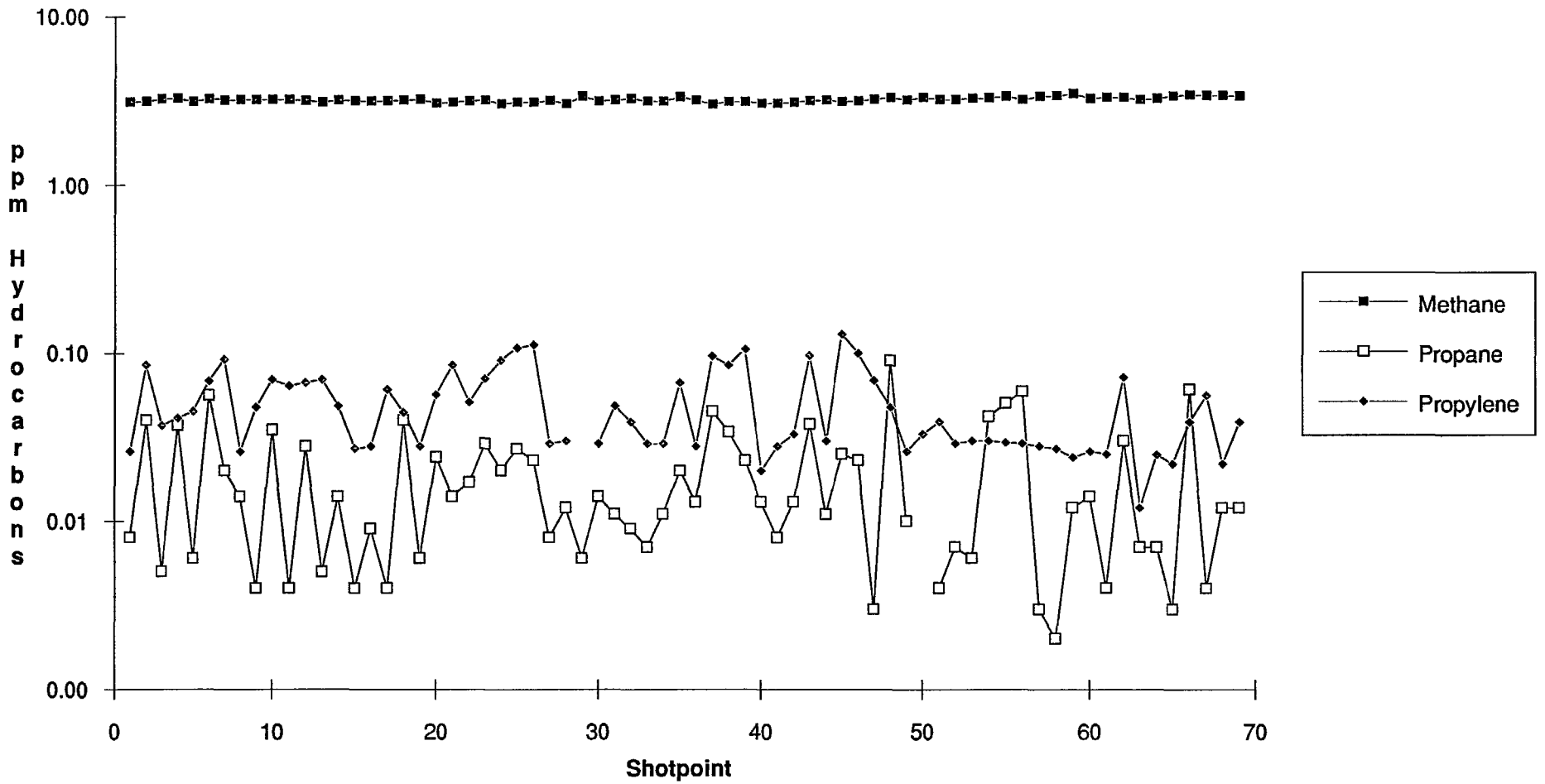
# Line 970GH THC, Methane



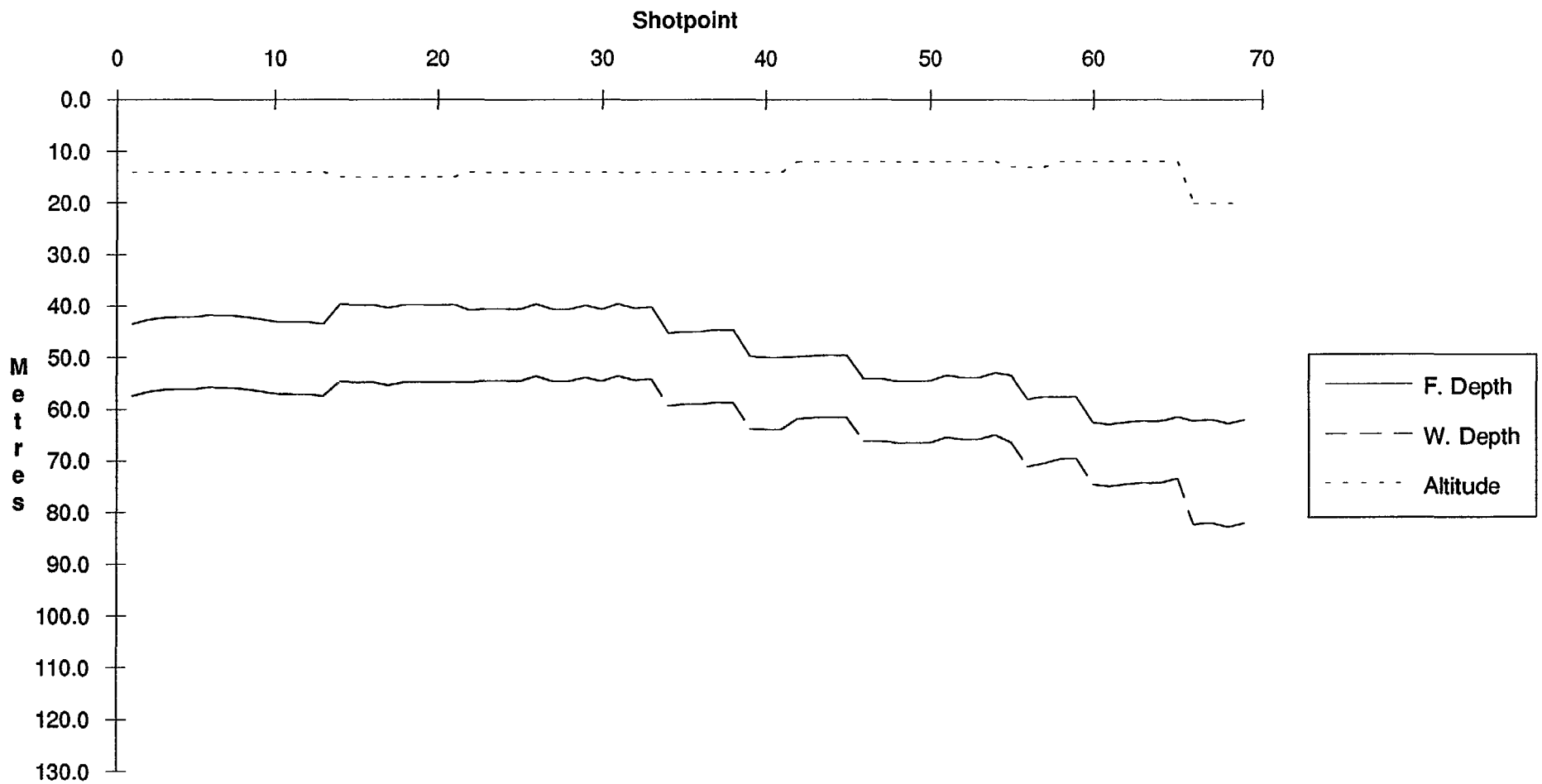
## Line 970GH Methane, Ethane, Ethylene



# Line 970GH Methane, Propane, Propylene



# Line 970GH Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 970IJ |
| No. of Shotpoints | 97 |

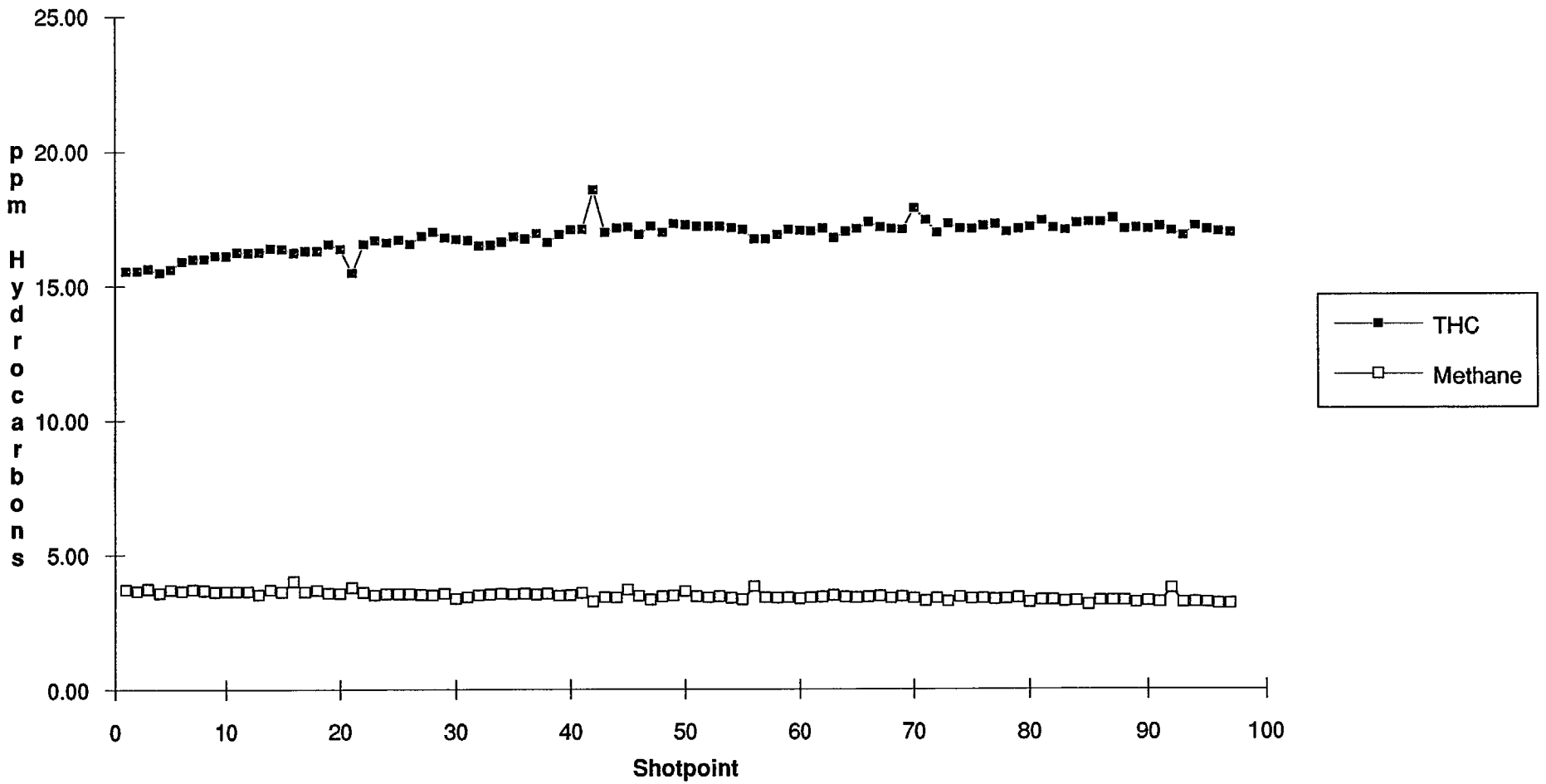
| | Shotpoint | Date | Time | Latitude | | Longitude | |
|---|---|---|---|---|---|---|---|
| Start | 1 | 22-Oct-90 | 17:13:35 | 19 | 29.880 | 116 | 25.853 |
| End | 98 | 22-Oct-90 | 20:41:28 | 19 | 40.417 | 116 | 34.232 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 16.810 | 3.453 | 0.016 | 0.099 | 0.016 | 0.036 | 0.003 | 0.000 | 0.000 | 0.099 | 0.000 | 0.000 | 0.987 |
| Std. Dev. | 0.525 | 0.164 | 0.005 | 0.012 | 0.012 | 0.026 | 0.011 | 0.000 | 0.000 | 0.028 | 0.000 | 0.000 | 0.531 |
| Minimum | 15.465 | 3.135 | 0.000 | 0.075 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.084 |
| Maximum | 18.531 | 3.999 | 0.032 | 0.140 | 0.064 | 0.131 | 0.060 | 0.000 | 0.000 | 0.128 | 0.000 | 0.000 | 3.351 |

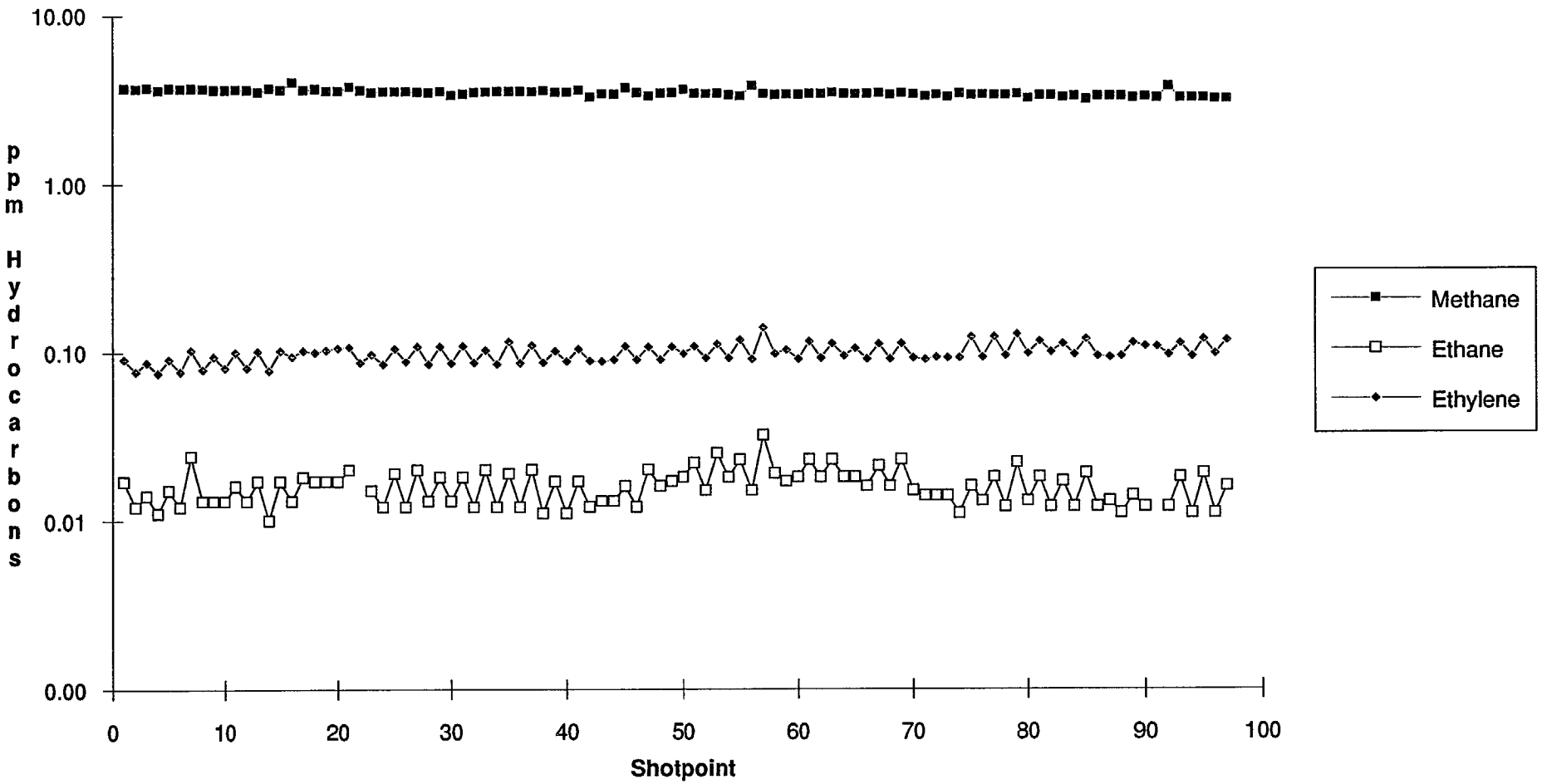
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 52.948 | 24.499 | 60.030 | 73.019 | 12.990 |
| Std. Dev. | 0.214 | 0.229 | 14.240 | 15.032 | 1.490 |
| Minimum | 52.350 | 23.850 | 42.942 | 54.942 | 9.000 |
| Maximum | 53.170 | 24.870 | 97.512 | 109.512 | 16.000 |

Notes No anomalies.

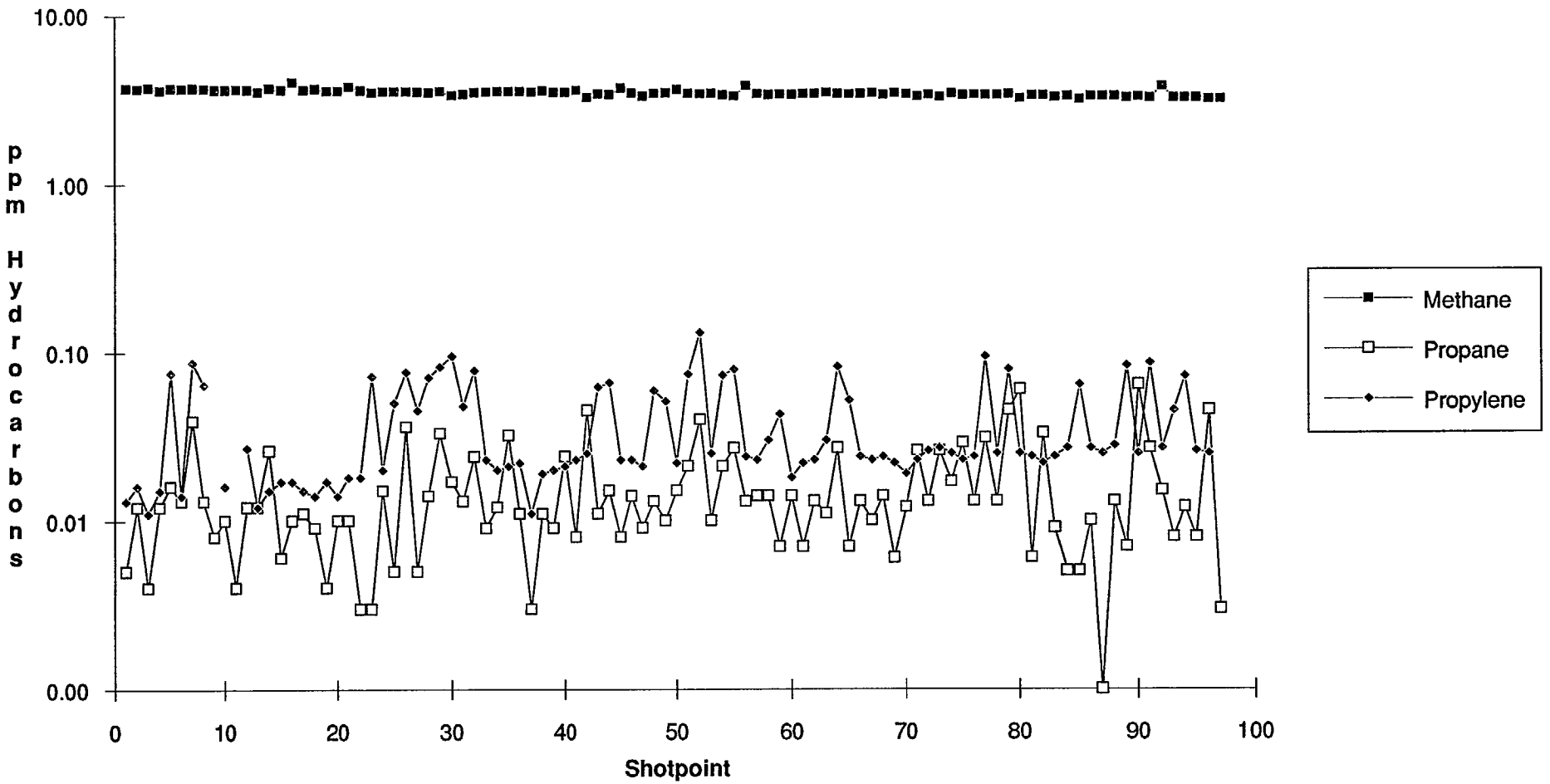
# Line 970lJ THC, Methane



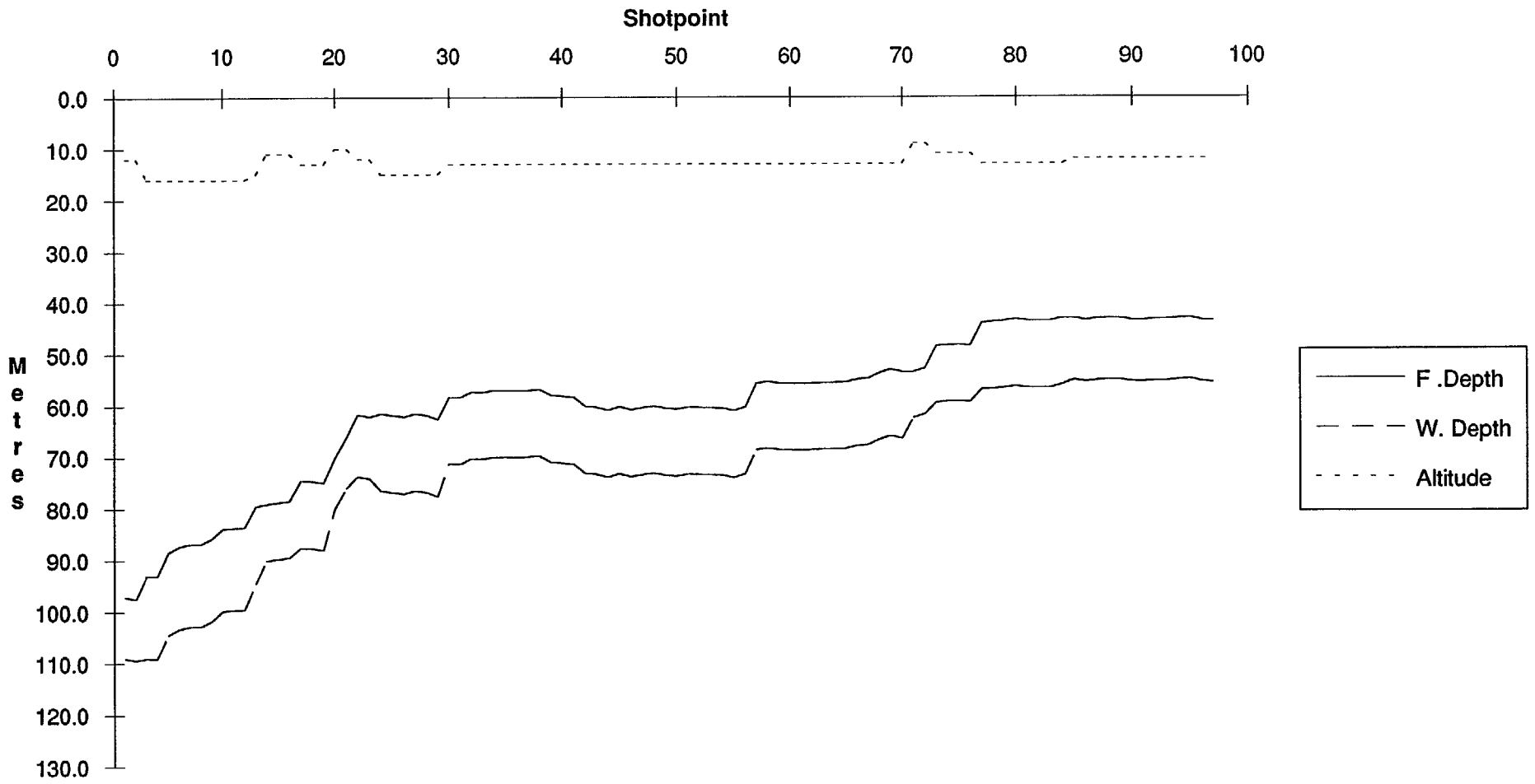
# Line 970IJ Methane, Ethane, Ethylene



# Line 970lJ Methane, Propane, Propylene



# Line 970IJ Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 970KL |
| No. of Shotpoints | 169 |

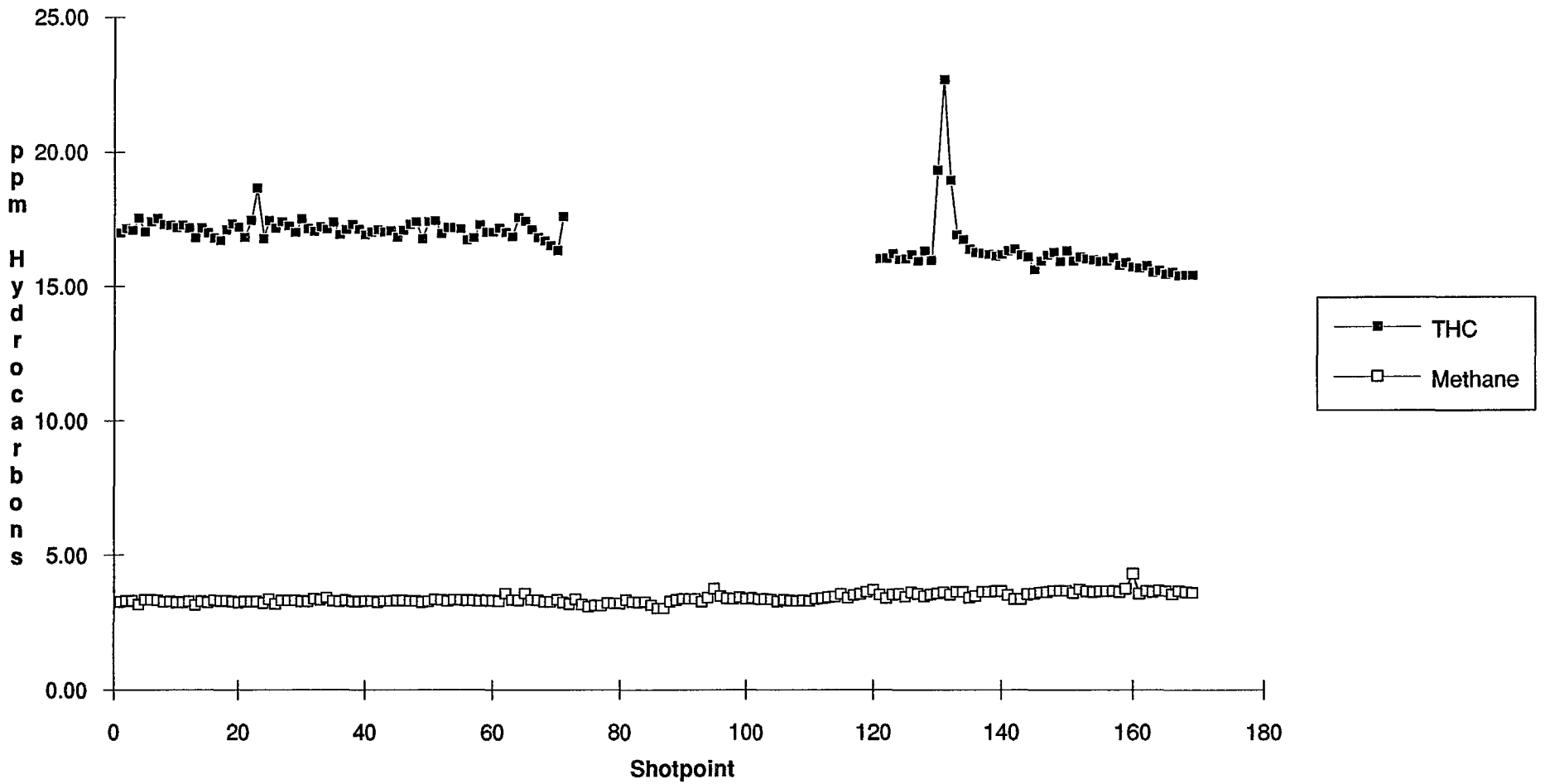
| | Shotpoint | Date | Time | Latitude | Longitude |
|---|---|---|---|---|---|
| Start | 1 | 23-Oct-90 | 10:45:41 | 19 31.1 | 116 23.3 |
| End | 169 | 23-Oct-90 | 16:21:35 | 19 41.7 | 116 31.6 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 16.772 | 3.391 | 0.016 | 0.097 | 0.024 | 0.059 | 0.008 | 0.000 | 0.000 | 0.085 | 0.014 | 0.000 | 1.388 |
| Std. Dev. | 0.891 | 0.178 | 0.004 | 0.012 | 0.019 | 0.042 | 0.020 | 0.000 | 0.000 | 0.038 | 0.036 | 0.000 | 0.935 |
| Minimum | 15.392 | 3.009 | 0.000 | 0.072 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.239 |
| Maximum | 22.659 | 4.295 | 0.031 | 0.141 | 0.083 | 0.156 | 0.098 | 0.000 | 0.000 | 0.134 | 0.435 | 0.000 | 5.521 |

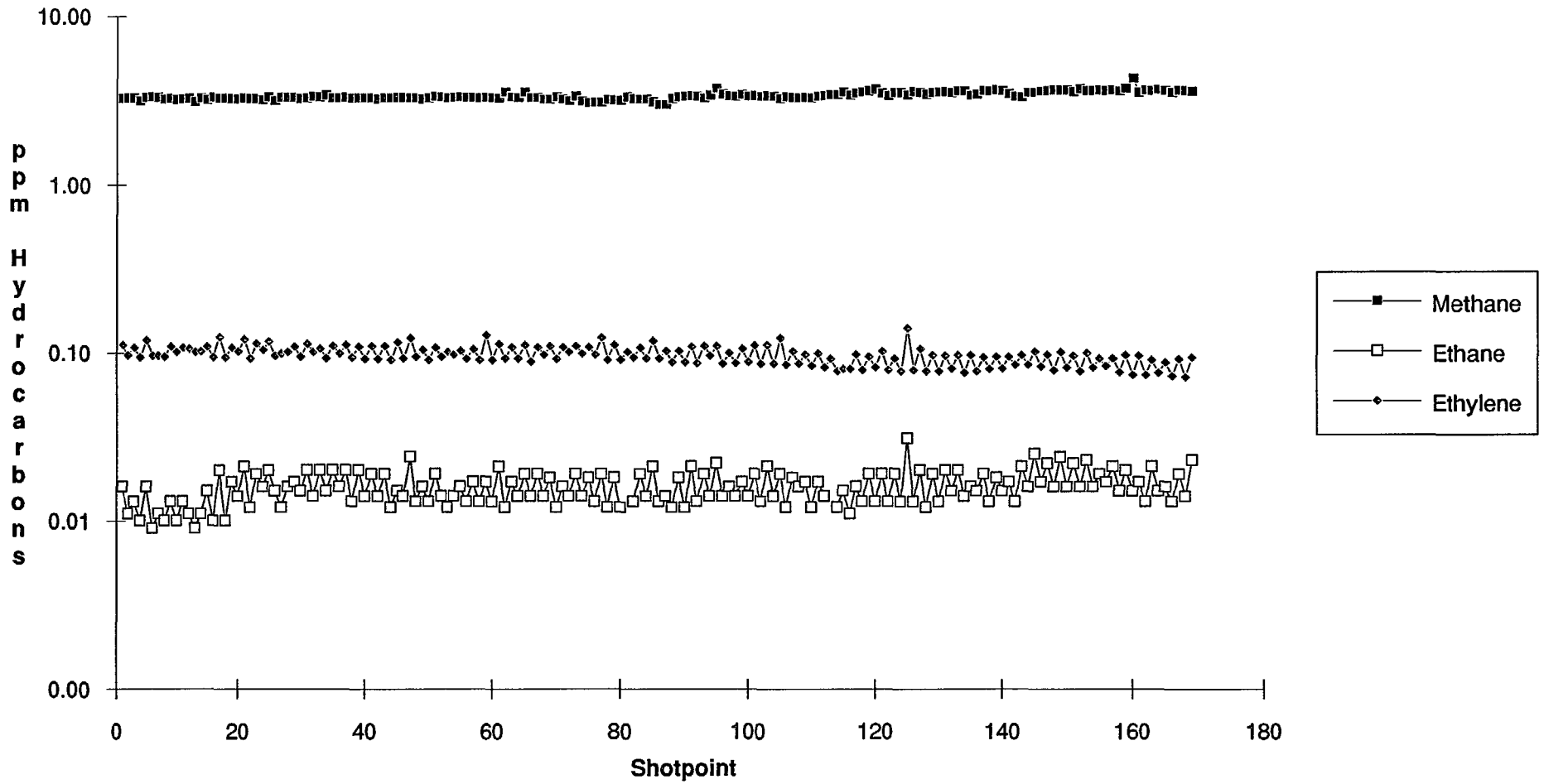
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 52.928 | 24.549 | 58.798 | 73.769 | 14.970 |
| Std. Dev. | 0.265 | 0.276 | 16.768 | 16.806 | 1.791 |
| Minimum | 52.440 | 23.980 | 42.432 | 58.432 | 12.000 |
| Maximum | 53.300 | 25.010 | 93.432 | 113.126 | 20.000 |

Notes No anomalies. Slight increase in THC near shotpoint 135.

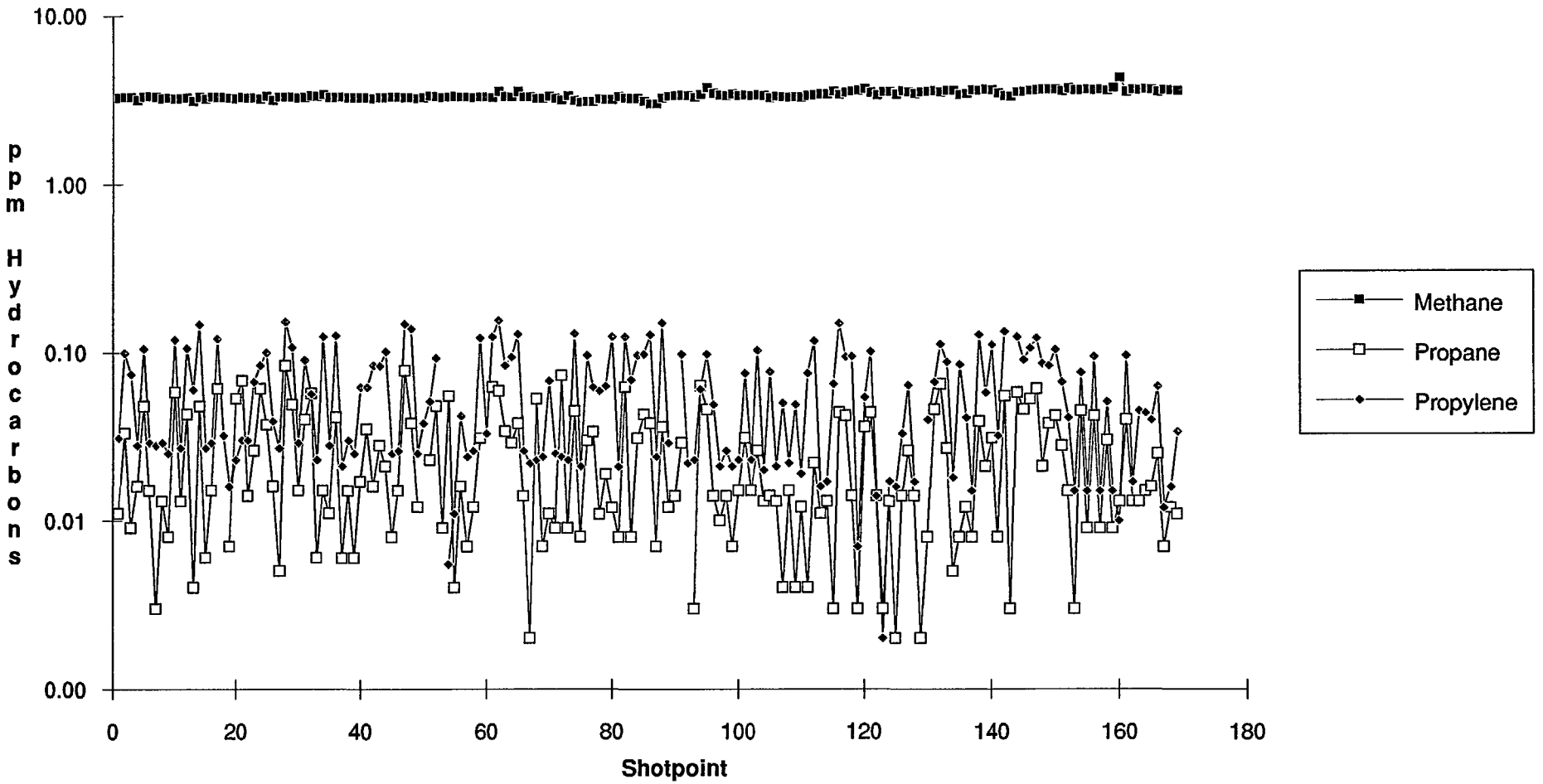
# Line 970KL THC, Methane



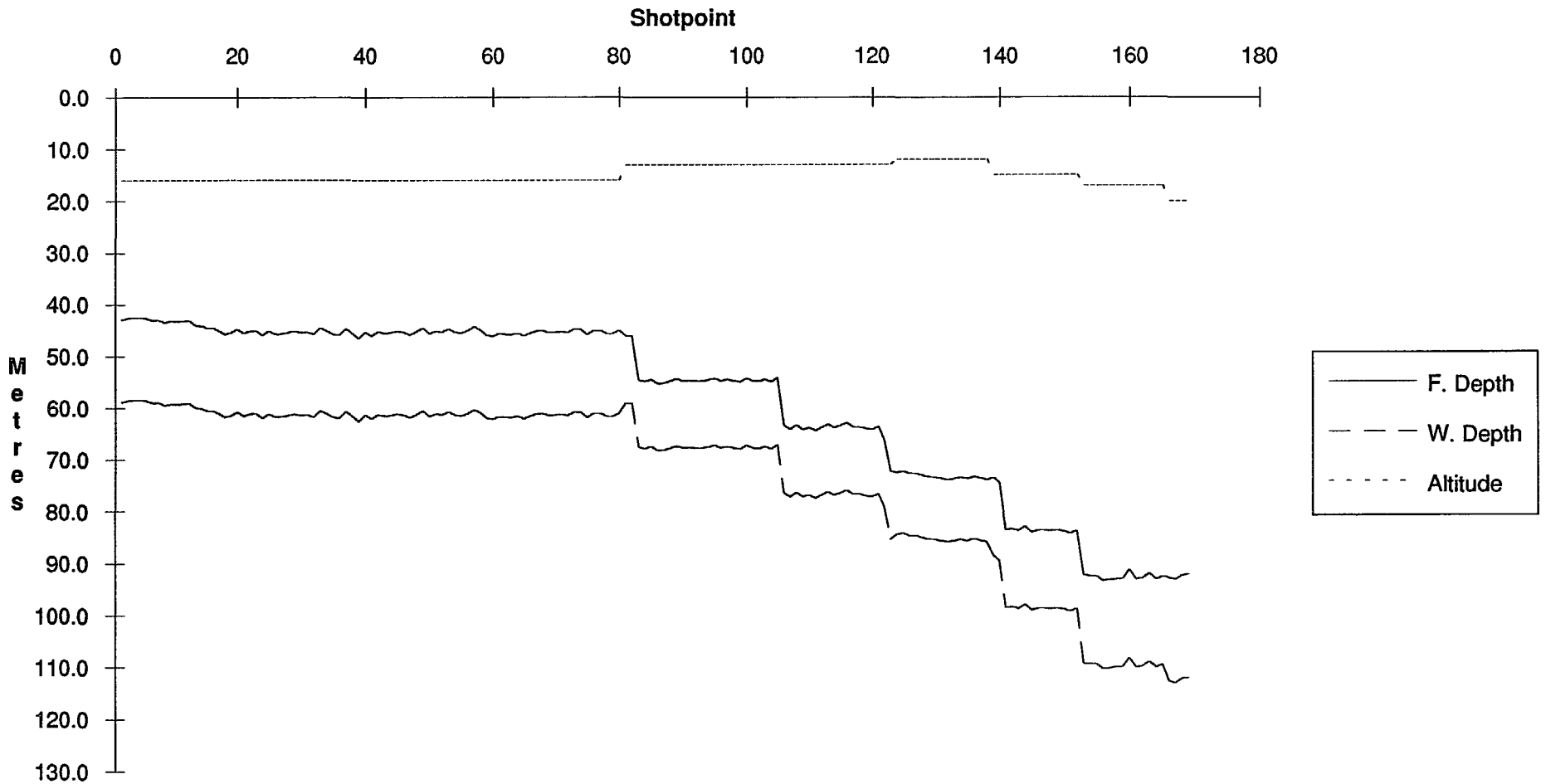
# Line 970KL Methane, Ethane, Ethylene



# Line 970KL Methane, Propane, Propylene



# Line 970KL Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 970ON2 |
| No. of Shotpoints | 58 |

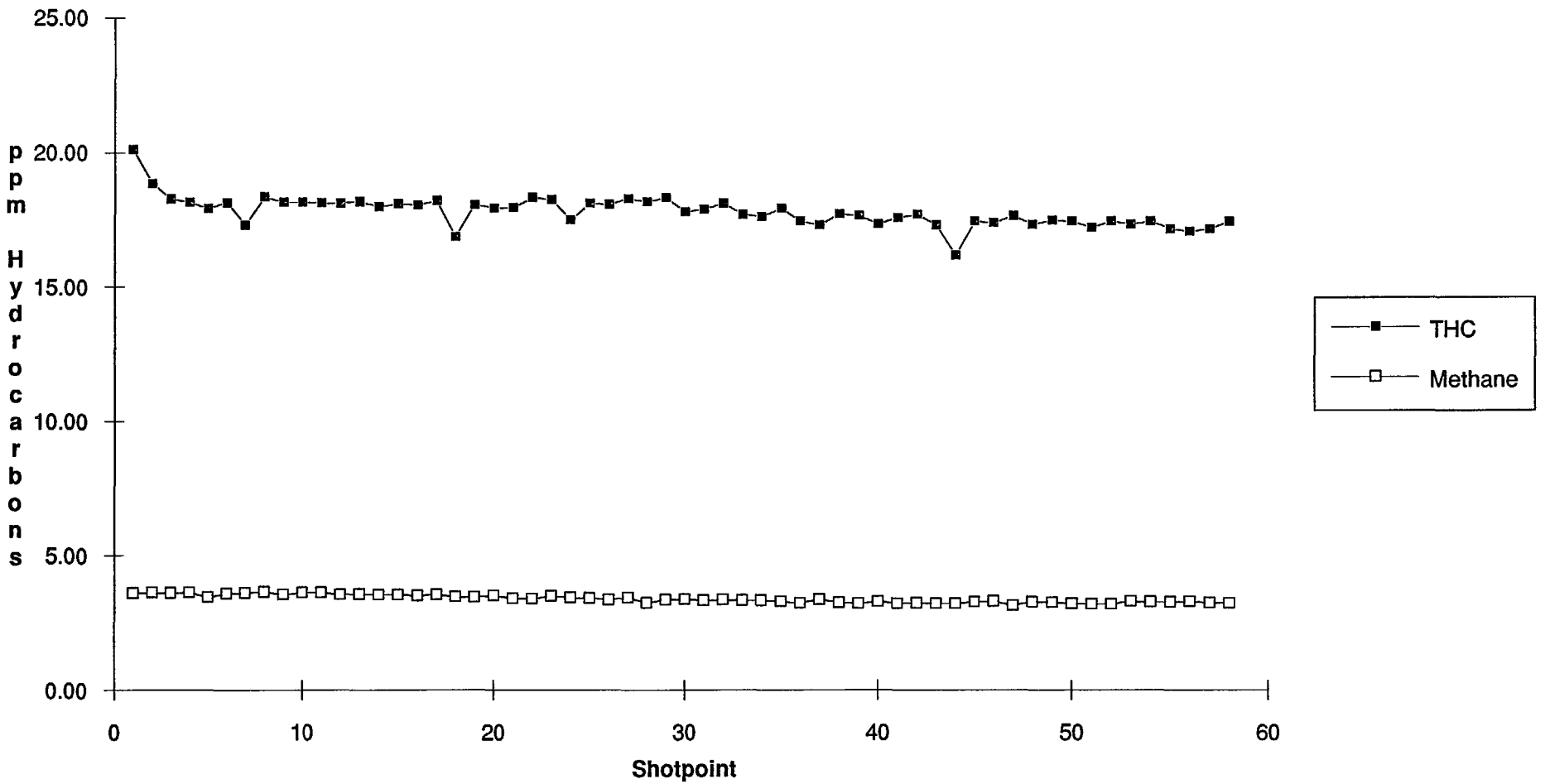
| | Shotpoint | Date | Time | Latitude | Longitude |
|---|---|---|---|---|---|
| Start | 1 | 23-Oct-90 | 08:43:00 | 19 34.8 | 116 24.4 |
| End | 58 | 23-Oct-90 | 10:36:58 | 19 42.1 | 116 29.8 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 17.790 | 3.383 | 0.014 | 0.100 | 0.018 | 0.041 | 0.000 | 0.000 | 0.000 | 0.116 | 0.034 | 0.000 | 0.912 |
| Std. Dev. | 0.555 | 0.147 | 0.003 | 0.010 | 0.012 | 0.026 | 0.000 | 0.000 | 0.000 | 0.030 | 0.018 | 0.000 | 0.370 |
| Minimum | 16.164 | 3.125 | 0.010 | 0.084 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.353 |
| Maximum | 20.095 | 3.641 | 0.022 | 0.128 | 0.055 | 0.111 | 0.000 | 0.000 | 0.000 | 0.143 | 0.069 | 0.000 | 2.017 |

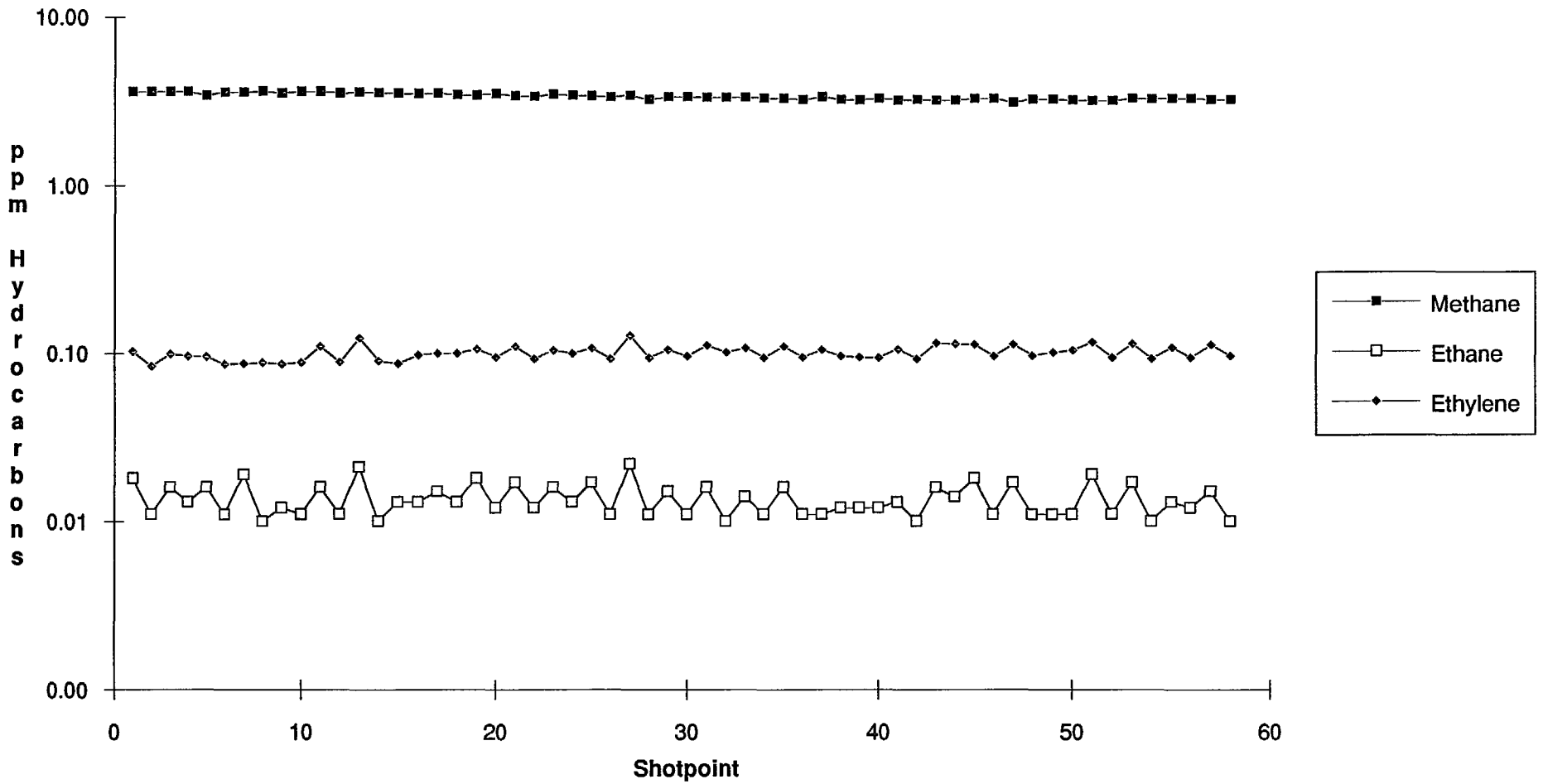
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 53.599 | 25.119 | 50.294 | 69.587 | 19.293 |
| Std. Dev. | 0.128 | 0.170 | 4.507 | 6.835 | 2.478 |
| Minimum | 53.320 | 24.710 | 43.350 | 60.350 | 14.000 |
| Maximum | 53.730 | 25.420 | 57.324 | 80.324 | 23.000 |

Notes

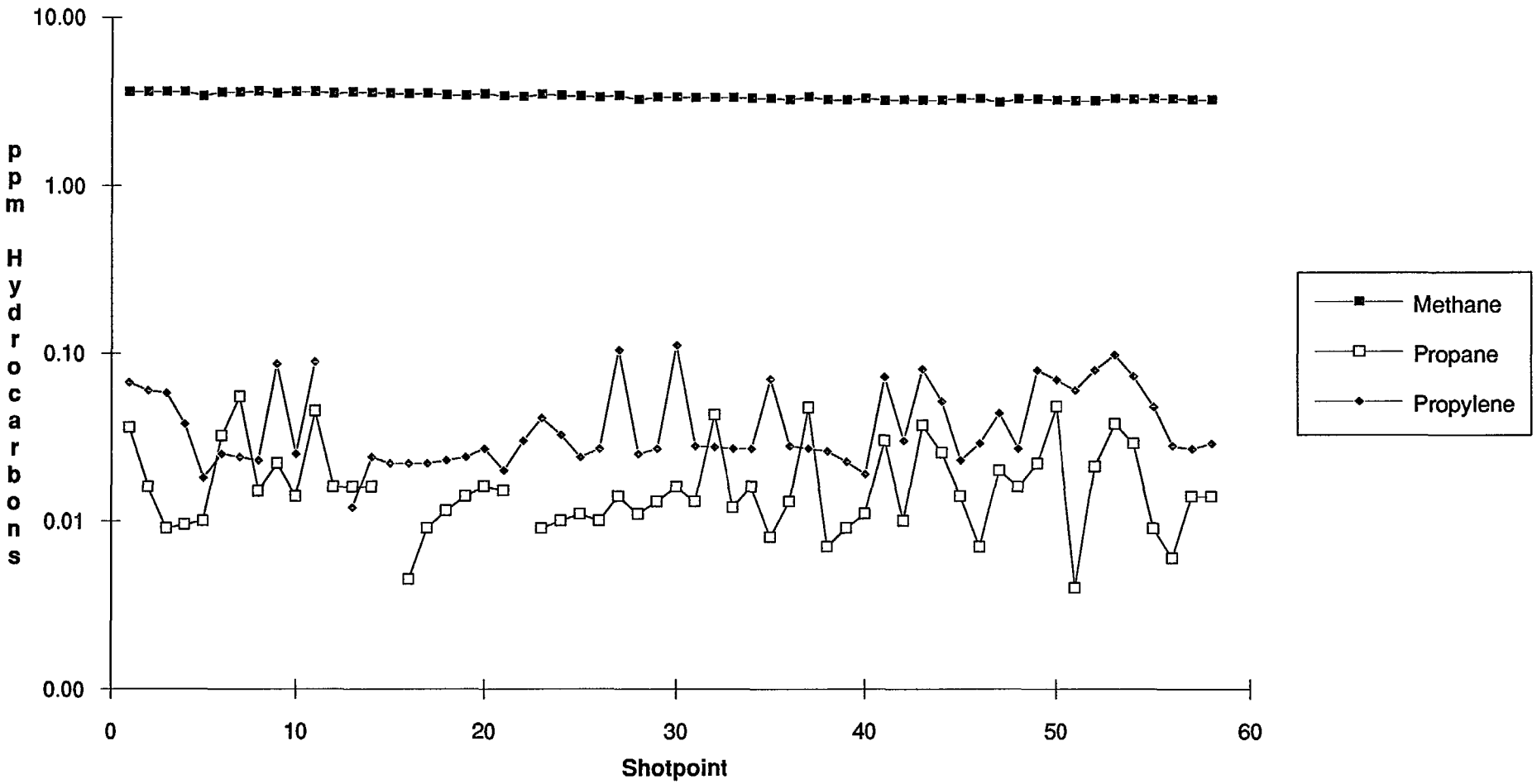
# Line 970ON2 THC, Methane



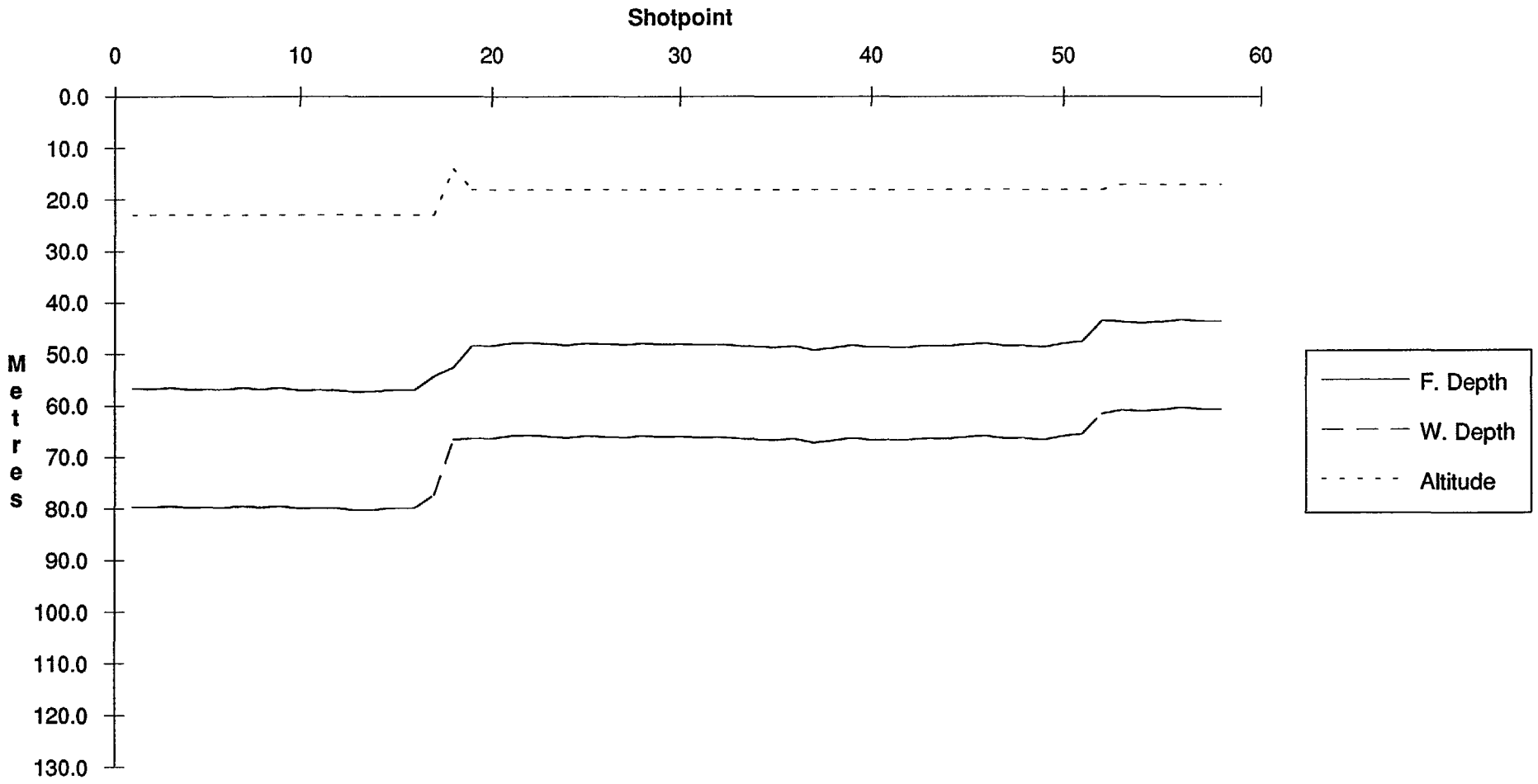
# Line 970ON2 Methane, Ethane, Ethylene



## Line 970ON2 Methane, Propane, Propylene



# Line 970ON2 Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 970OP |
| No. of Shotpoints | 91 |

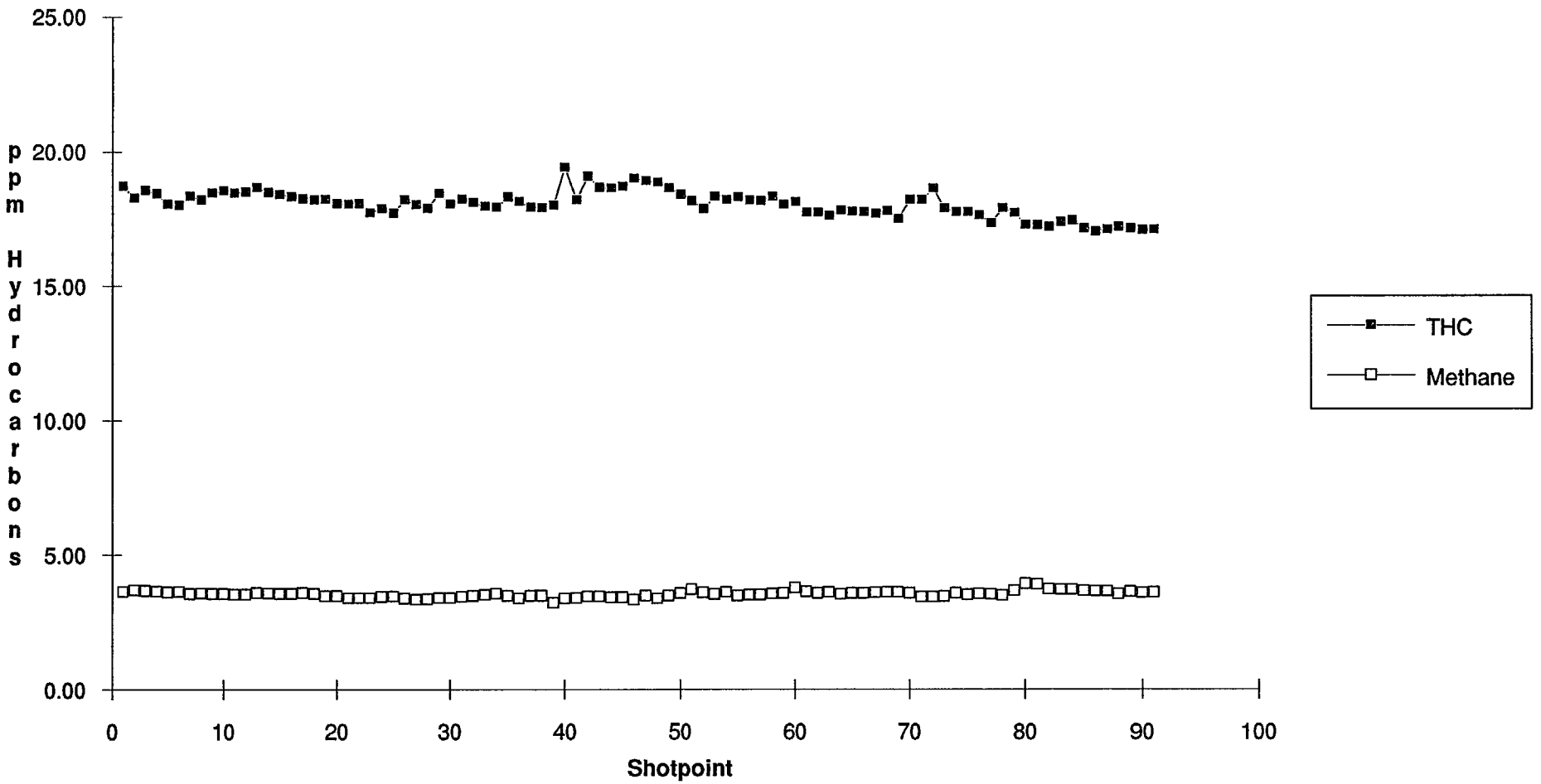
| | Shotpoint | Date | Time | Latitude | | Longitude | |
|---|---|---|---|---|---|---|---|
| Start | 2 | 22-Oct-90 | 04:12:35 | 19 | 45.000 | 116 | 27.544 |
| End | 92 | 22-Oct-90 | 07:12:37 | 19 | 33.041 | 116 | 20.454 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 18.050 | 3.529 | 0.014 | 0.099 | 0.023 | 0.058 | 0.004 | 0.000 | 0.000 | 0.111 | 0.029 | 0.000 | 1.146 |
| Std. Dev. | 0.494 | 0.121 | 0.003 | 0.010 | 0.018 | 0.045 | 0.014 | 0.000 | 0.000 | 0.034 | 0.017 | 0.000 | 0.655 |
| Minimum | 17.020 | 3.200 | 0.010 | 0.080 | 0.005 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.434 |
| Maximum | 19.400 | 3.920 | 0.032 | 0.120 | 0.083 | 0.213 | 0.089 | 0.000 | 0.000 | 0.154 | 0.065 | 0.000 | 3.144 |

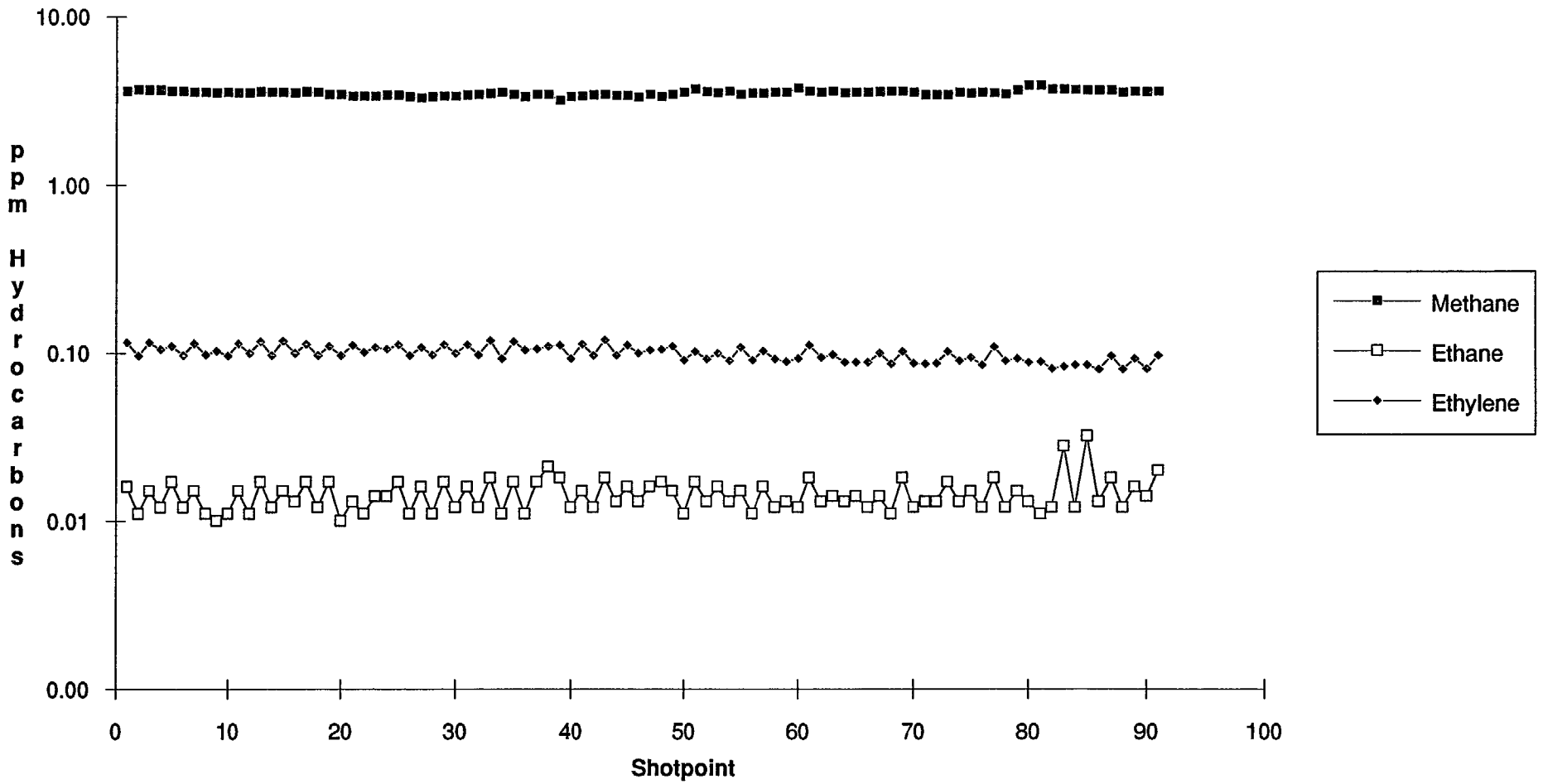
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 55.369 | 26.664 | 58.869 | 72.033 | 13.165 |
| Std. Dev. | 0.238 | 0.224 | 14.077 | 14.393 | 1.186 |
| Minimum | 54.710 | 26.100 | 47.430 | 60.430 | 11.000 |
| Maximum | 55.810 | 27.160 | 89.760 | 103.046 | 16.000 |

Notes No anomalies.

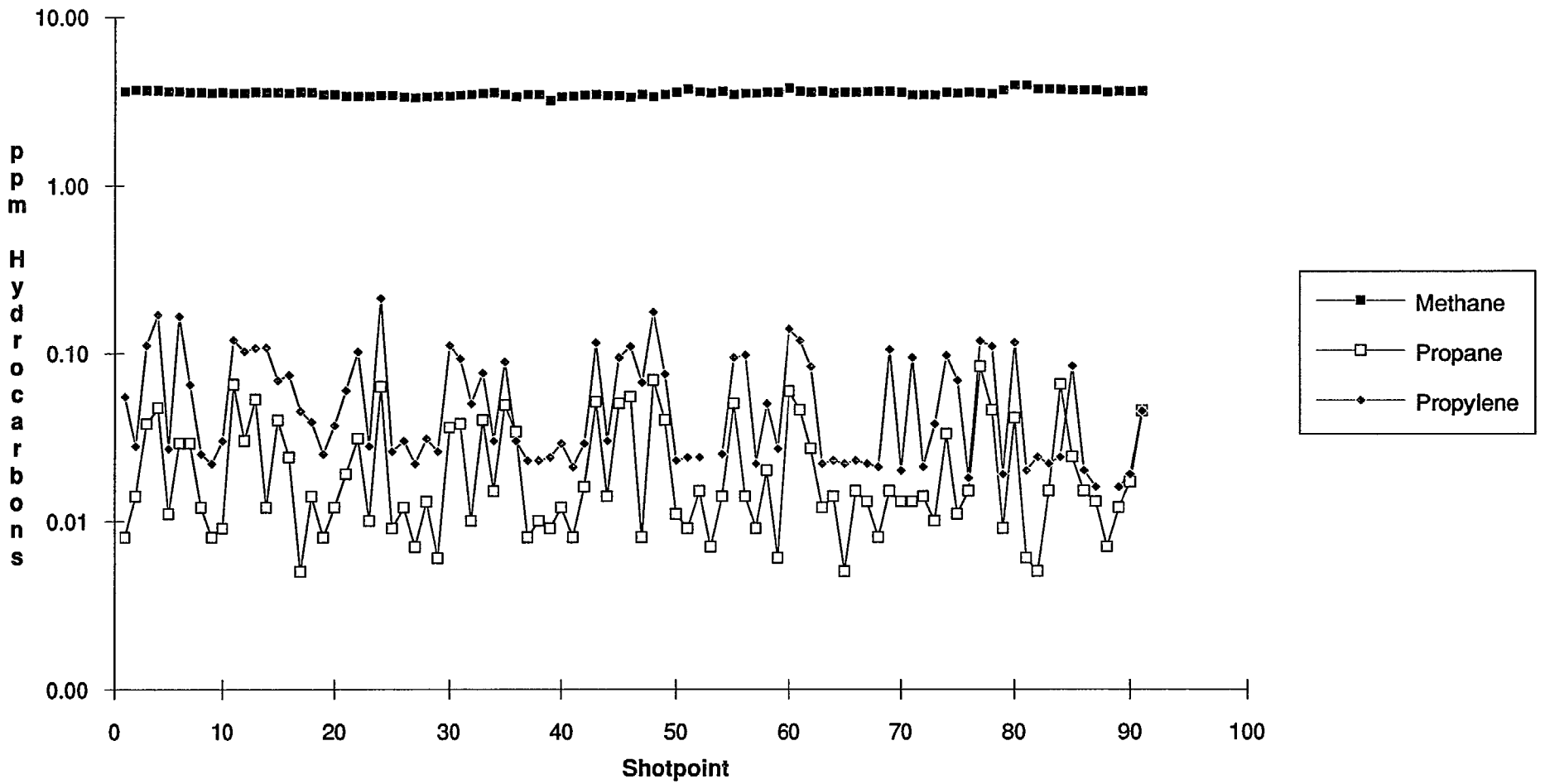
# Line 970OP THC, Methane



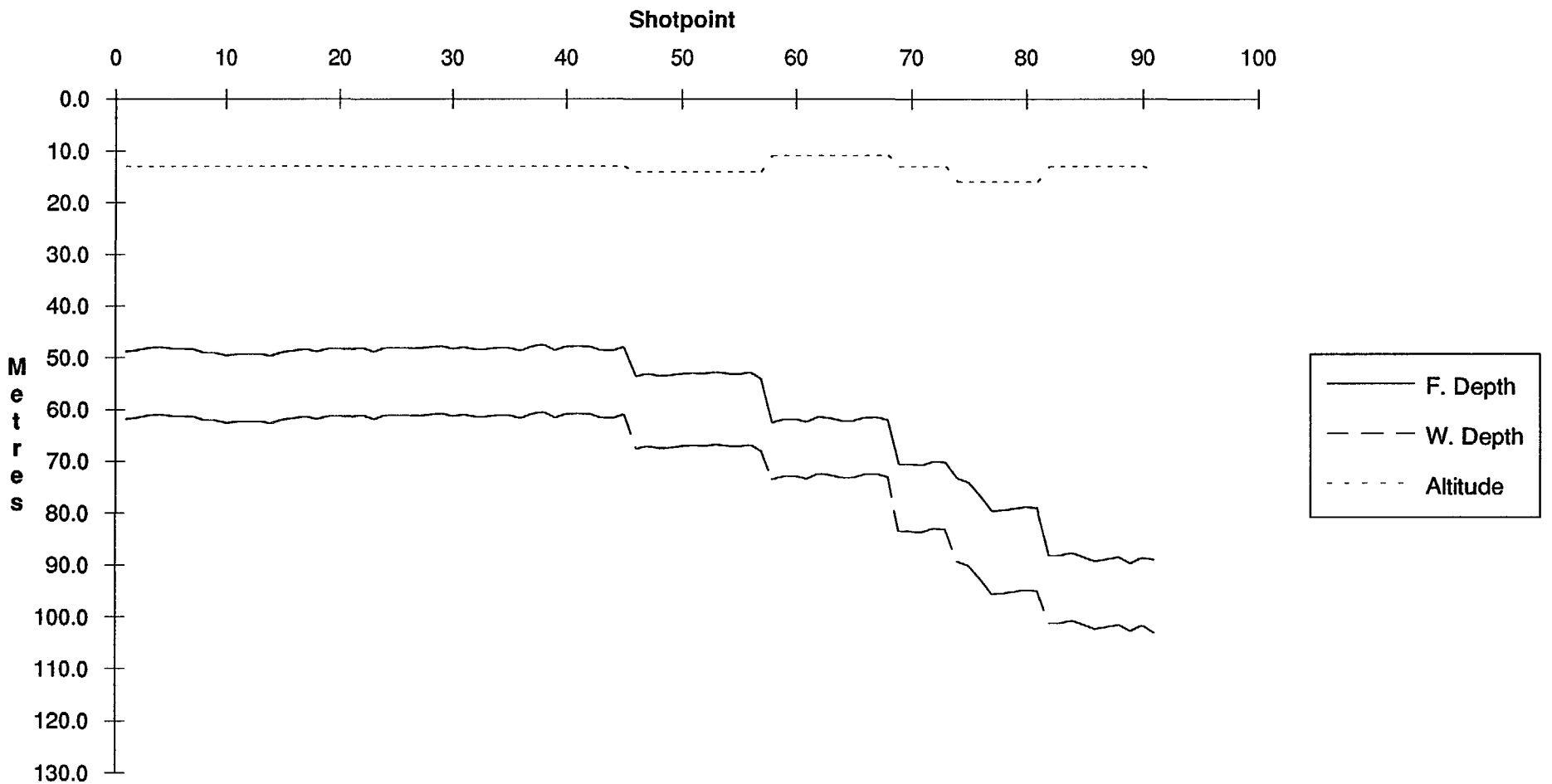
# Line 970OP Methane, Ethane, Ethylene



## Line 970OP Methane, Propane, Propylene



# Line 970OP Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 970QR |
| No. of Shotpoints | 80 |

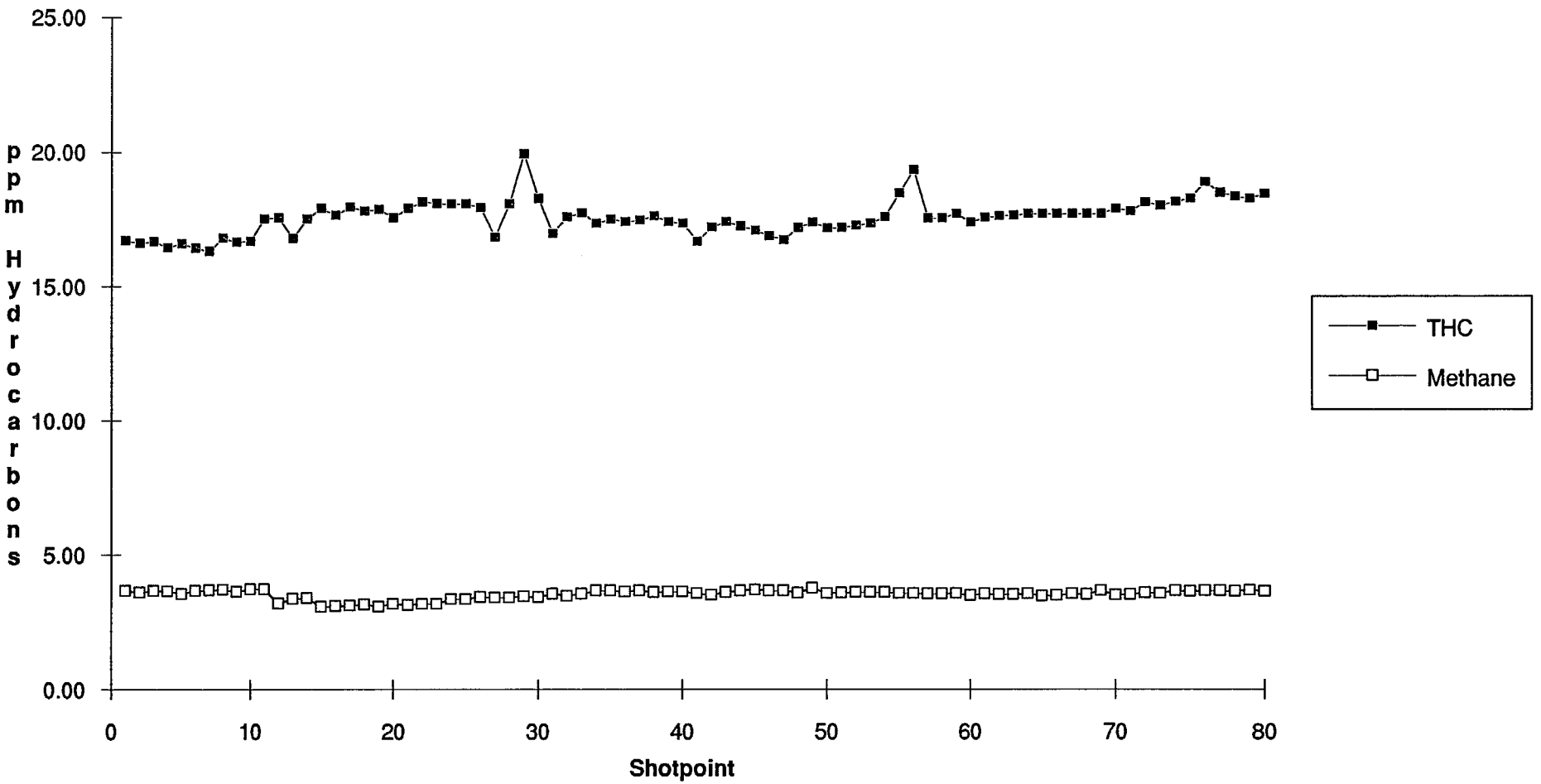
| | Shotpoint | Date | Time | Latitude | | Longitude | |
|---|---|---|---|---|---|---|---|
| Start | 3 | 23-Oct-90 | 01:30:33 | 19 | 34.762 | 116 | 19.078 |
| End | 82 | 23-Oct-90 | 04:08:35 | 19 | 44.826 | 116 | 27.212 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 17.566 | 3.522 | 0.016 | 0.098 | 0.021 | 0.043 | 0.008 | 0.000 | 0.000 | 0.095 | 0.028 | 0.000 | 1.255 |
| Std. Dev. | 0.644 | 0.173 | 0.003 | 0.011 | 0.015 | 0.025 | 0.018 | 0.000 | 0.000 | 0.029 | 0.013 | 0.000 | 0.760 |
| Minimum | 16.311 | 3.070 | 0.011 | 0.077 | 0.005 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.503 |
| Maximum | 19.921 | 3.766 | 0.026 | 0.137 | 0.090 | 0.099 | 0.077 | 0.000 | 0.000 | 0.131 | 0.053 | 0.000 | 3.735 |

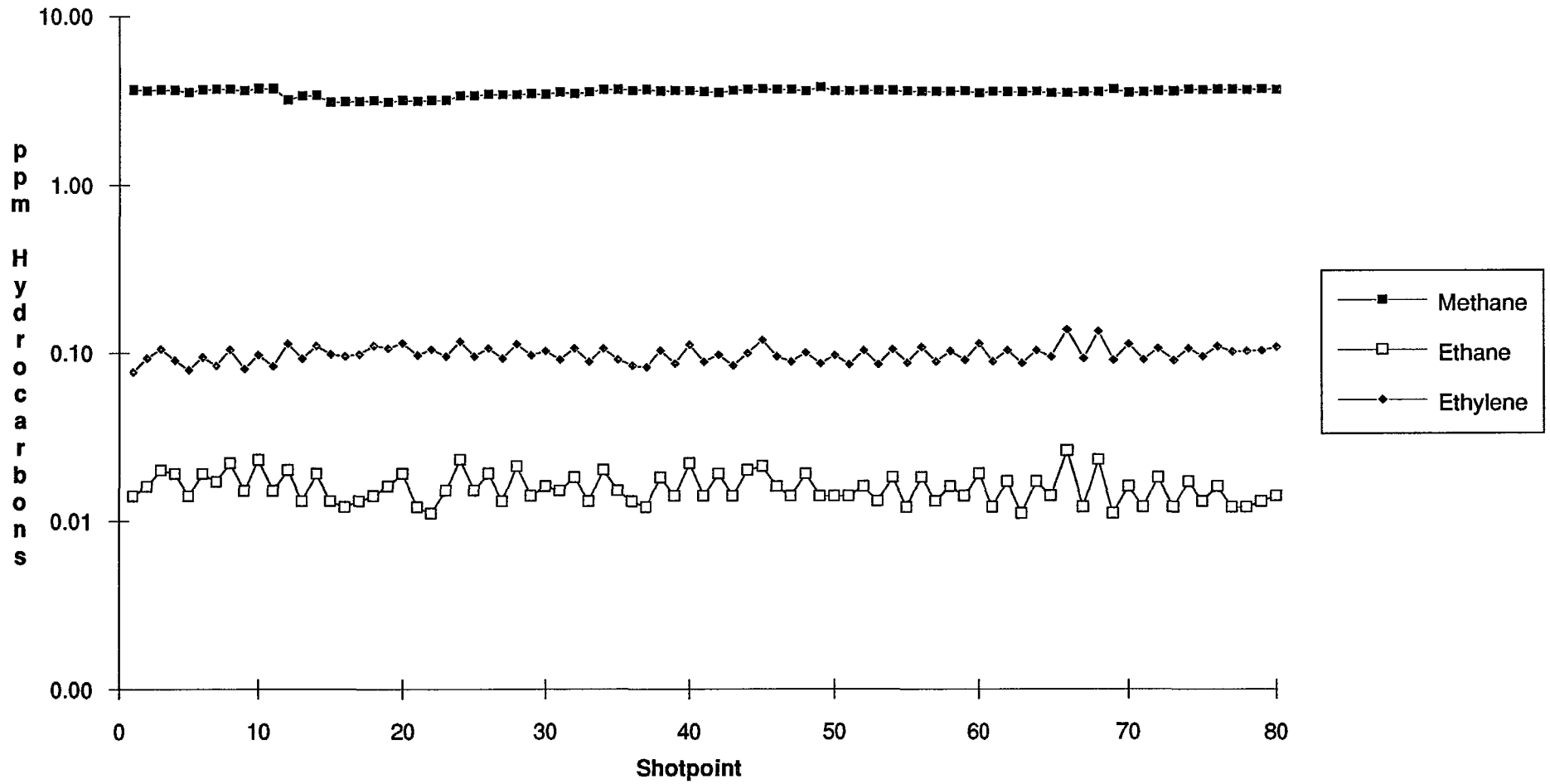
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 54.431 | 25.964 | 61.153 | 73.503 | 12.350 |
| Std. Dev. | 0.242 | 0.224 | 11.386 | 12.699 | 1.722 |
| Minimum | 53.890 | 25.310 | 48.858 | 60.858 | 11.000 |
| Maximum | 54.840 | 26.380 | 90.678 | 106.678 | 17.000 |

Notes No anomalies.

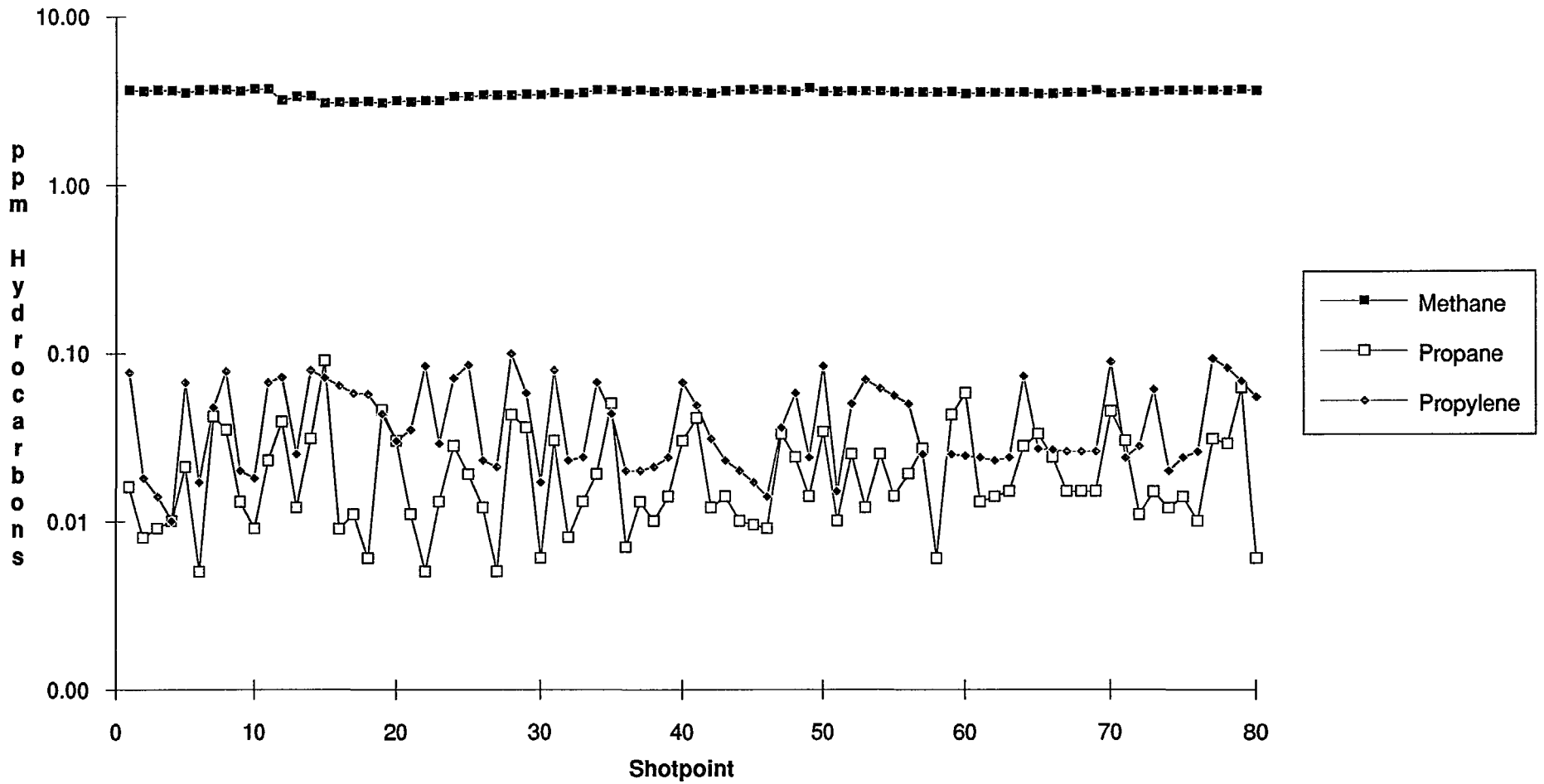
# Line 970QR THC, Methane



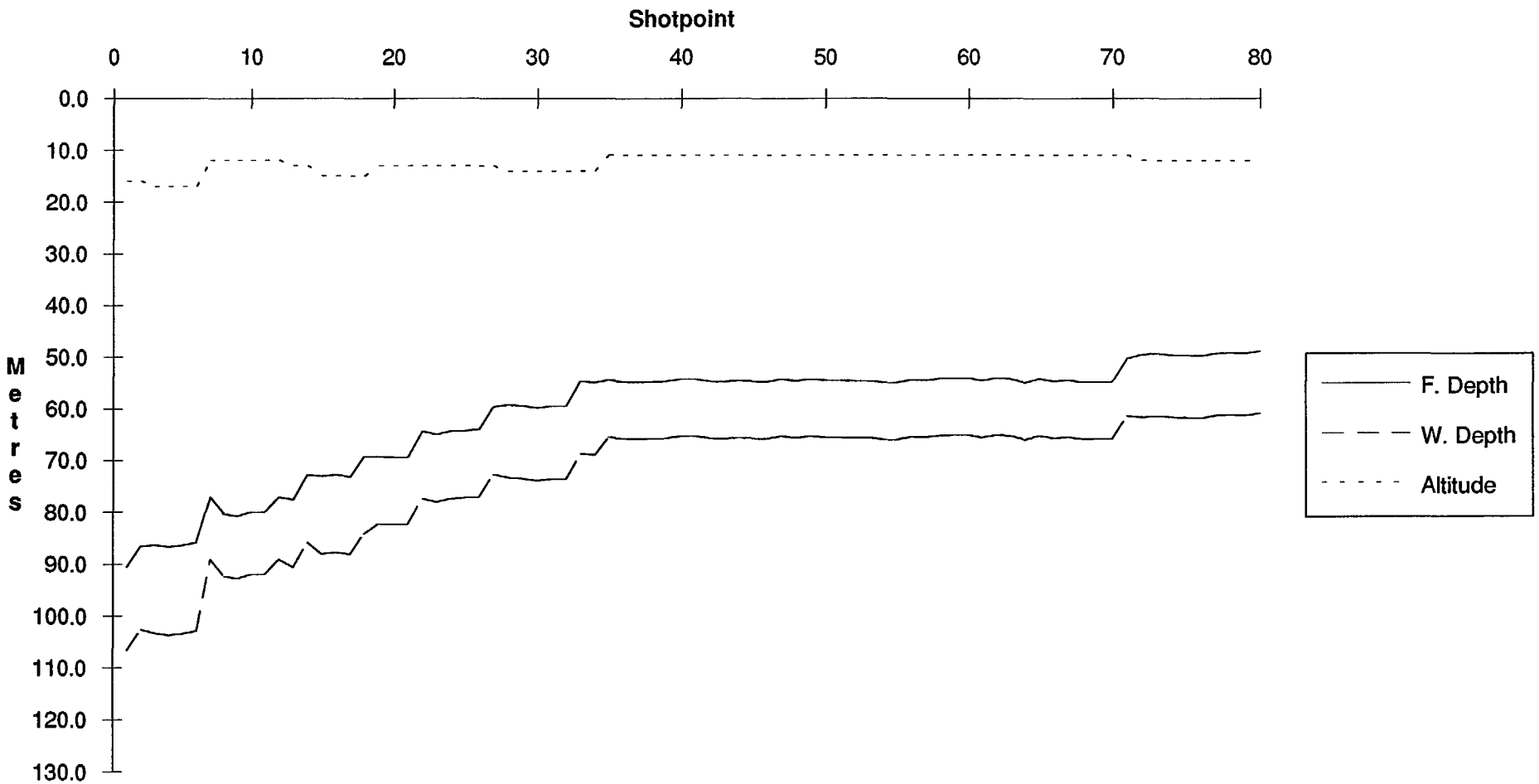
# Line 970QR Methane, Ethane, Ethylene



# Line 970QR Methane, Propane, Propylene



# Line 970QR Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 97001 |
| No. of Shotpoints | 76 |

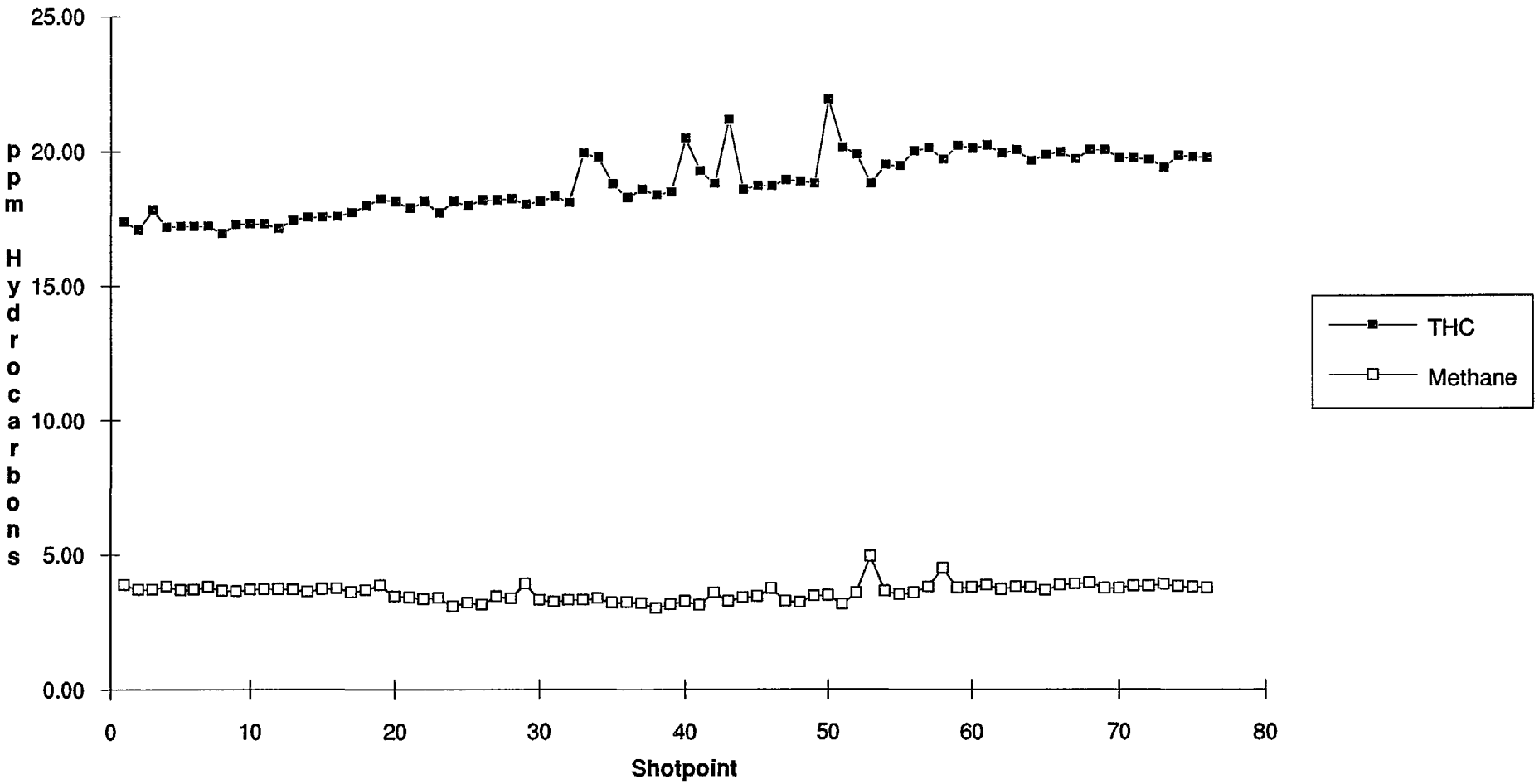
| | Shotpoint | Date | Time | Latitude | | Longitude | |
|---|---|---|---|---|---|---|---|
| Start | 1 | 24-Oct-90 | 00:19:17 | 19 | 31.599 | 116 | 30.392 |
| End | 76 | 24-Oct-90 | 02:49:18 | 19 | 39.667 | 116 | 20.800 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 18.790 | 3.597 | 0.014 | 0.098 | 0.029 | 0.040 | 0.009 | 0.000 | 0.000 | 0.107 | 0.000 | 0.000 | 1.412 |
| Std. Dev. | 1.128 | 0.312 | 0.002 | 0.008 | 0.023 | 0.022 | 0.018 | 0.000 | 0.000 | 0.035 | 0.000 | 0.000 | 0.759 |
| Minimum | 16.934 | 3.011 | 0.011 | 0.087 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.327 |
| Maximum | 21.928 | 4.926 | 0.021 | 0.120 | 0.095 | 0.096 | 0.082 | 0.004 | 0.000 | 0.151 | 0.000 | 0.000 | 3.672 |

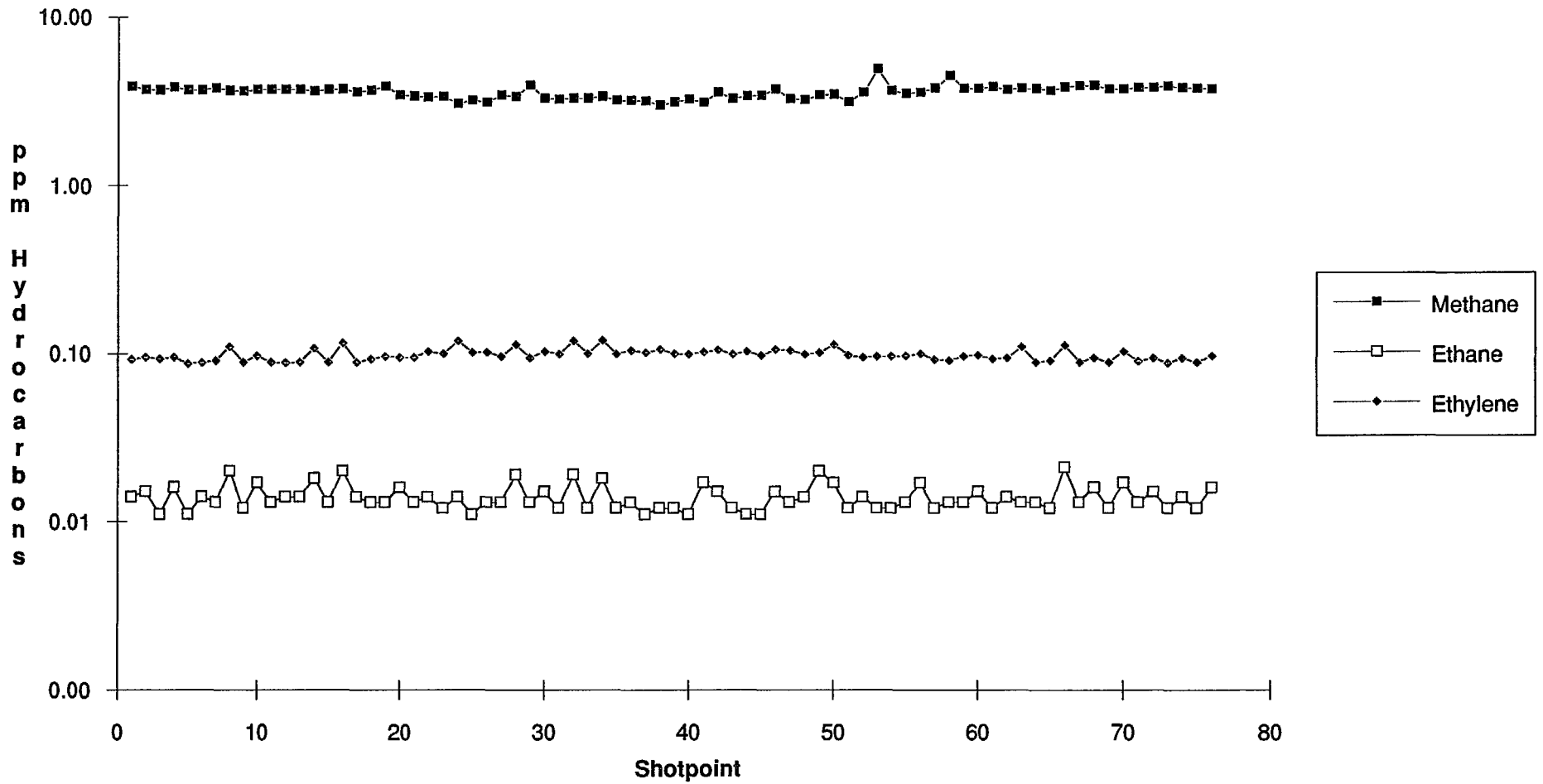
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 55.129 | 26.307 | 58.618 | 76.019 | 17.401 |
| Std. Dev. | 0.373 | 0.341 | 6.153 | 5.042 | 4.189 |
| Minimum | 54.290 | 25.370 | 44.166 | 60.166 | 12.000 |
| Maximum | 55.470 | 26.750 | 67.626 | 83.126 | 24.000 |

Notes No anomalies.

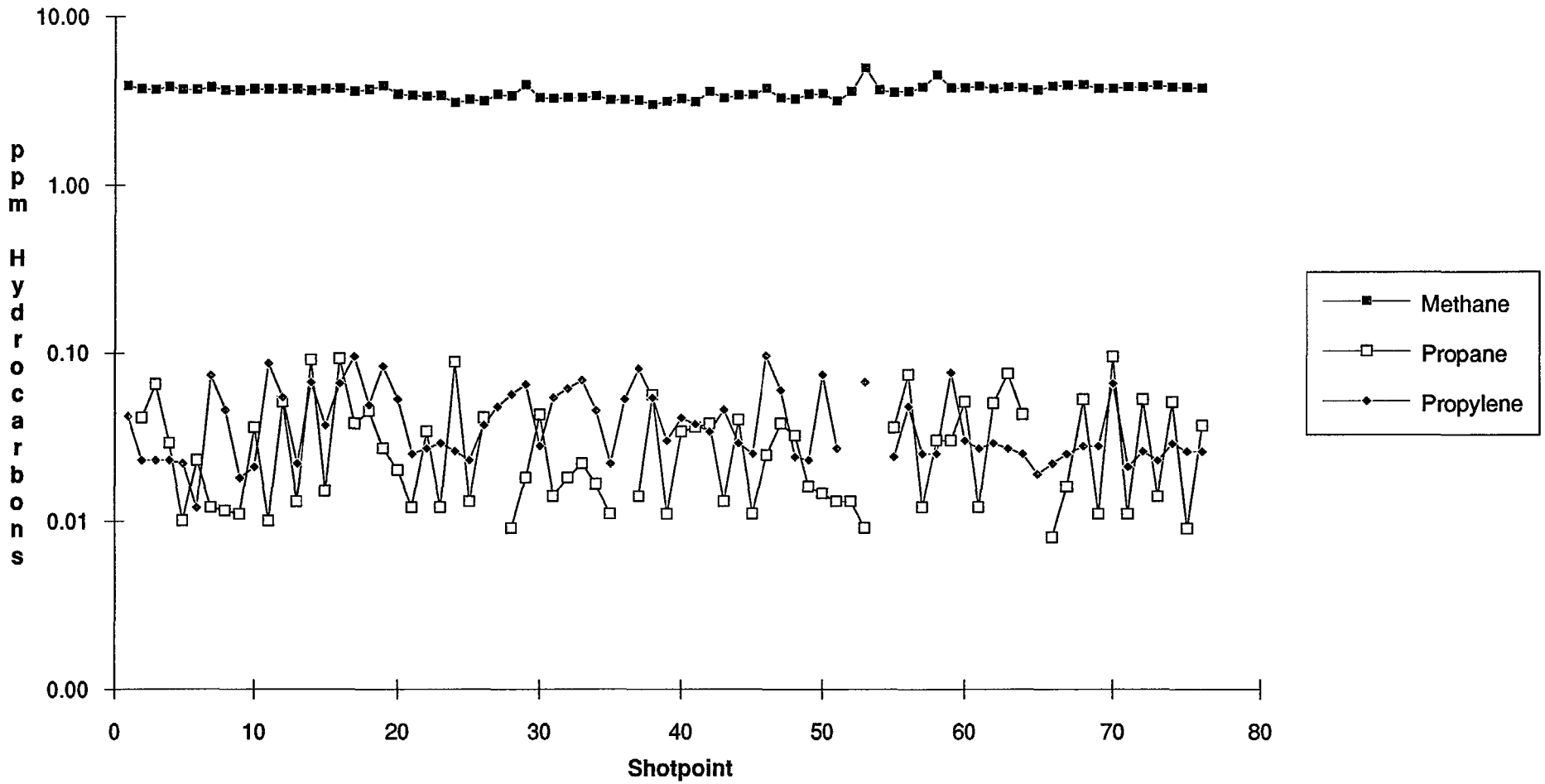
# Line 97001 THC, Methane



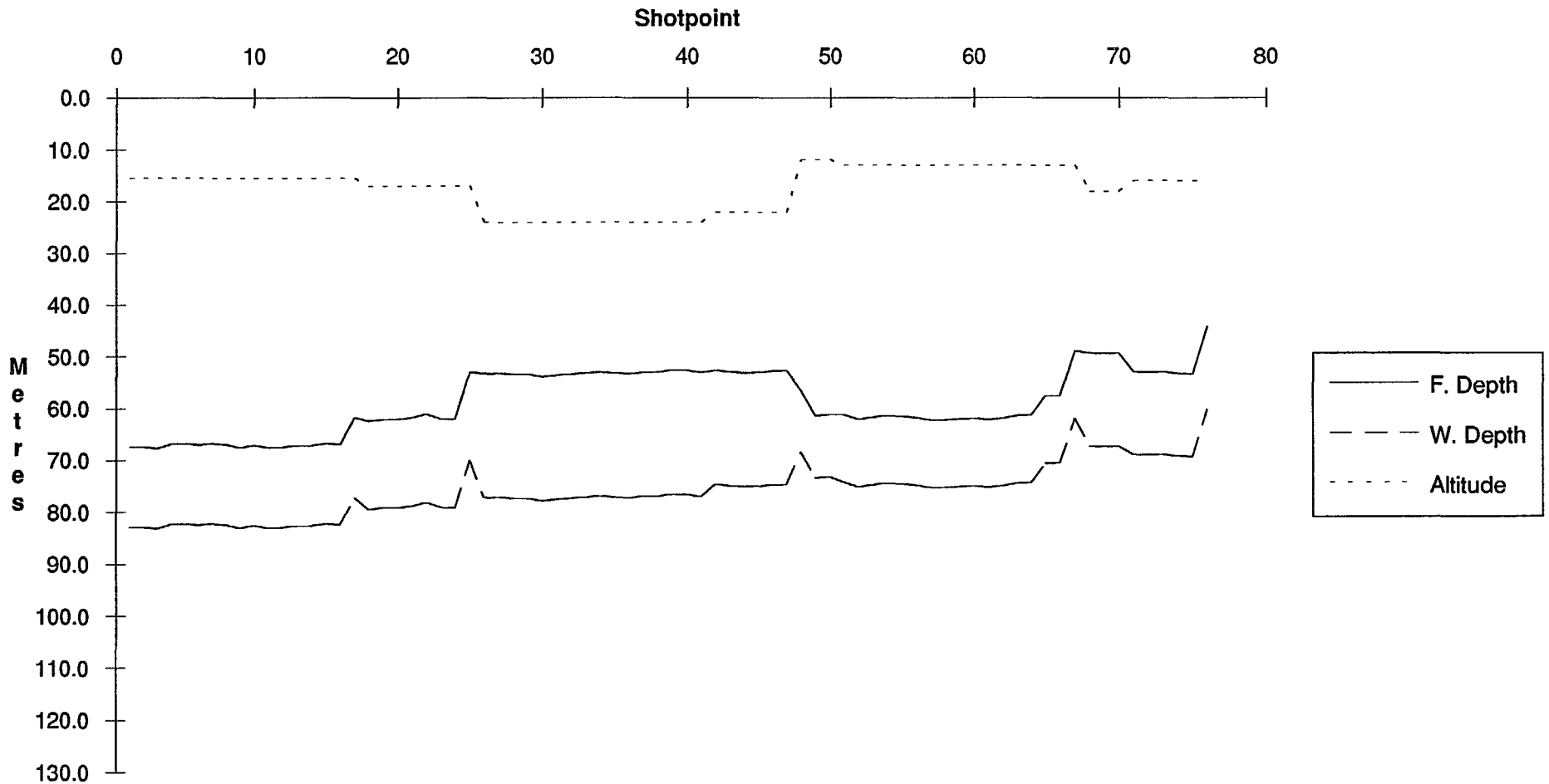
# Line 97001 Methane, Ethane, Ethylene



# Line 97001 Methane, Propane, Propylene



# Line 97001 Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 97002 |
| No. of Shotpoints | 97 |

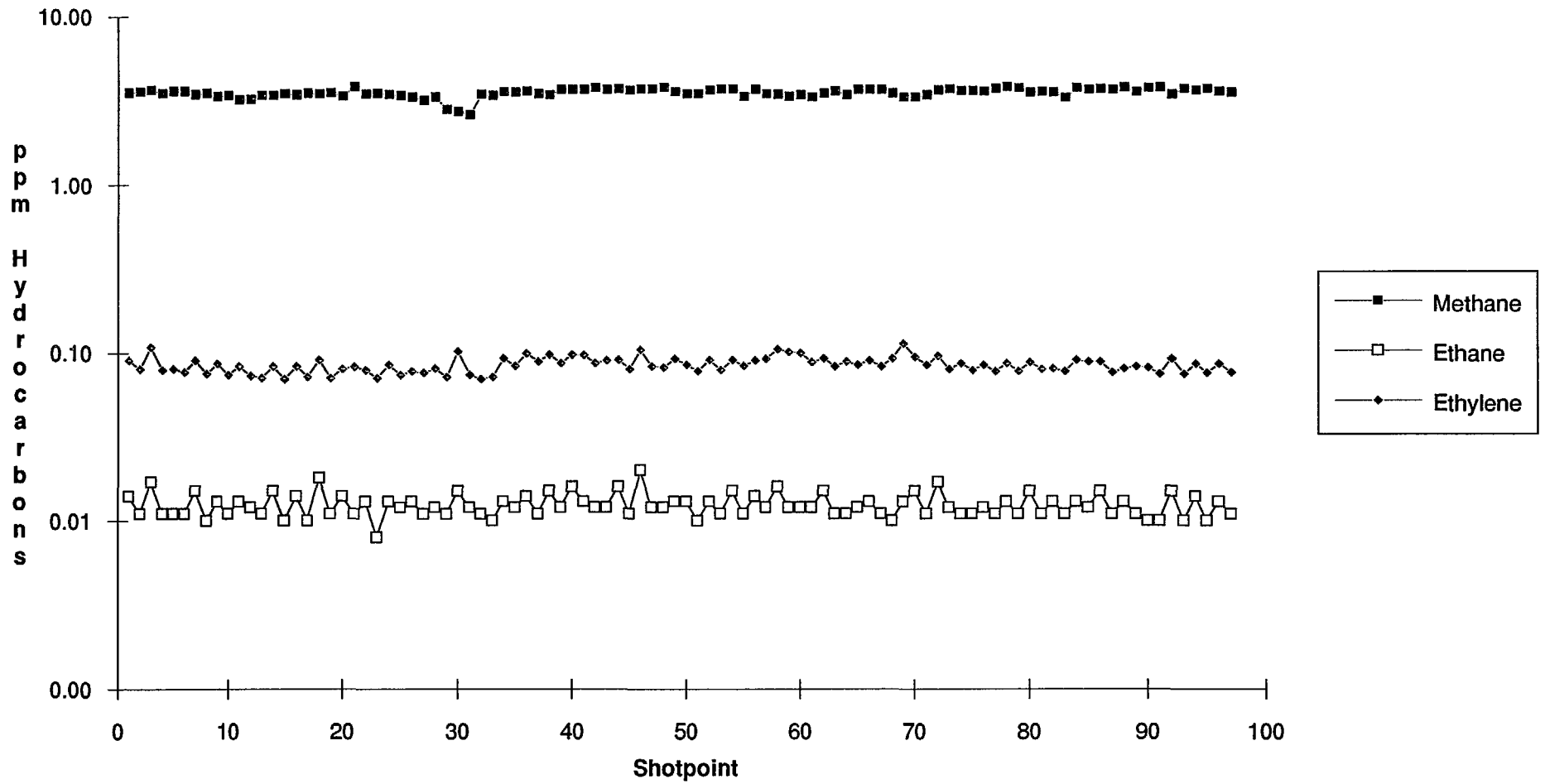
| | Shotpoint | Date | Time | Latitude | | Longitude | |
|---|---|---|---|---|---|---|---|
| Start | 3 | 24-Oct-90 | 04:13:13 | 19 | 37.251 | 116 | 21.863 |
| End | 99 | 24-Oct-90 | 07:31:36 | 19 | 29.736 | 116 | 36.904 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 20.748 | 3.536 | 0.012 | 0.085 | 0.022 | 0.027 | 0.007 | 0.001 | 0.000 | 0.113 | 0.137 | 0.000 | 1.172 |
| Std. Dev. | 0.675 | 0.209 | 0.002 | 0.009 | 0.020 | 0.021 | 0.018 | 0.007 | 0.000 | 0.141 | 0.411 | 0.003 | 0.845 |
| Minimum | 19.653 | 2.628 | 0.008 | 0.070 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.294 |
| Maximum | 23.856 | 3.833 | 0.020 | 0.114 | 0.089 | 0.098 | 0.075 | 0.071 | 0.000 | 1.450 | 4.105 | 0.028 | 4.224 |

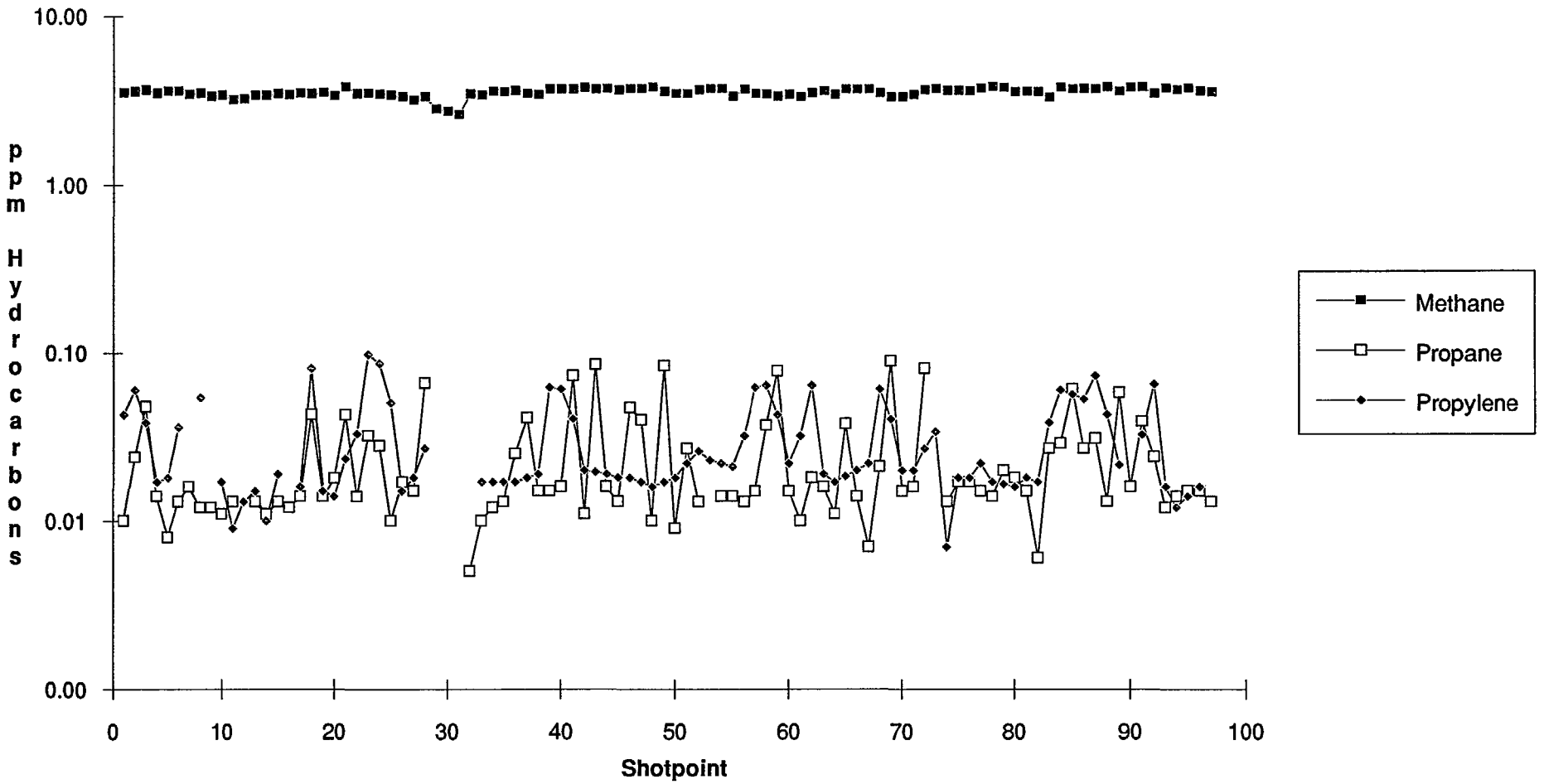
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 55.868 | 26.903 | 59.985 | 77.398 | 17.412 |
| Std. Dev. | 0.183 | 0.212 | 3.150 | 2.264 | 3.165 |
| Minimum | 55.520 | 26.400 | 55.182 | 71.182 | 12.000 |
| Maximum | 56.270 | 27.400 | 66.402 | 89.402 | 23.000 |

Notes No anomalies.

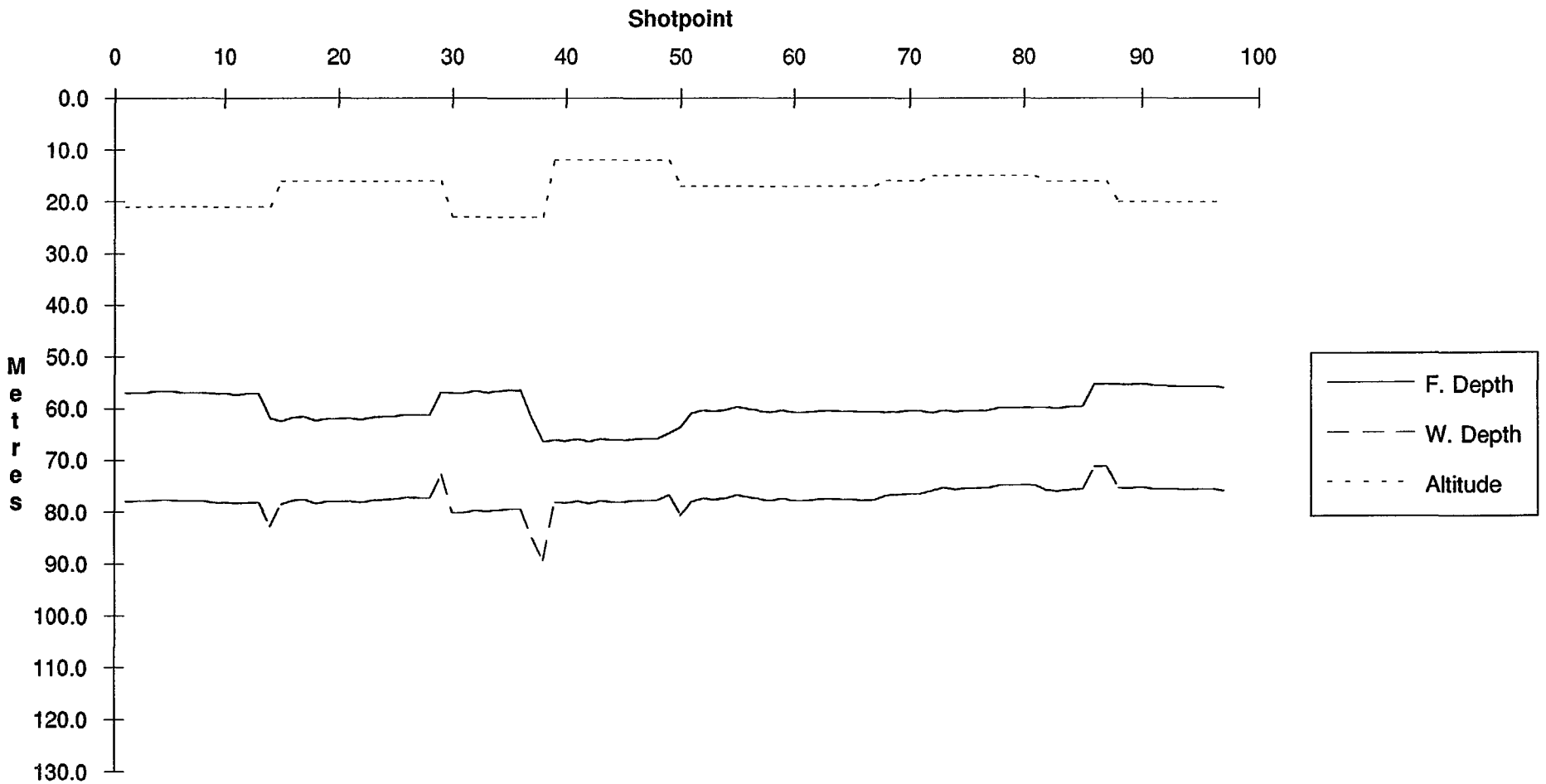
# Line 97002 Methane, Ethane, Ethylene



# Line 97002 Methane, Propane, Propylene



# Line 97002 Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 97003 |
| No. of Shotpoints | 244 |

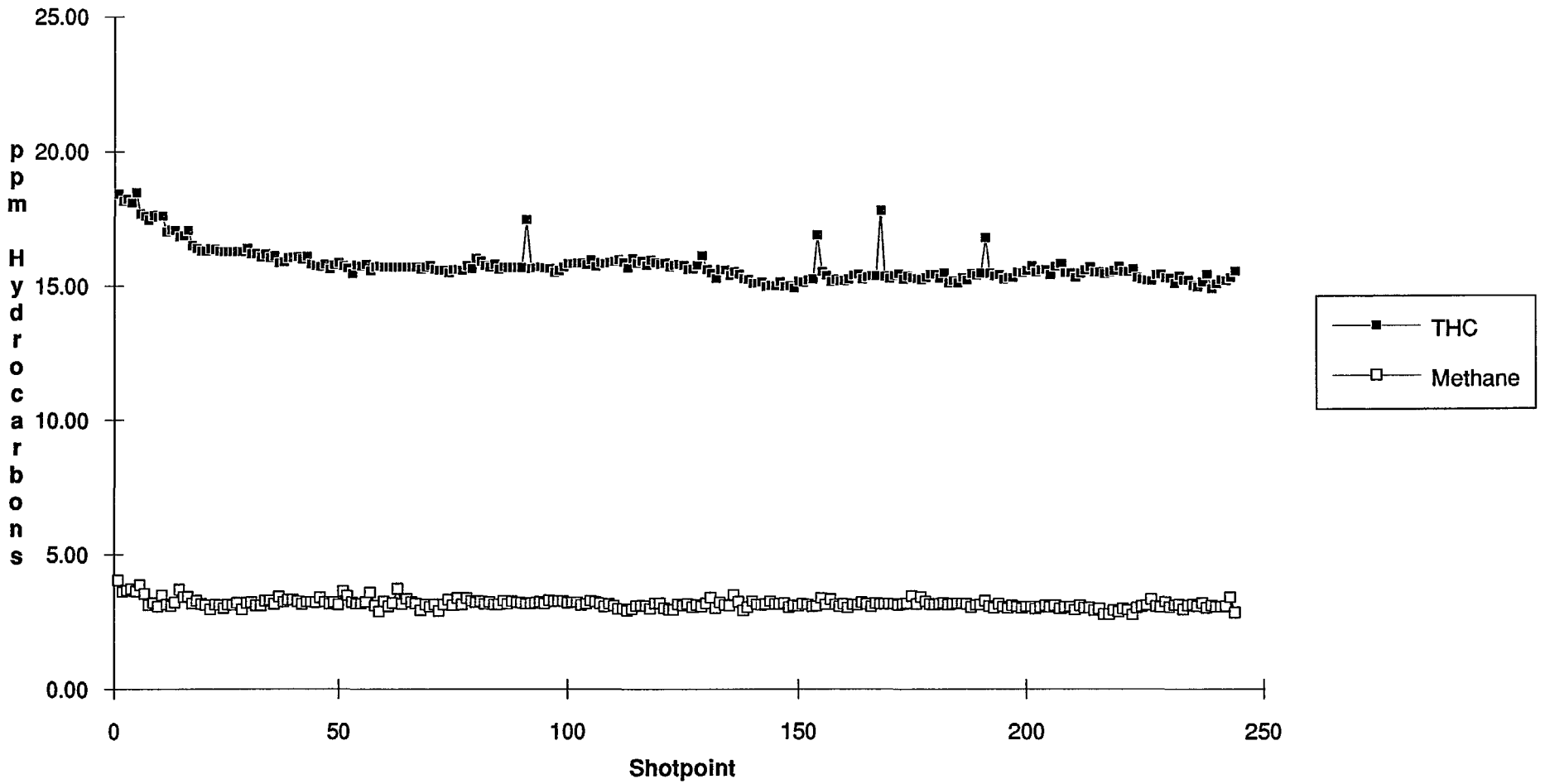
| | Shotpoint | Date | Time | Latitude | | Longitude | |
|---|---|---|---|---|---|---|---|
| Start | 1 | 24-Oct-90 | 08:58:57 | 19 | 27.873 | 116 | 43.976 |
| End | 244 | 24-Oct-90 | 17:04:52 | 19 | 41.368 | 116 | 21.020 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 15.748 | 3.157 | 0.011 | 0.073 | 0.017 | 0.024 | 0.009 | 0.000 | 0.000 | 0.076 | 0.028 | 0.000 | 1.154 |
| Std. Dev. | 0.646 | 0.172 | 0.004 | 0.008 | 0.018 | 0.018 | 0.020 | 0.002 | 0.000 | 0.021 | 0.012 | 0.000 | 0.924 |
| Minimum | 14.893 | 2.752 | 0.000 | 0.061 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.183 |
| Maximum | 18.463 | 4.034 | 0.061 | 0.112 | 0.095 | 0.092 | 0.099 | 0.027 | 0.000 | 0.113 | 0.059 | 0.000 | 4.513 |

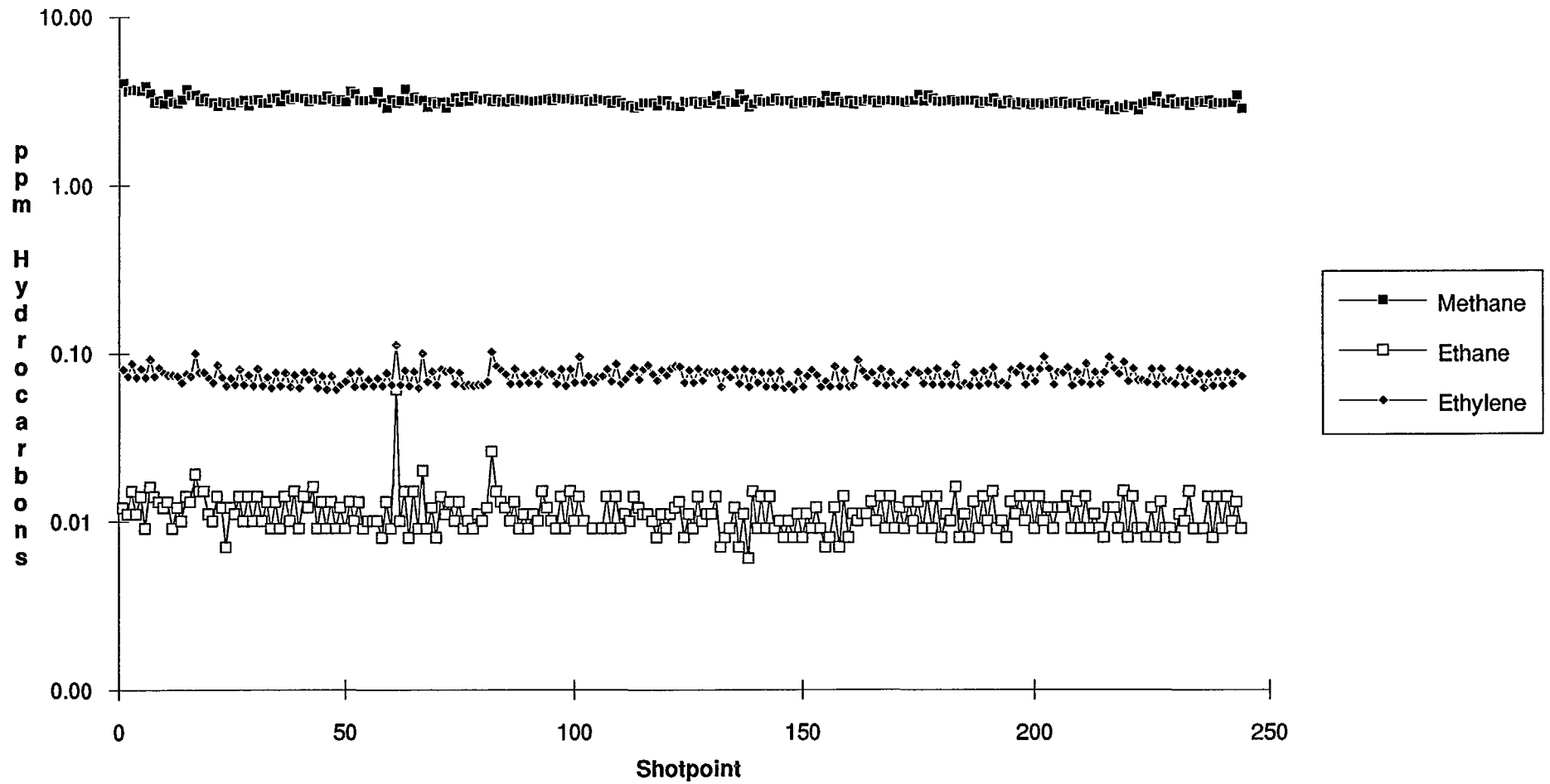
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 53.389 | 24.776 | 62.280 | 77.887 | 15.607 |
| Std. Dev. | 0.361 | 0.354 | 9.779 | 10.893 | 3.370 |
| Minimum | 53.020 | 24.320 | 43.350 | 55.350 | 10.000 |
| Maximum | 54.730 | 26.100 | 90.984 | 109.984 | 25.000 |

Notes No anomalies.

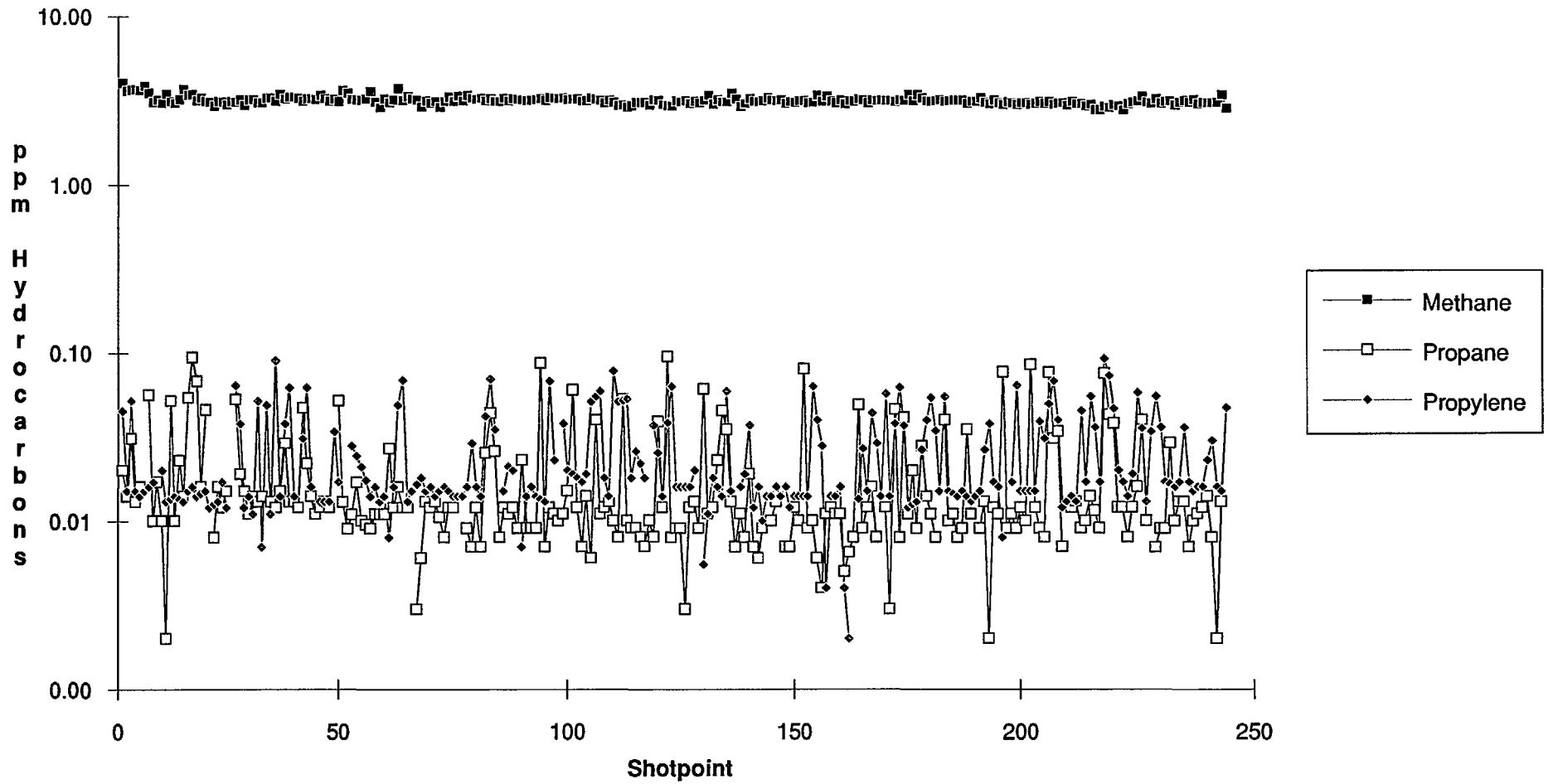
# Line 97003 THC, Methane



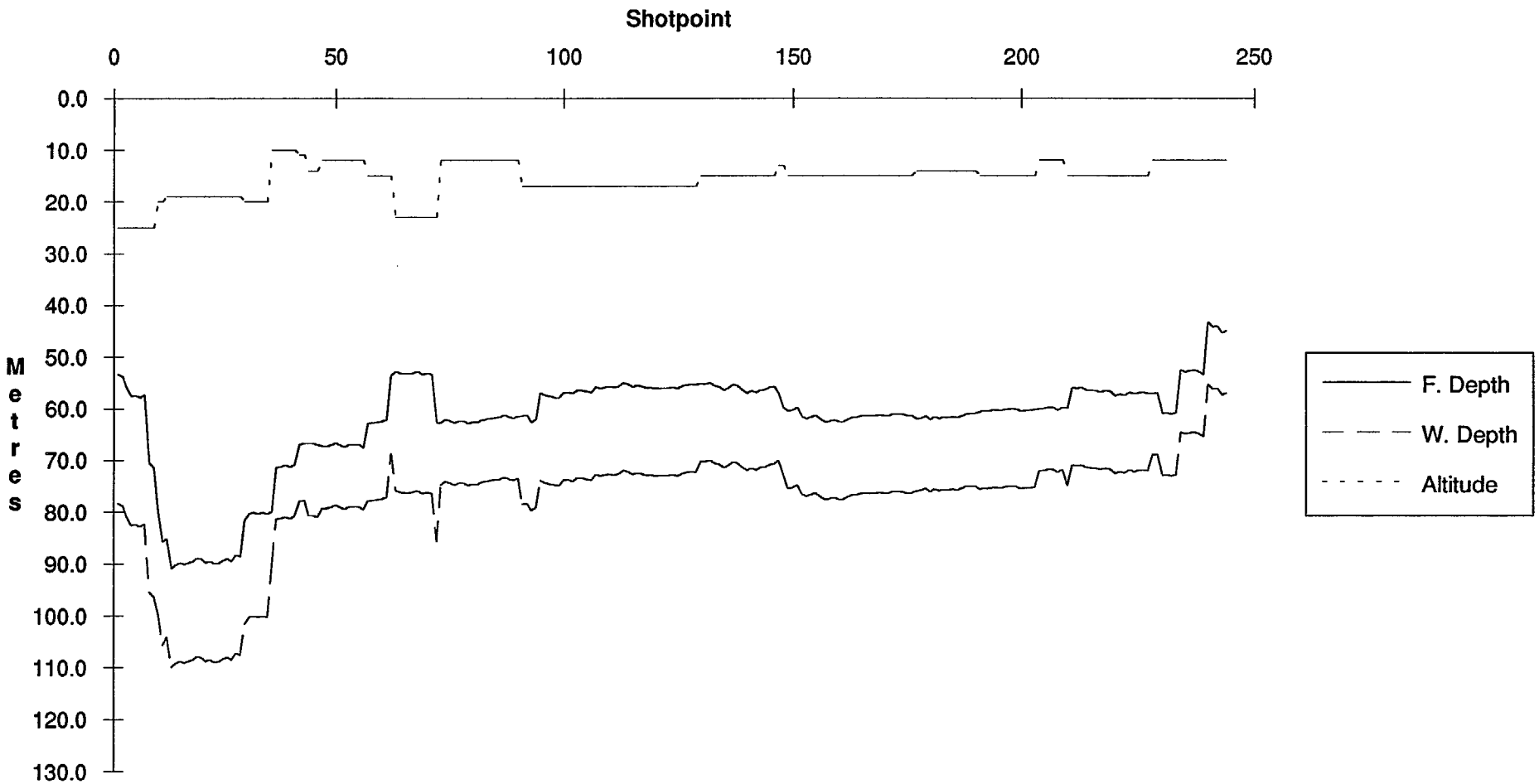
# Line 97003 Methane, Ethane, Ethylene



# Line 97003 Methane, Propane, Propylene



# Line 97003 Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 97004 |
| No. of Shotpoints | 34 |

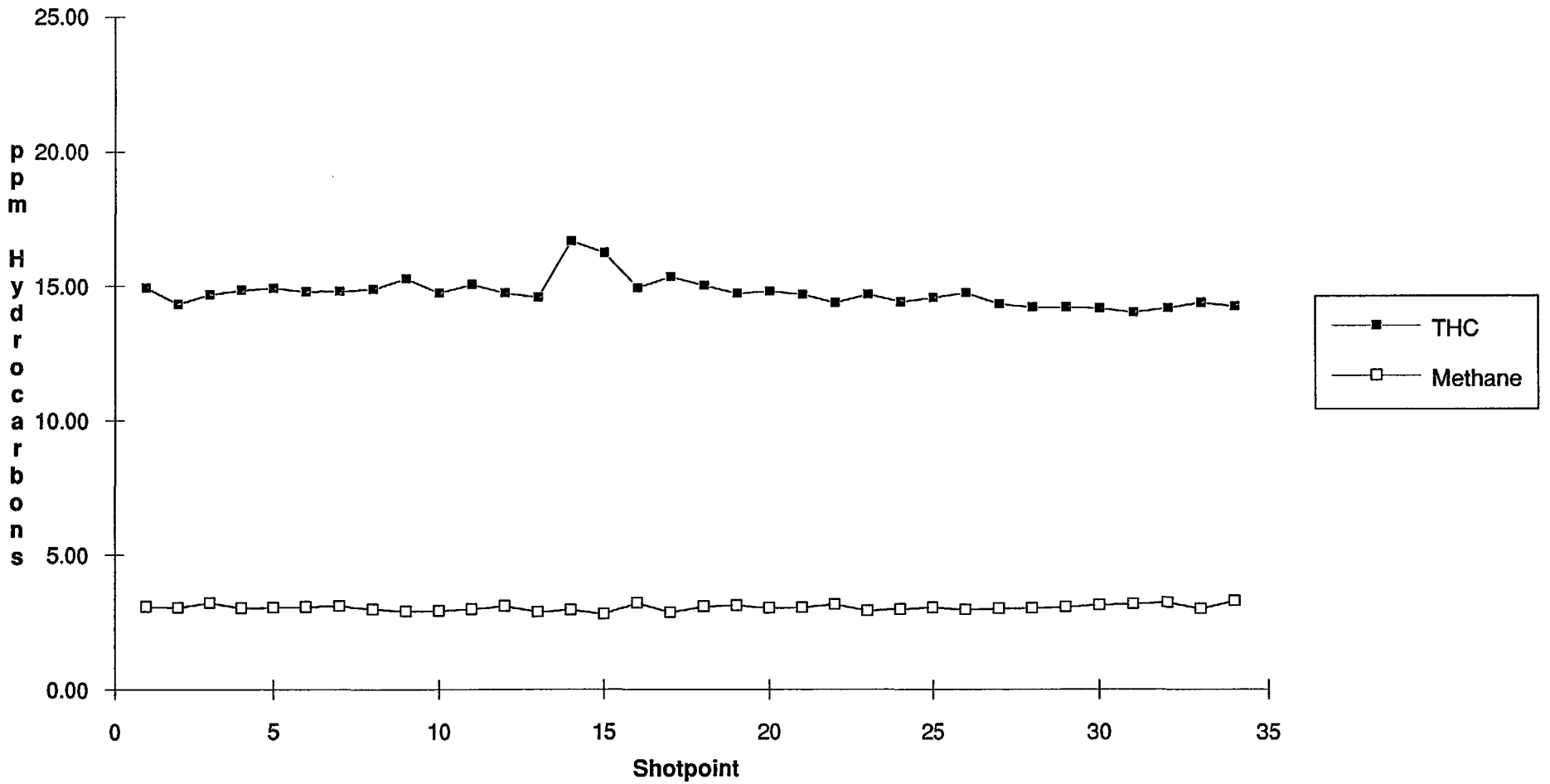
| | Shotpoint | Date | Time | Latitude | | Longitude | |
|---|---|---|---|---|---|---|---|
| Start | 2 | 24-Oct-90 | 19:13:29 | 19 | 39.248 | 116 | 25.156 |
| End | 35 | 24-Oct-90 | 20:19:28 | 19 | 35.628 | 116 | 20.623 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 14.737 | 3.033 | 0.011 | 0.067 | 0.013 | 0.026 | 0.005 | 0.000 | 0.000 | 0.068 | 0.022 | 0.000 | 0.949 |
| Std. Dev. | 0.544 | 0.113 | 0.003 | 0.008 | 0.009 | 0.018 | 0.014 | 0.000 | 0.000 | 0.015 | 0.008 | 0.000 | 0.533 |
| Minimum | 13.996 | 2.791 | 0.008 | 0.055 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.265 |
| Maximum | 16.670 | 3.295 | 0.022 | 0.085 | 0.048 | 0.067 | 0.049 | 0.000 | 0.000 | 0.092 | 0.039 | 0.000 | 2.853 |

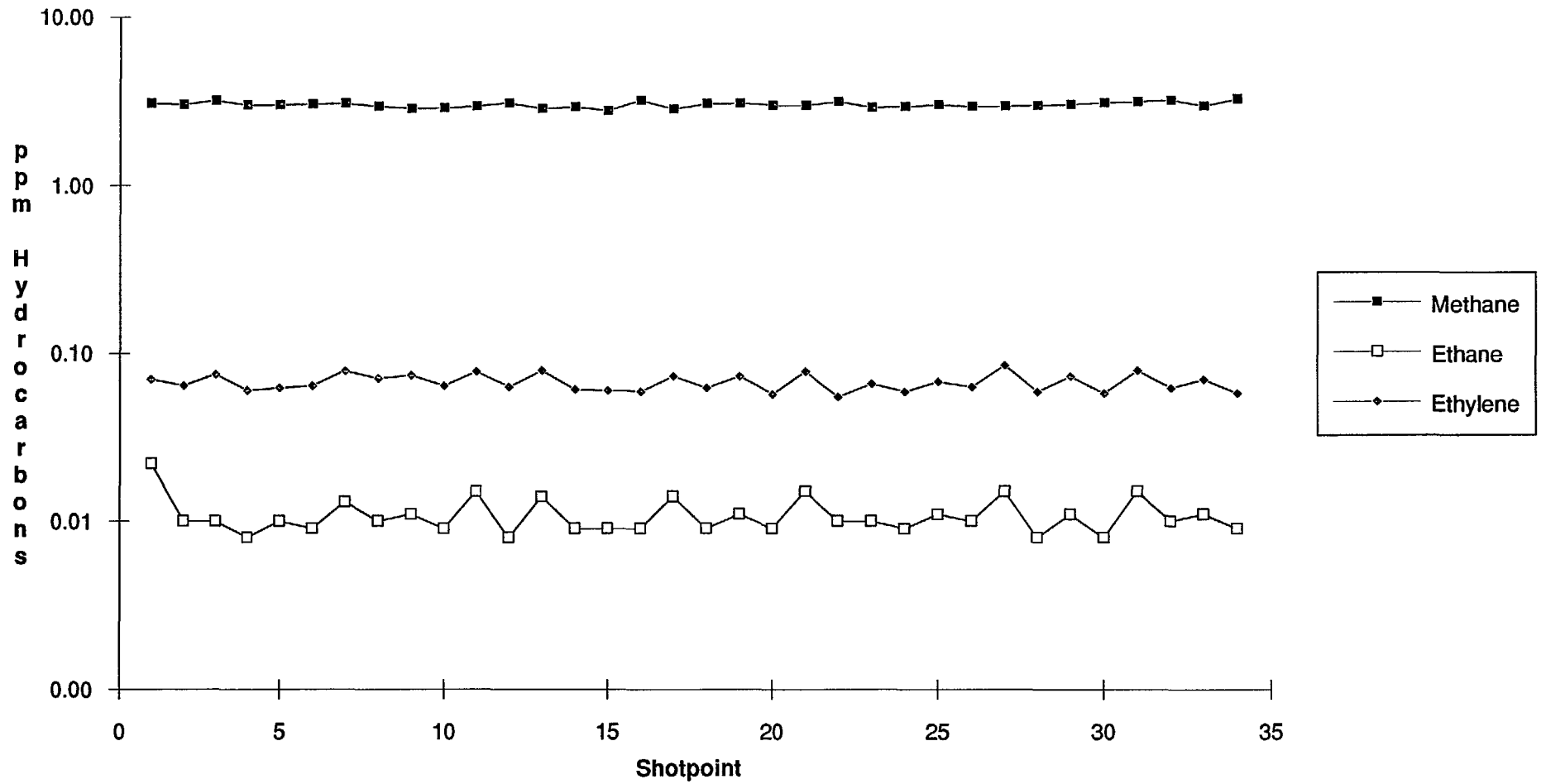
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 53.155 | 24.589 | 62.487 | 76.722 | 14.235 |
| Std. Dev. | 0.190 | 0.185 | 8.341 | 9.231 | 3.016 |
| Minimum | 52.890 | 24.210 | 52.122 | 65.142 | 11.000 |
| Maximum | 53.450 | 24.930 | 80.376 | 95.376 | 20.000 |

Notes No anomalies.

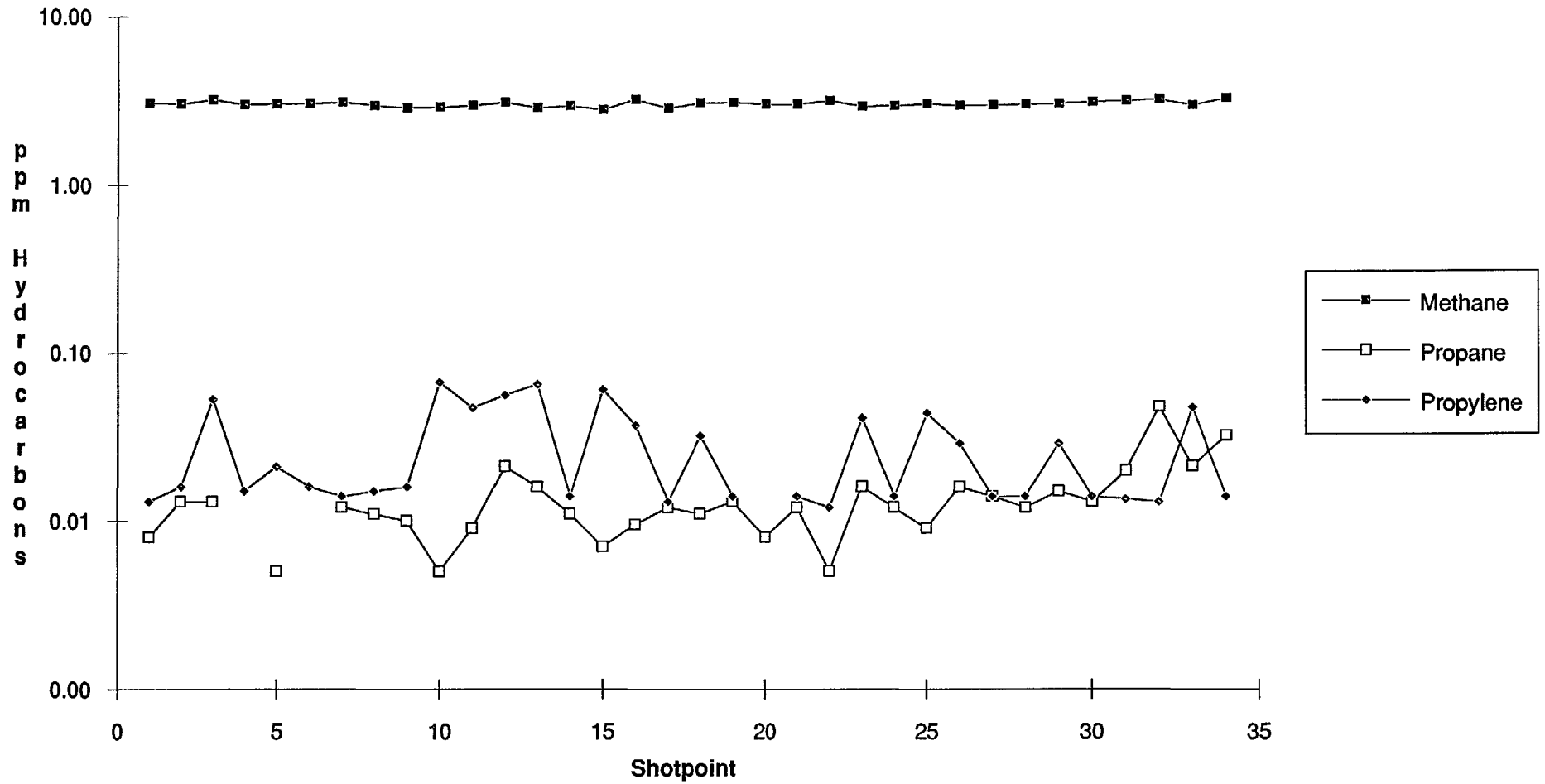
# Line 97004 THC, Methane



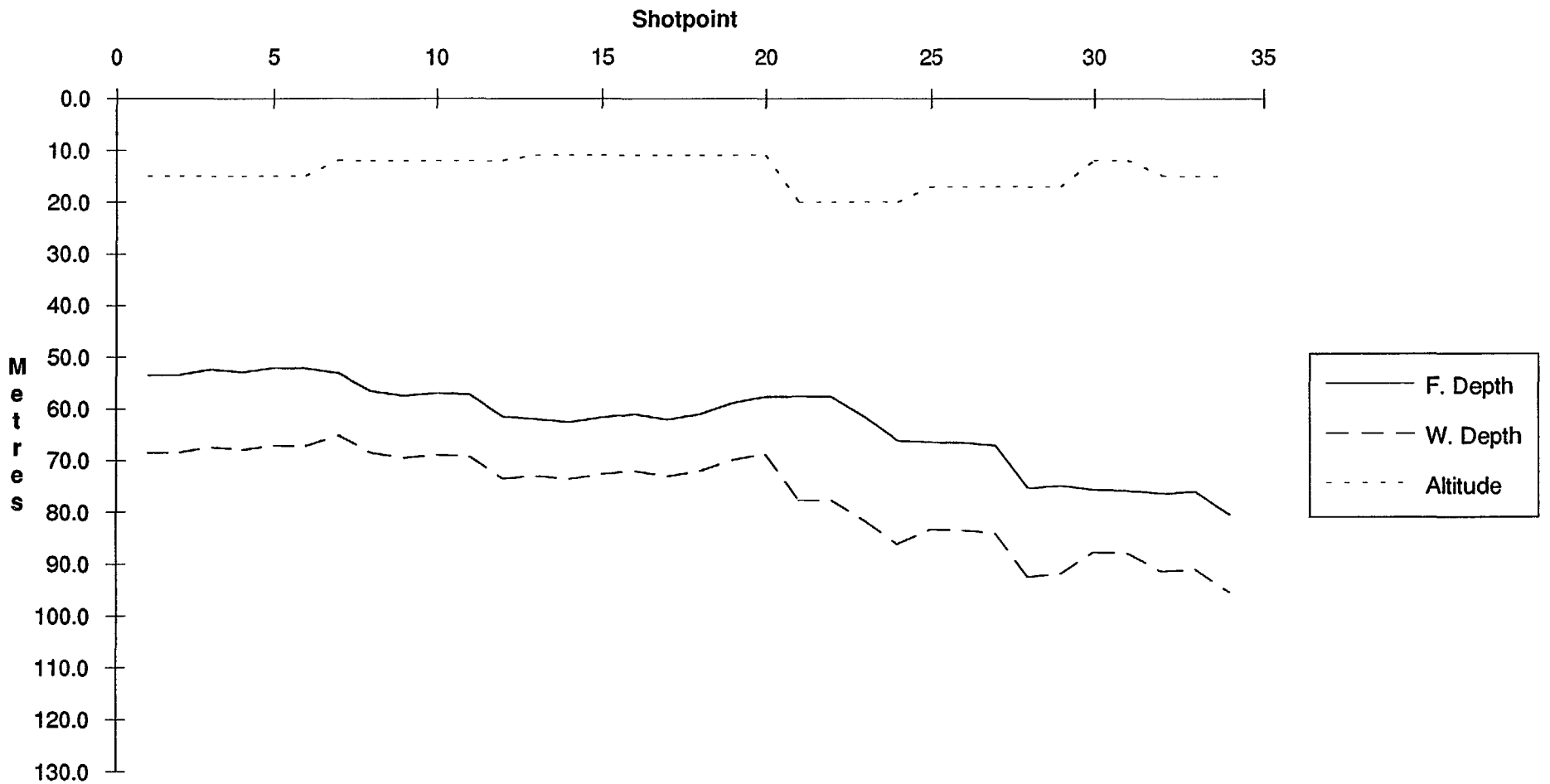
## Line 97004 Methane, Ethane, Ethylene



## Line 97004 Methane, Propane, Propylene



# Line 97004 Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 97005A |
| No. of Shotpoints | 40 |

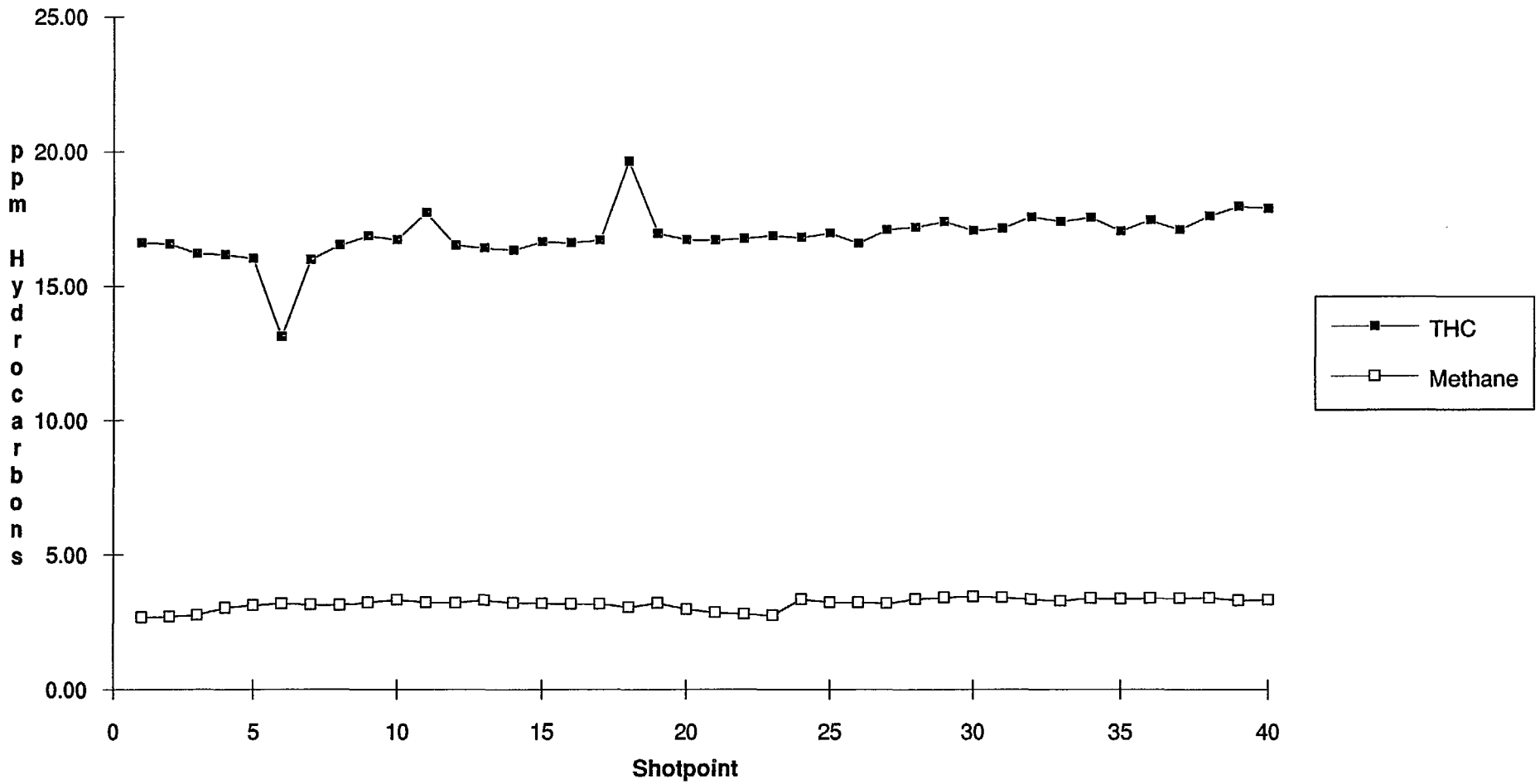
| | Shotpoint | Date | Time | Latitude | | Longitude | |
|---|---|---|---|---|---|---|---|
| Start | 1 | 26-Oct-90 | 18:09:02 | 19 | 34.585 | 116 | 21.978 |
| End | 40 | 26-Oct-90 | 19:27:05 | 19 | 38.621 | 116 | 27.172 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 16.879 | 3.181 | 0.011 | 0.085 | 0.016 | 0.023 | 0.000 | 0.000 | 0.000 | 0.072 | 0.028 | 0.000 | 0.862 |
| Std. Dev. | 0.893 | 0.212 | 0.003 | 0.005 | 0.009 | 0.009 | 0.000 | 0.000 | 0.000 | 0.024 | 0.010 | 0.000 | 0.307 |
| Minimum | 13.129 | 2.684 | 0.000 | 0.076 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.248 |
| Maximum | 19.637 | 3.452 | 0.017 | 0.097 | 0.048 | 0.047 | 0.000 | 0.000 | 0.000 | 0.100 | 0.042 | 0.000 | 1.864 |

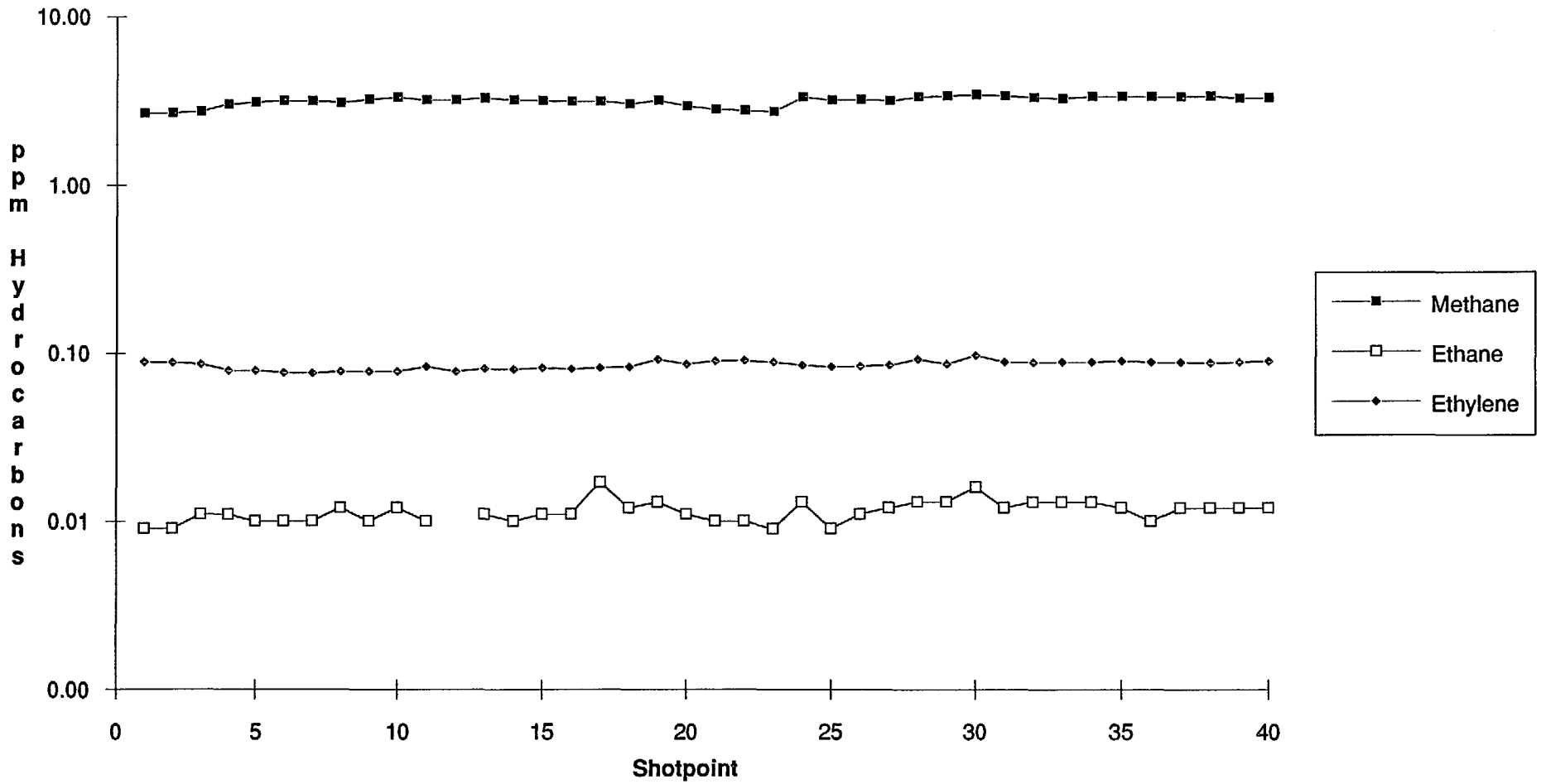
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 52.914 | 24.183 | 61.764 | 79.914 | 18.150 |
| Std. Dev. | 0.090 | 0.199 | 10.361 | 12.054 | 6.930 |
| Minimum | 52.820 | 23.900 | 28.254 | 66.254 | 12.000 |
| Maximum | 53.210 | 24.540 | 78.234 | 128.602 | 52.000 |

Notes No anomalies.

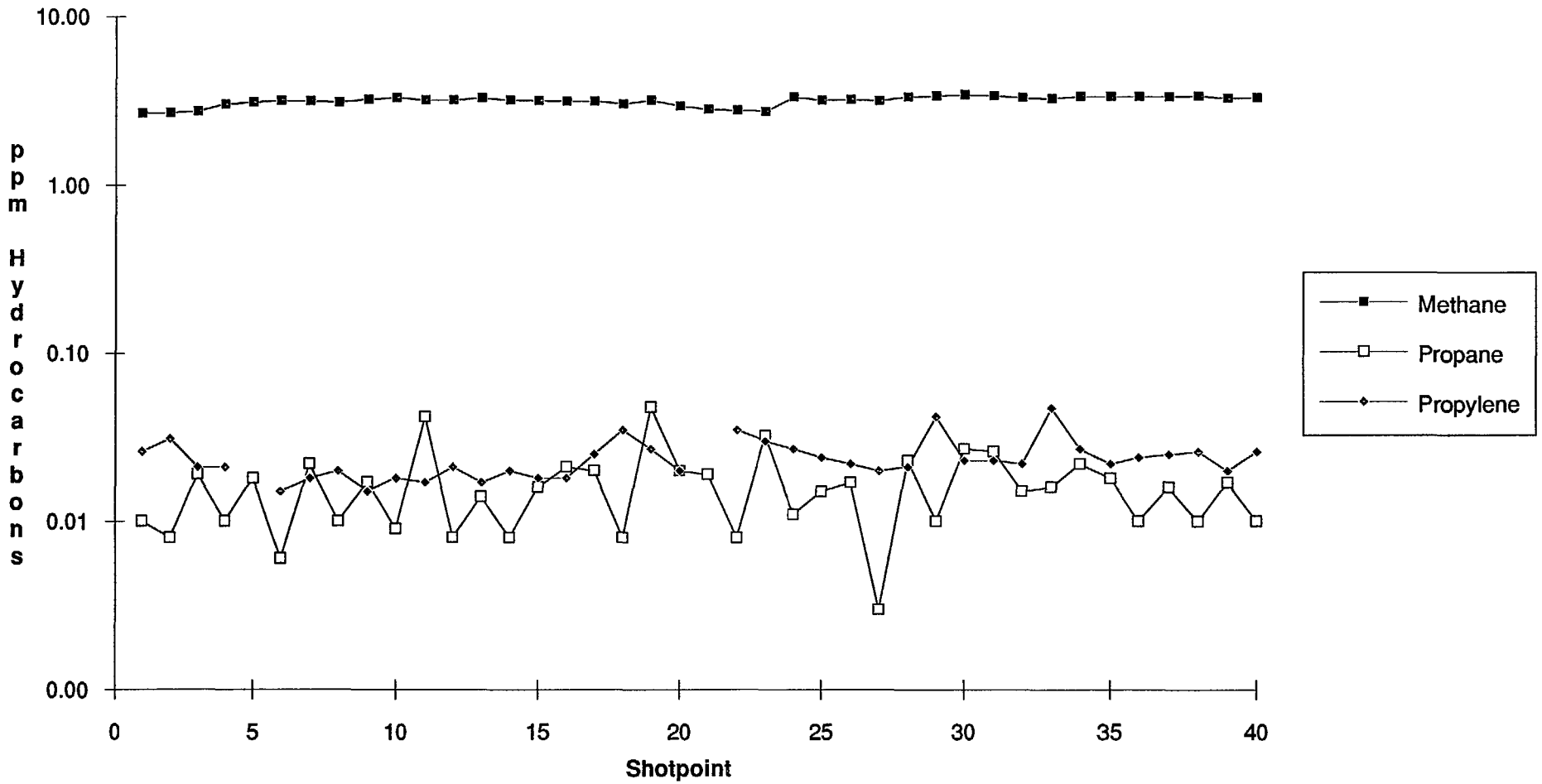
# Line 97005 THC, Methane



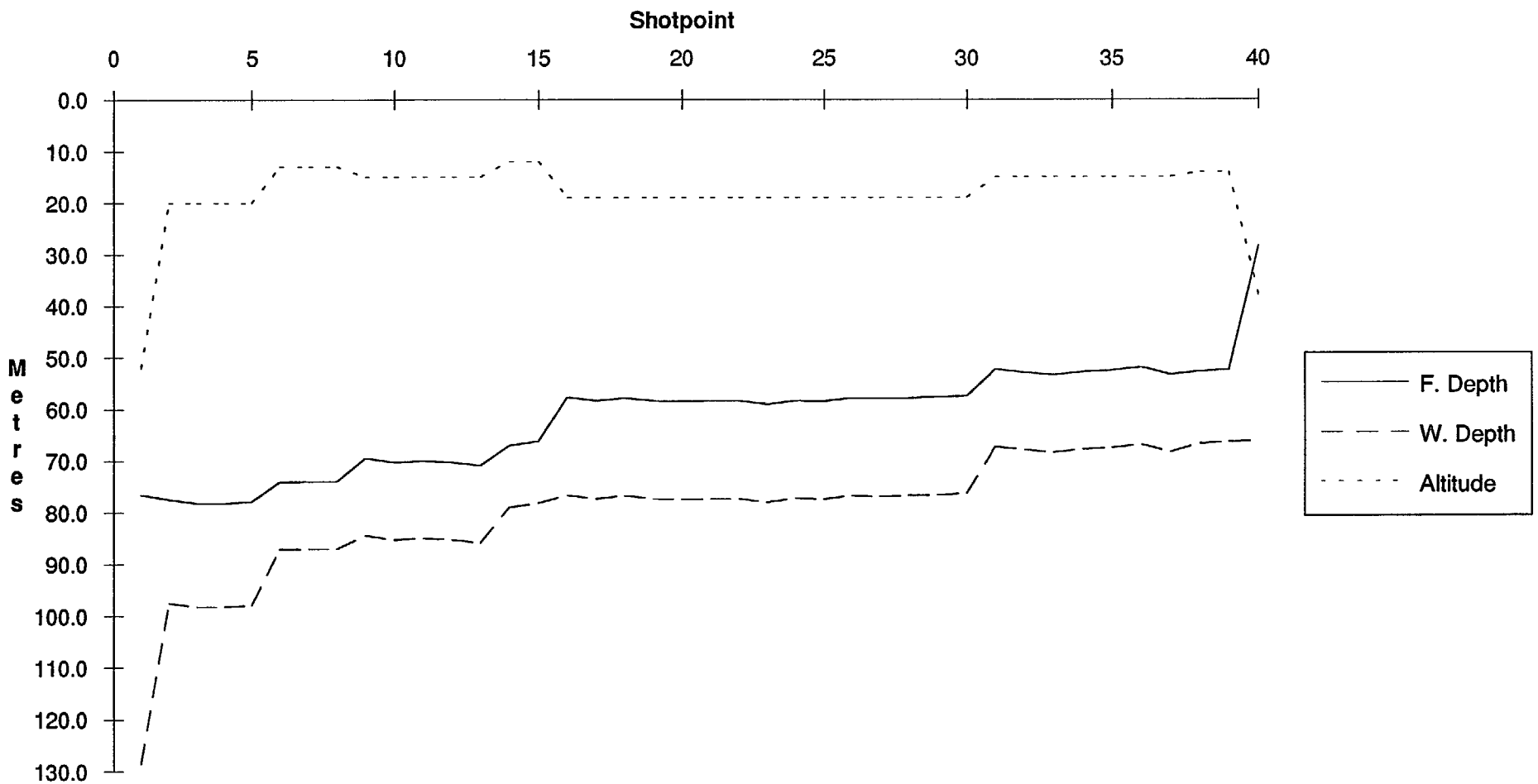
## Line 97005 Methane, Ethane, Ethylene



## Line 97005 Methane, Propane, Propylene



# Line 97005 Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 97006 |
| No. of Shotpoints | 70 |

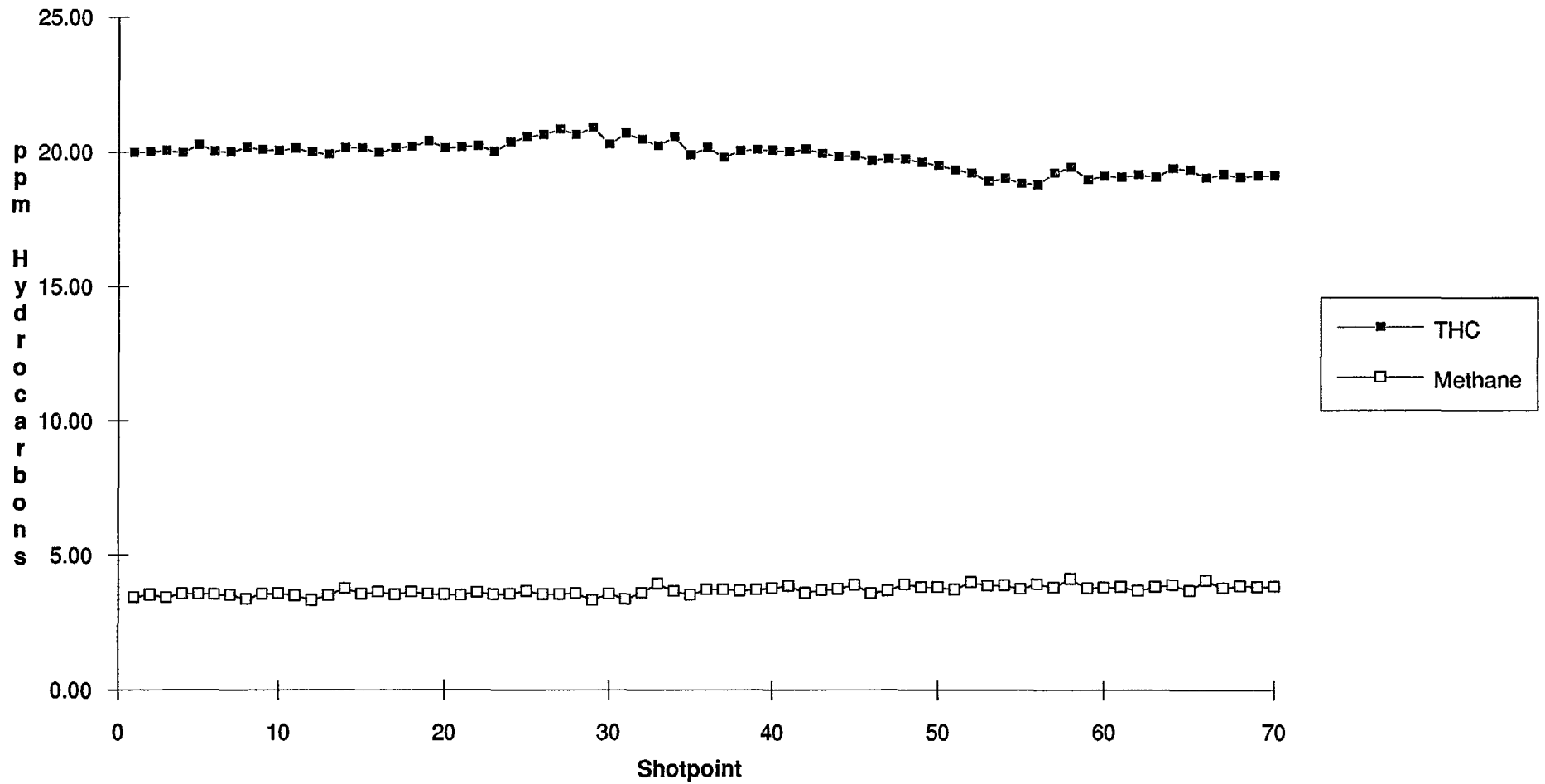
| | Shotpoint | Date | Time | Latitude | | Longitude | |
|---|---|---|---|---|---|---|---|
| Start | 1 | 25-Oct-90 | 01:10:45 | 19 | 38.467 | 116 | 29.904 |
| End | 70 | 25-Oct-90 | 03:28:49 | 19 | 30.919 | 116 | 20.280 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 19.854 | 3.680 | 0.014 | 0.104 | 0.018 | 0.038 | 0.005 | 0.000 | 0.000 | 0.118 | 0.004 | 0.000 | 1.023 |
| Std. Dev. | 0.534 | 0.171 | 0.002 | 0.006 | 0.012 | 0.022 | 0.012 | 0.001 | 0.000 | 0.030 | 0.008 | 0.000 | 0.480 |
| Minimum | 18.799 | 3.333 | 0.011 | 0.090 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.326 |
| Maximum | 20.918 | 4.115 | 0.019 | 0.114 | 0.073 | 0.096 | 0.050 | 0.009 | 0.000 | 0.162 | 0.024 | 0.000 | 2.487 |

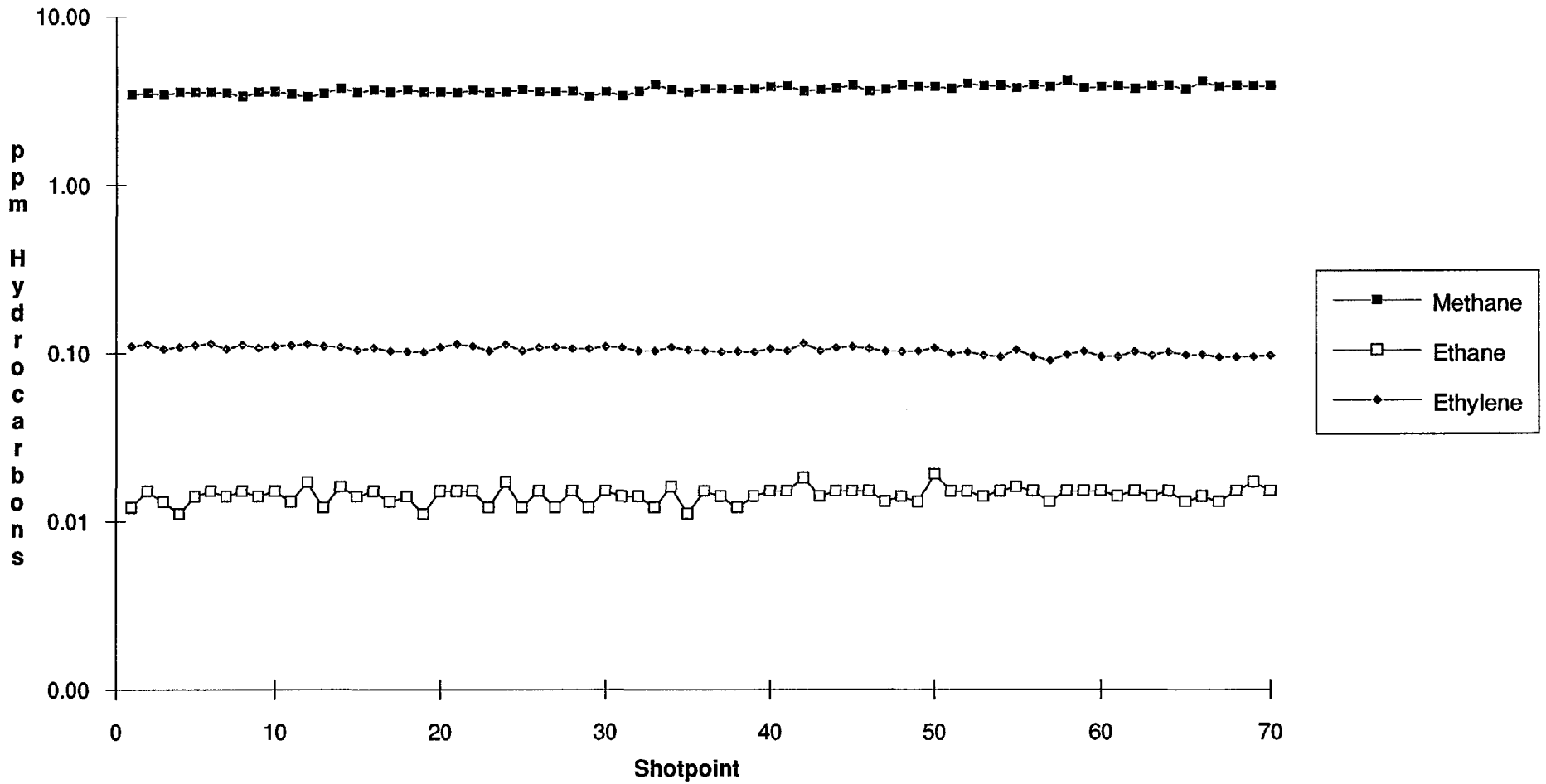
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 54.421 | 25.638 | 71.820 | 85.048 | 13.229 |
| Std. Dev. | 0.102 | 0.171 | 17.656 | 18.450 | 1.446 |
| Minimum | 54.220 | 25.280 | 50.388 | 62.490 | 11.000 |
| Maximum | 54.600 | 25.970 | 103.428 | 119.122 | 16.000 |

Notes No anomalies

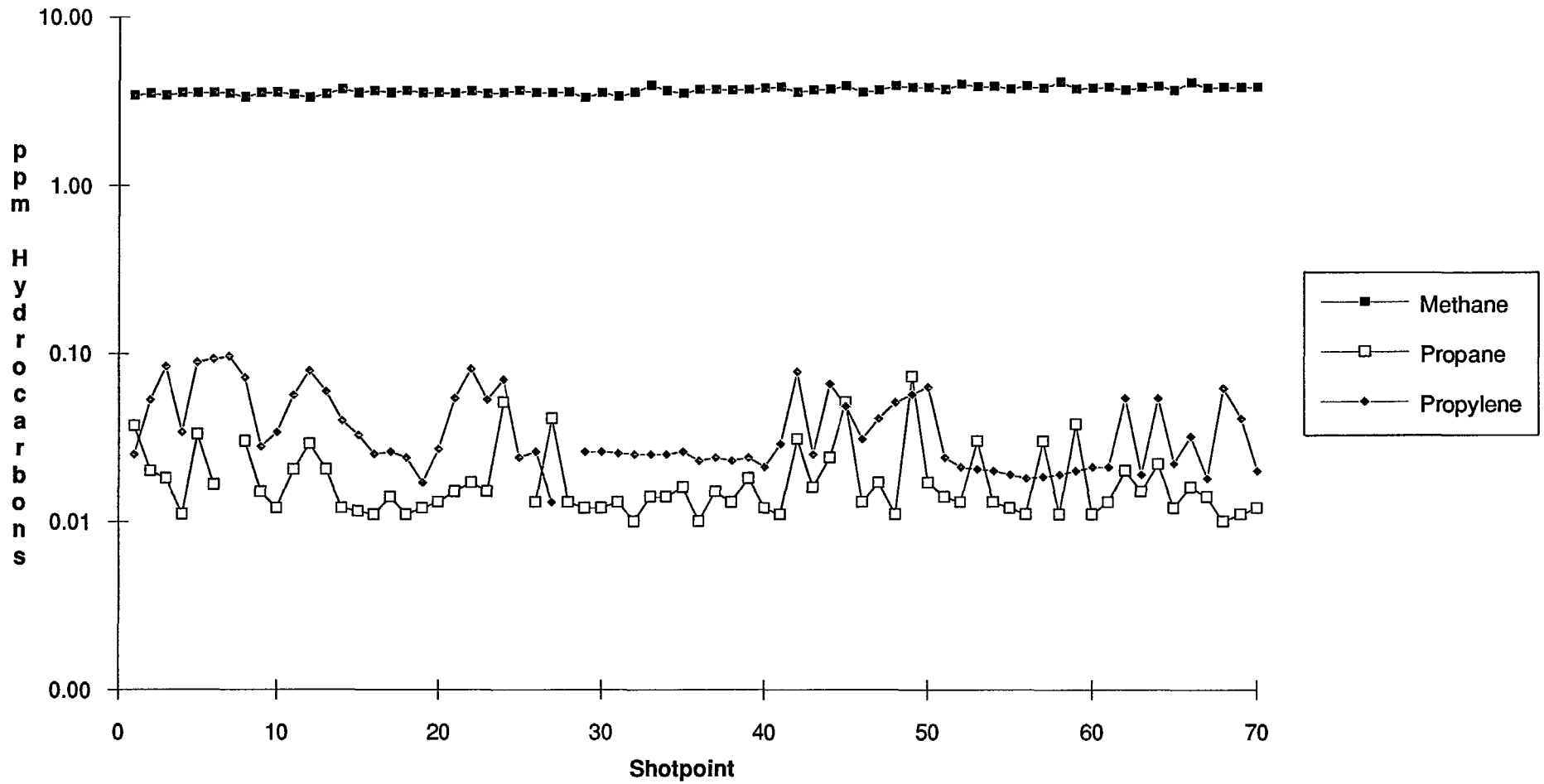
# Line 97006 THC, Methane



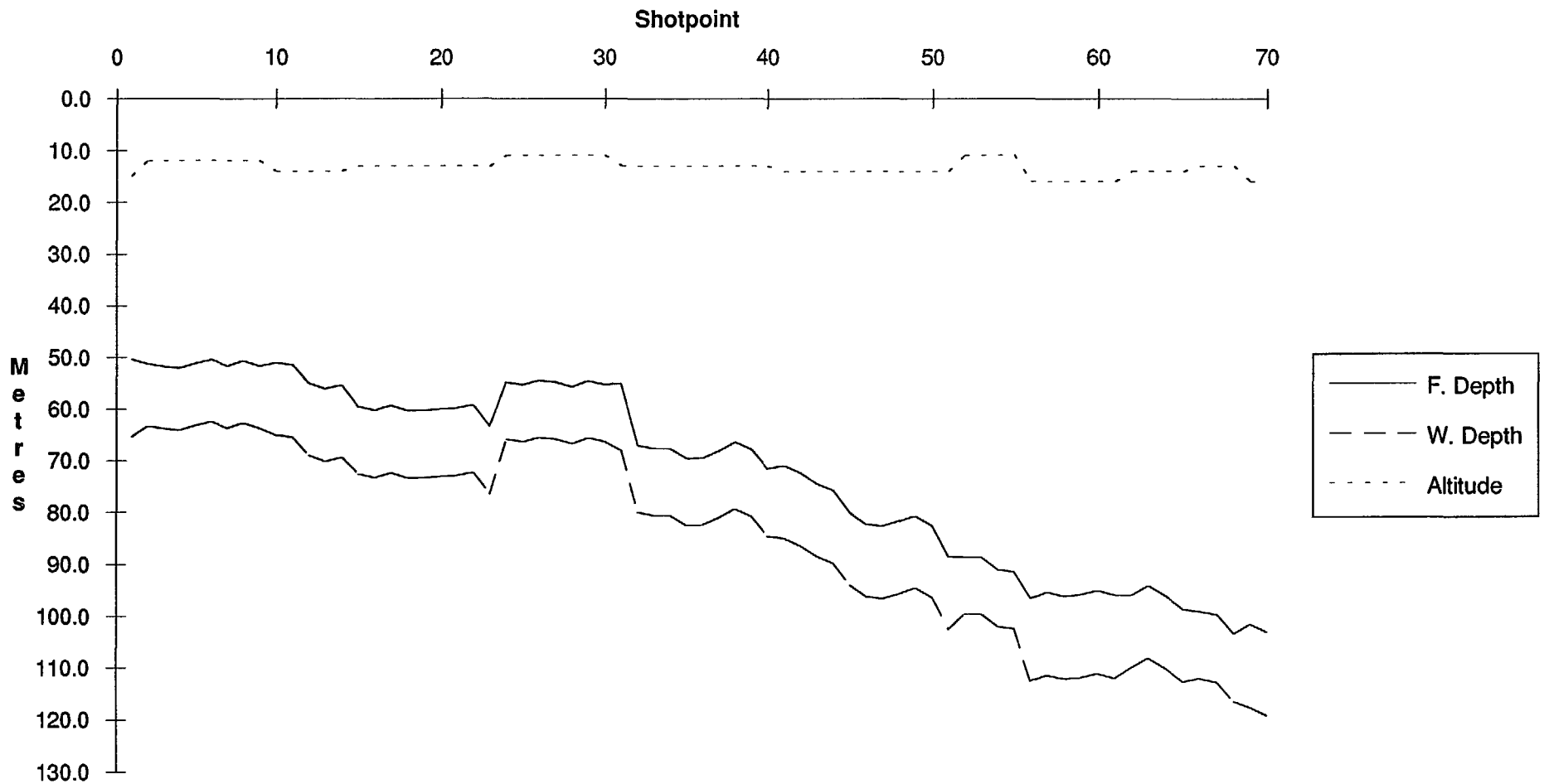
# Line 97006 Methane, Ethane, Ethylene



# Line 97006 Methane, Propane, Propylene



# Line 97006 Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 97007 |
| No. of Shotpoints | 47 |

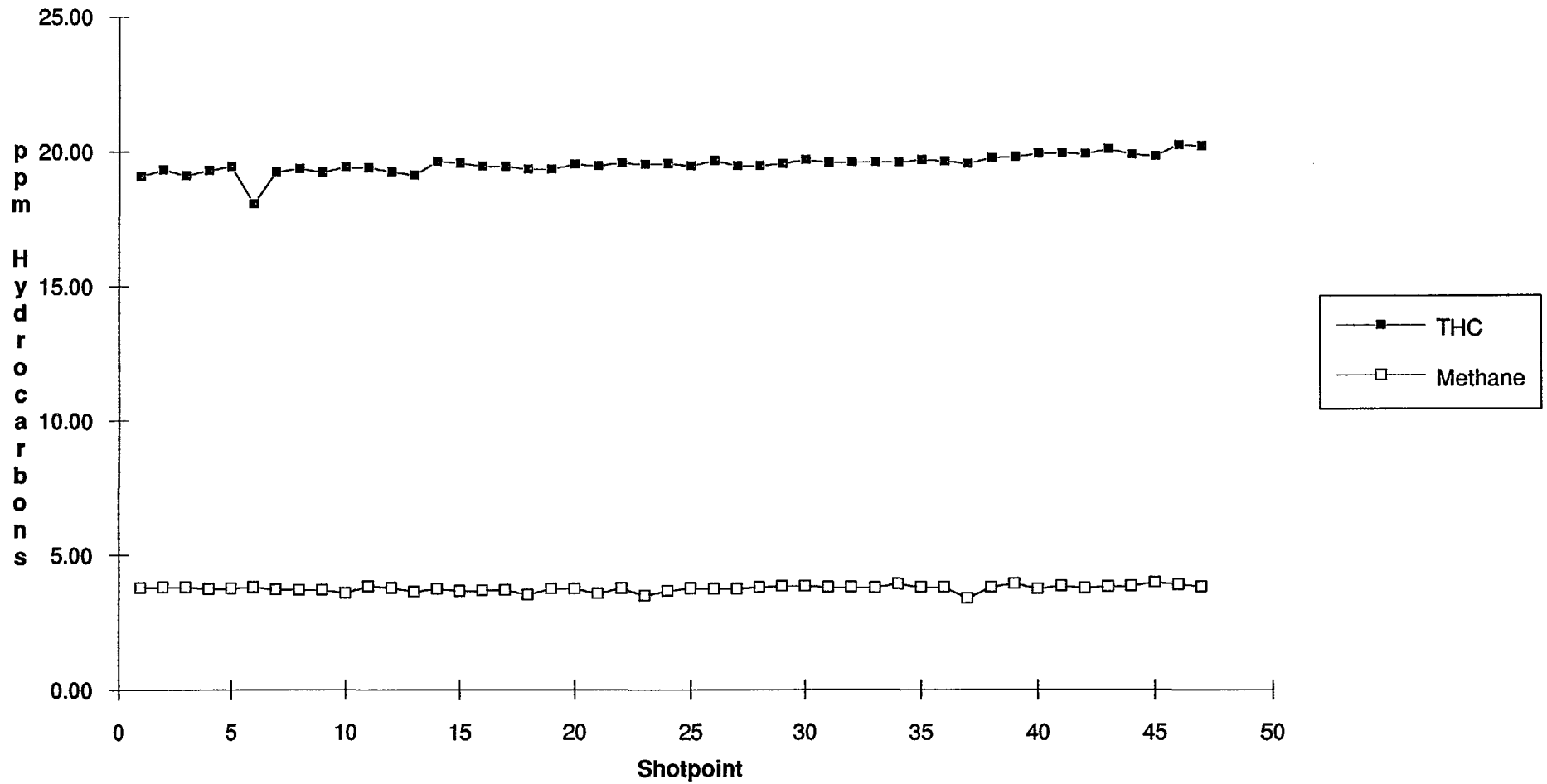
| | Shotpoint | Date | Time | Latitude | | Longitude | |
|---|---|---|---|---|---|---|---|
| Start | 1 | 25-Oct-90 | 07:02:49 | 19 | 31.958 | 116 | 23.646 |
| End | 47 | 25-Oct-90 | 08:34:47 | 19 | 37.013 | 116 | 29.850 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 19.533 | 3.755 | 0.013 | 0.101 | 0.019 | 0.032 | 0.004 | 0.000 | 0.000 | 0.104 | 0.003 | 0.000 | 0.957 |
| Std. Dev. | 0.340 | 0.112 | 0.001 | 0.005 | 0.017 | 0.018 | 0.014 | 0.001 | 0.000 | 0.027 | 0.007 | 0.000 | 0.600 |
| Minimum | 18.070 | 3.385 | 0.011 | 0.093 | 0.000 | 0.008 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.289 |
| Maximum | 20.239 | 3.977 | 0.016 | 0.113 | 0.082 | 0.085 | 0.074 | 0.008 | 0.000 | 0.140 | 0.028 | 0.000 | 3.038 |

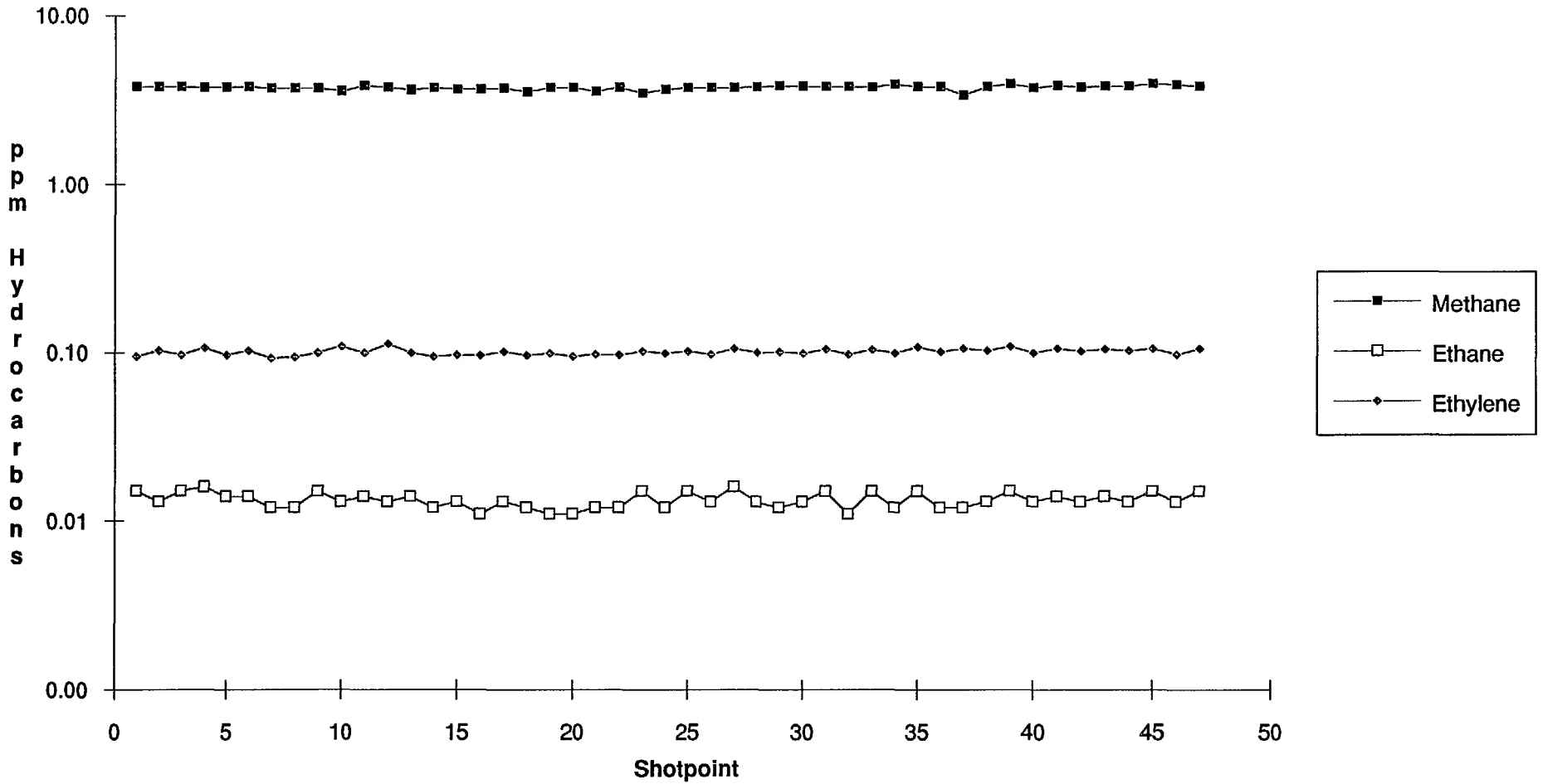
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 54.137 | 25.356 | 66.610 | 81.717 | 15.106 |
| Std. Dev. | 0.051 | 0.143 | 7.668 | 12.106 | 4.765 |
| Minimum | 53.990 | 25.090 | 51.306 | 62.306 | 11.000 |
| Maximum | 54.290 | 25.590 | 78.540 | 104.540 | 26.000 |

Notes No anomalies.

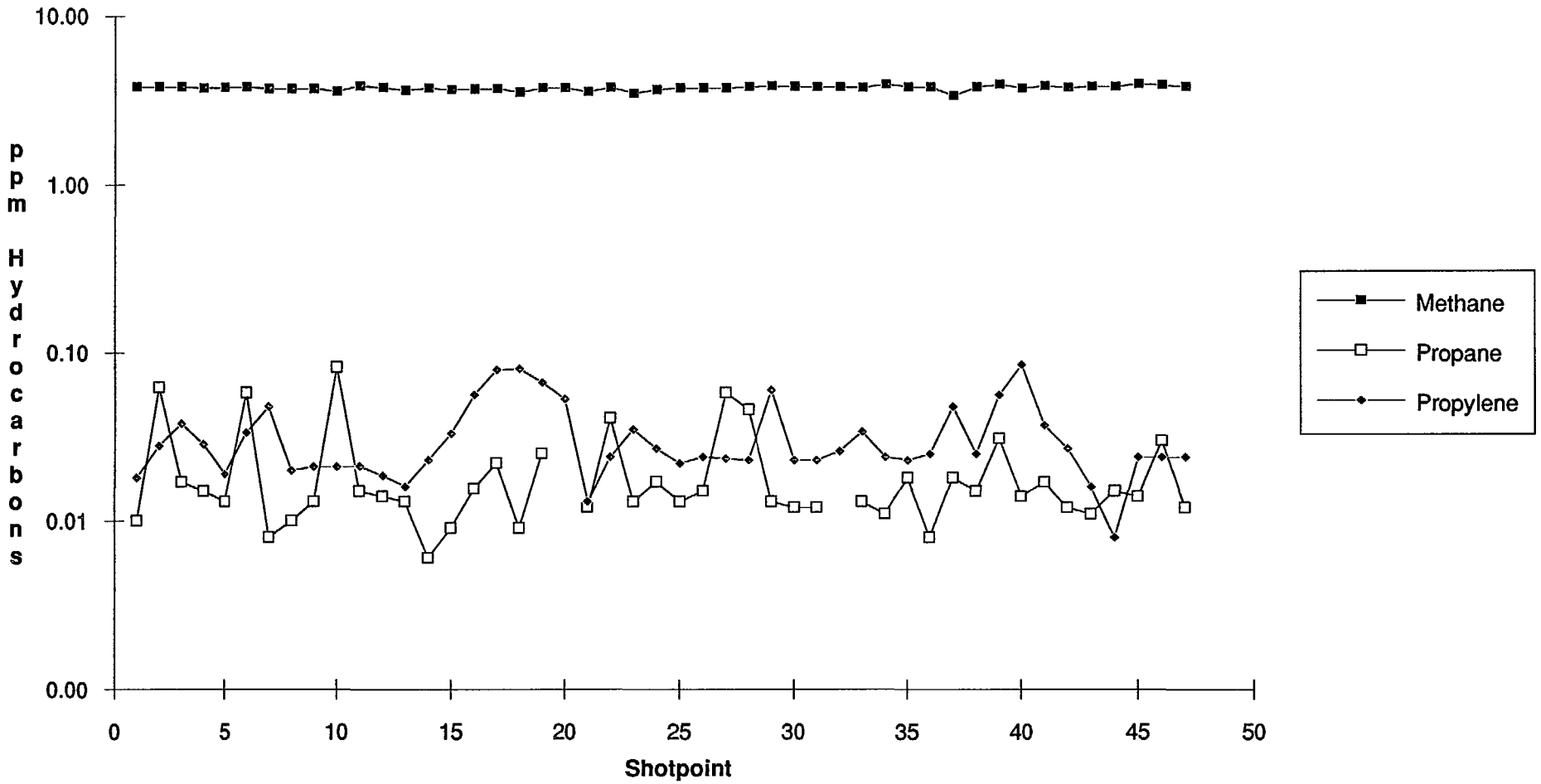
# Line 97007 THC, Methane



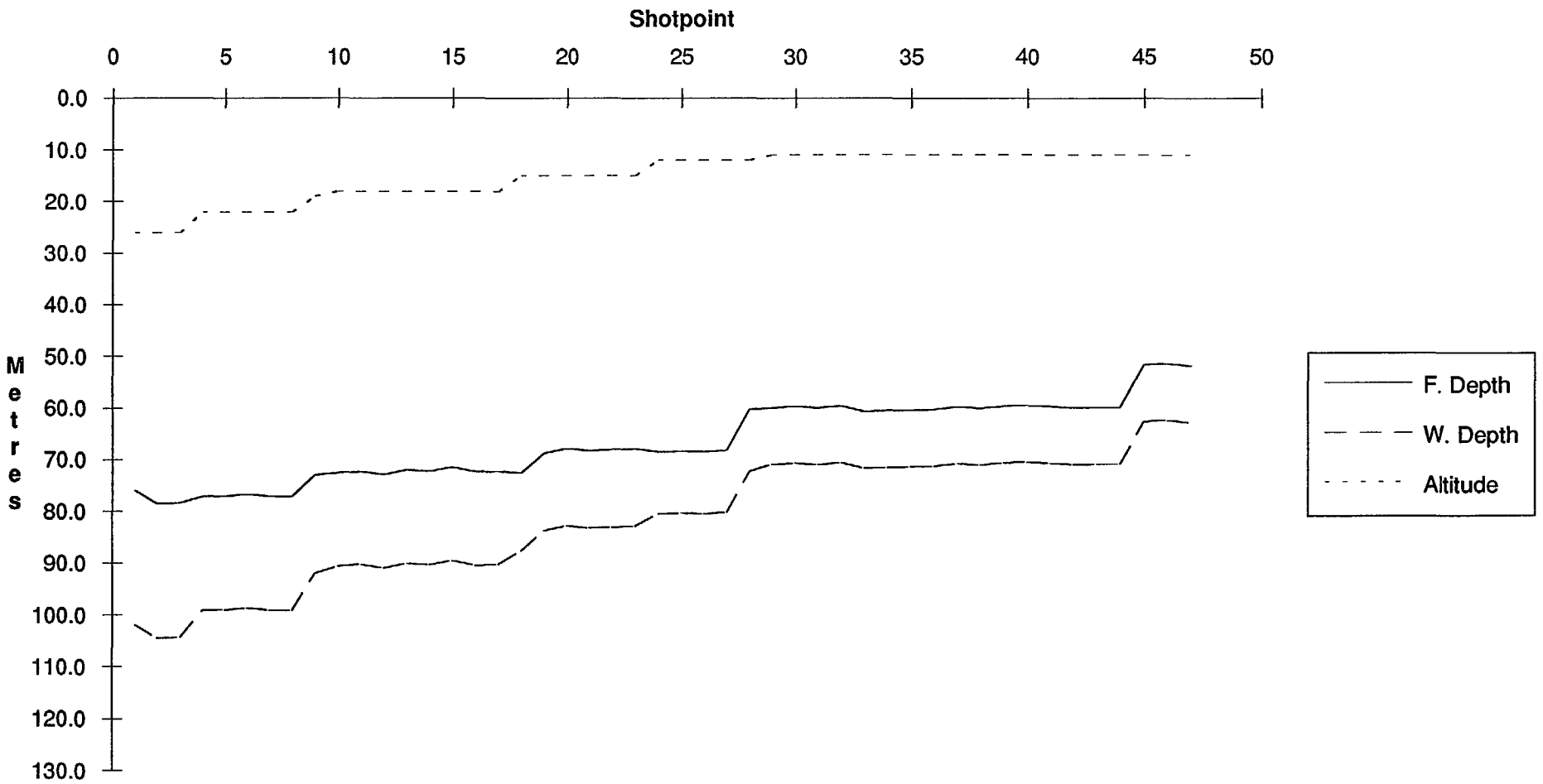
# Line 97007 Methane, Ethane, Ethylene



## Line 97007 Methane, Propane, Propylene



# Line 97007 Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 97008 |
| No. of Shotpoints | 42 |

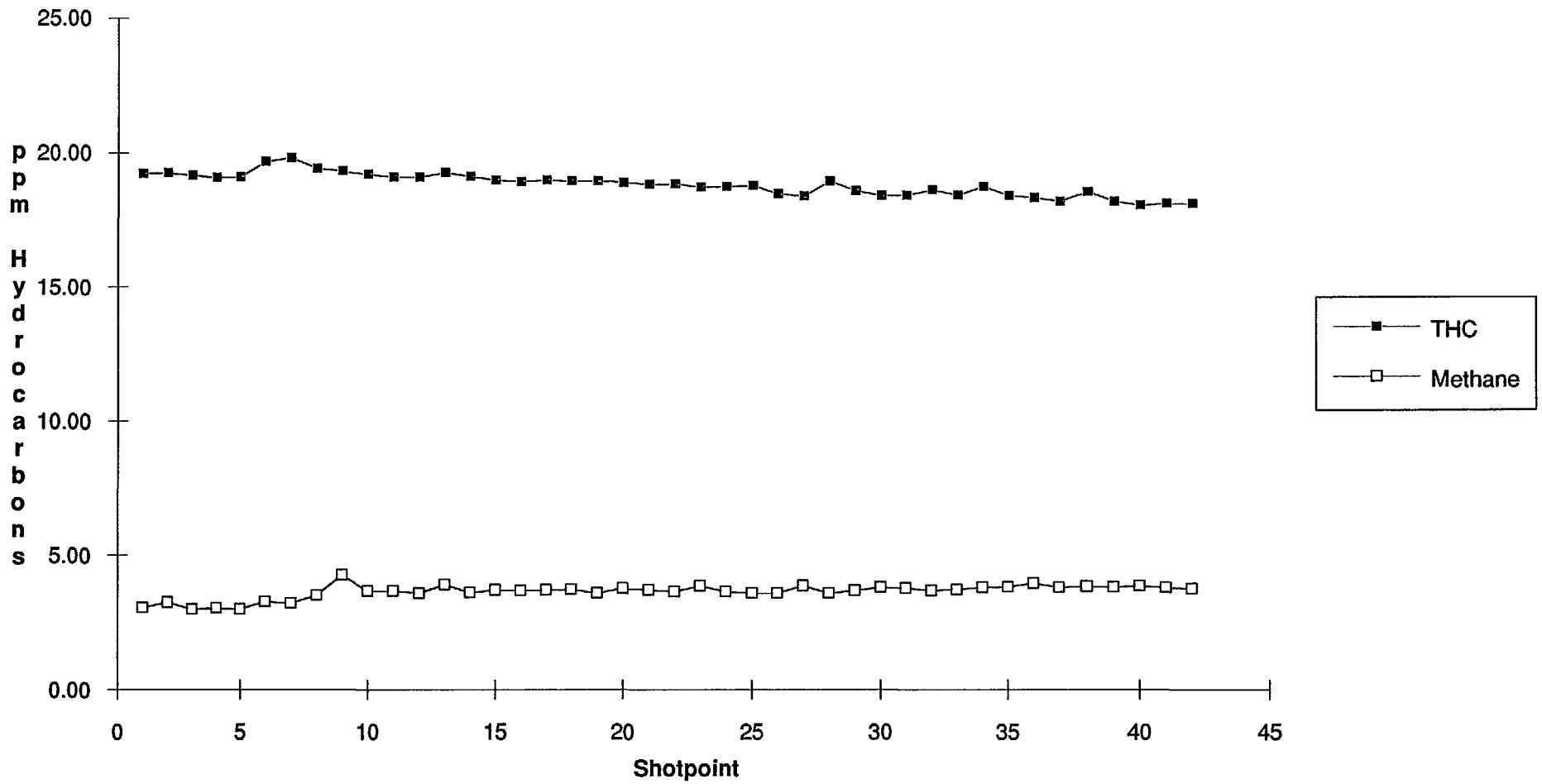
| | Shotpoint | Date | Time | Latitude | | Longitude | |
|---|---|---|---|---|---|---|---|
| Start | 1 | 25-Oct-90 | 10:07:06 | 19 | 36.411 | 116 | 31.081 |
| End | 42 | 25-Oct-90 | 11:29:04 | 19 | 31.400 | 116 | 25.850 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 18.811 | 3.637 | 0.014 | 0.103 | 0.013 | 0.037 | 0.004 | 0.001 | 0.000 | 0.103 | 0.001 | 0.000 | 0.878 |
| Std. Dev. | 0.424 | 0.273 | 0.003 | 0.006 | 0.008 | 0.020 | 0.013 | 0.008 | 0.000 | 0.032 | 0.005 | 0.000 | 0.517 |
| Minimum | 18.036 | 2.991 | 0.000 | 0.093 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.310 |
| Maximum | 19.798 | 4.262 | 0.018 | 0.128 | 0.036 | 0.095 | 0.055 | 0.054 | 0.000 | 0.142 | 0.022 | 0.000 | 2.767 |

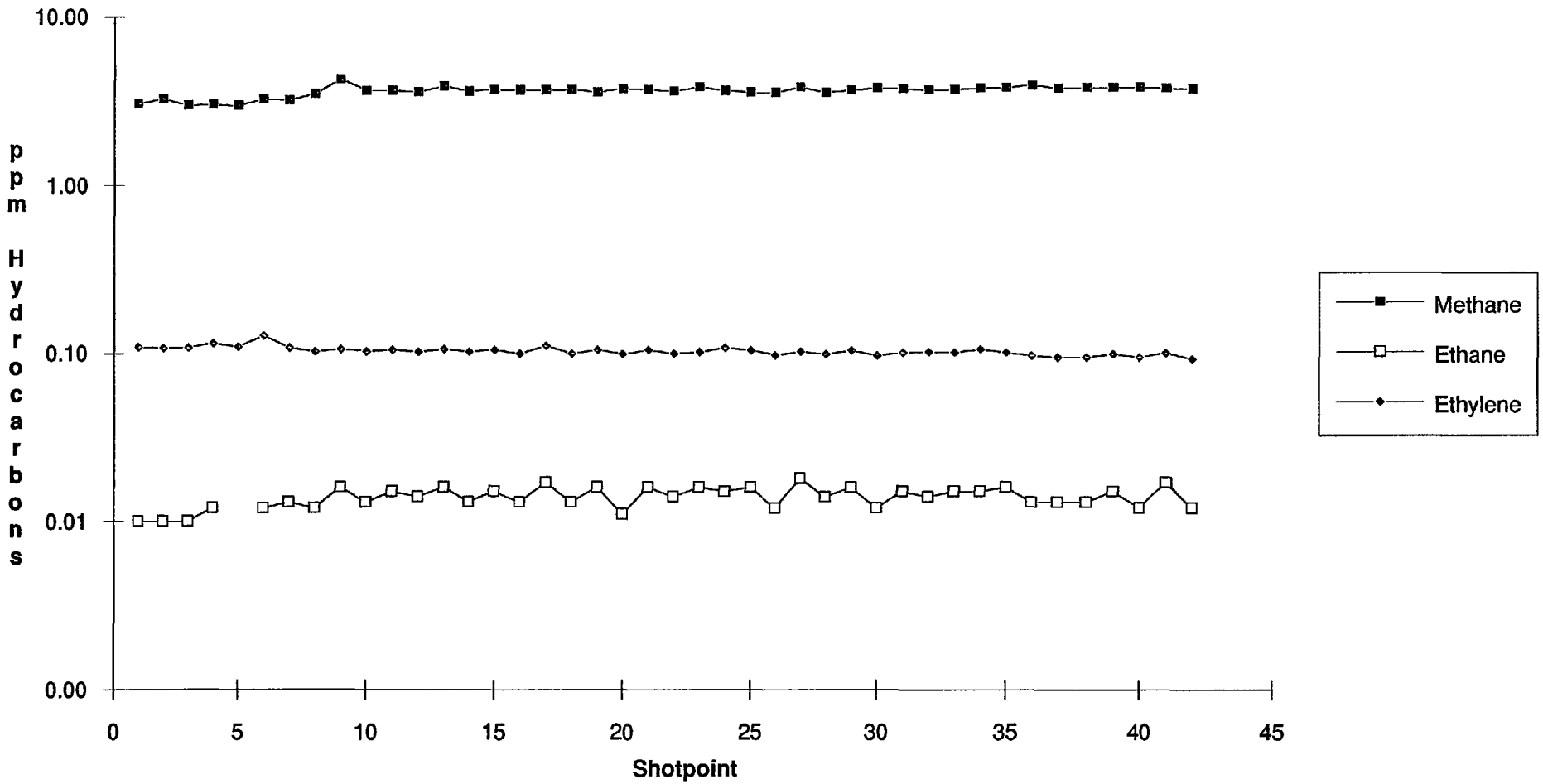
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 53.470 | 24.713 | 65.059 | 80.178 | 15.119 |
| Std. Dev. | 0.260 | 0.259 | 7.092 | 7.903 | 4.115 |
| Minimum | 52.990 | 24.290 | 44.064 | 70.976 | 11.000 |
| Maximum | 54.020 | 25.230 | 81.294 | 98.478 | 28.000 |

Notes No anomalies.

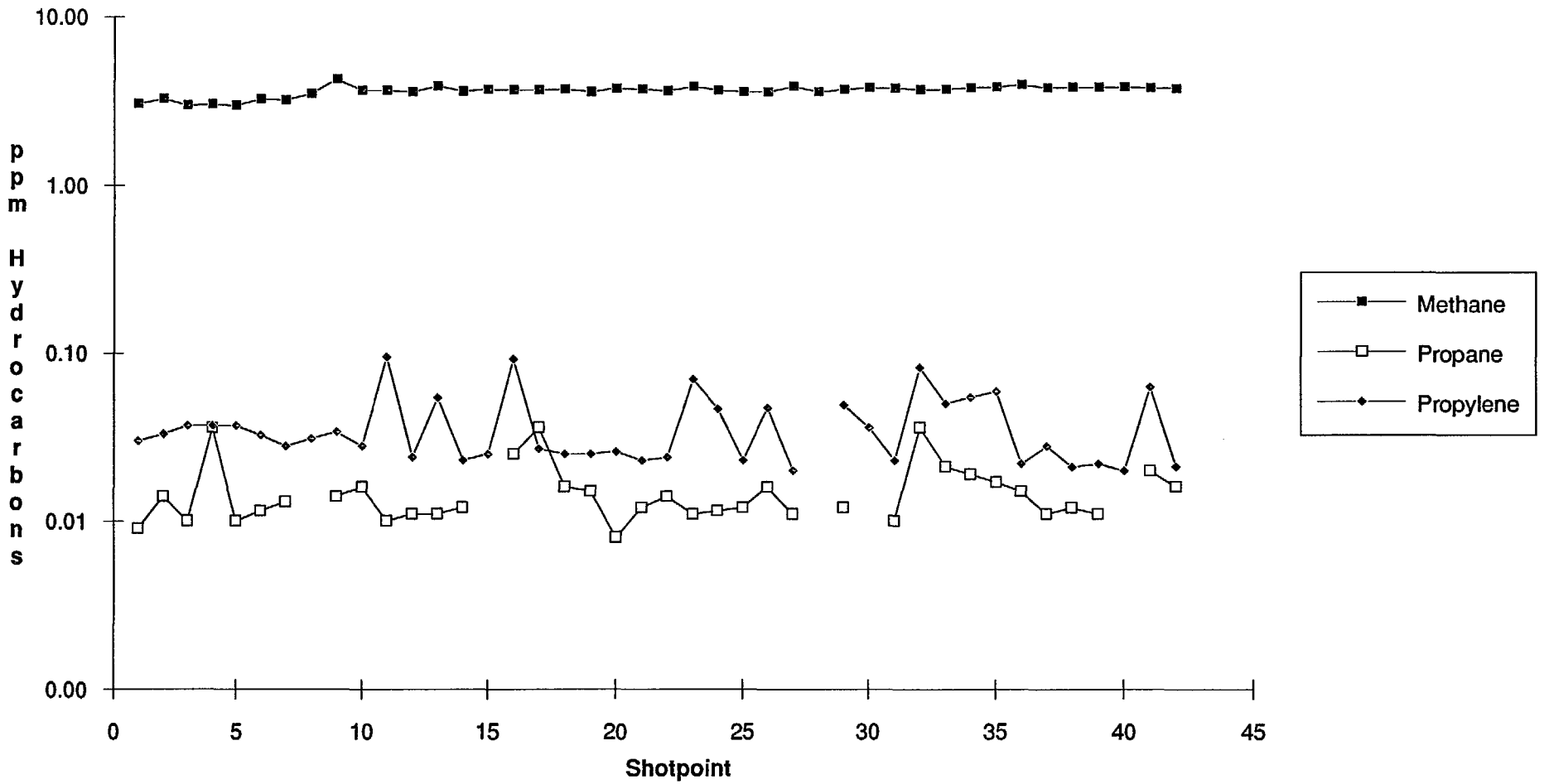
# Line 97008 THC, Methane



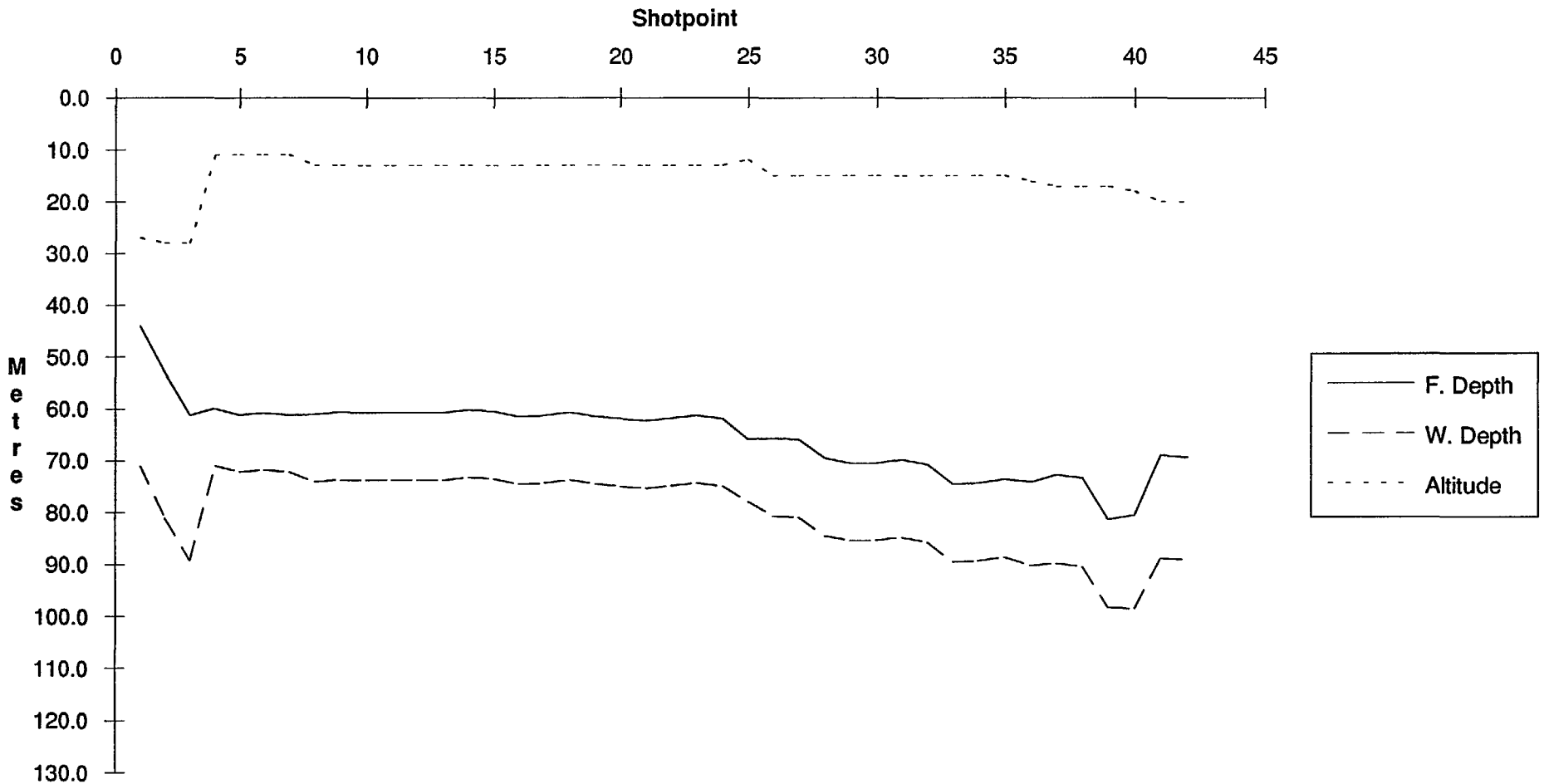
# Line 97008 Methane, Ethane, Ethylene



# Line 97008 Methane, Propane, Propylene



# Line 97008 Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 97009 |
| No. of Shotpoints | 42 |

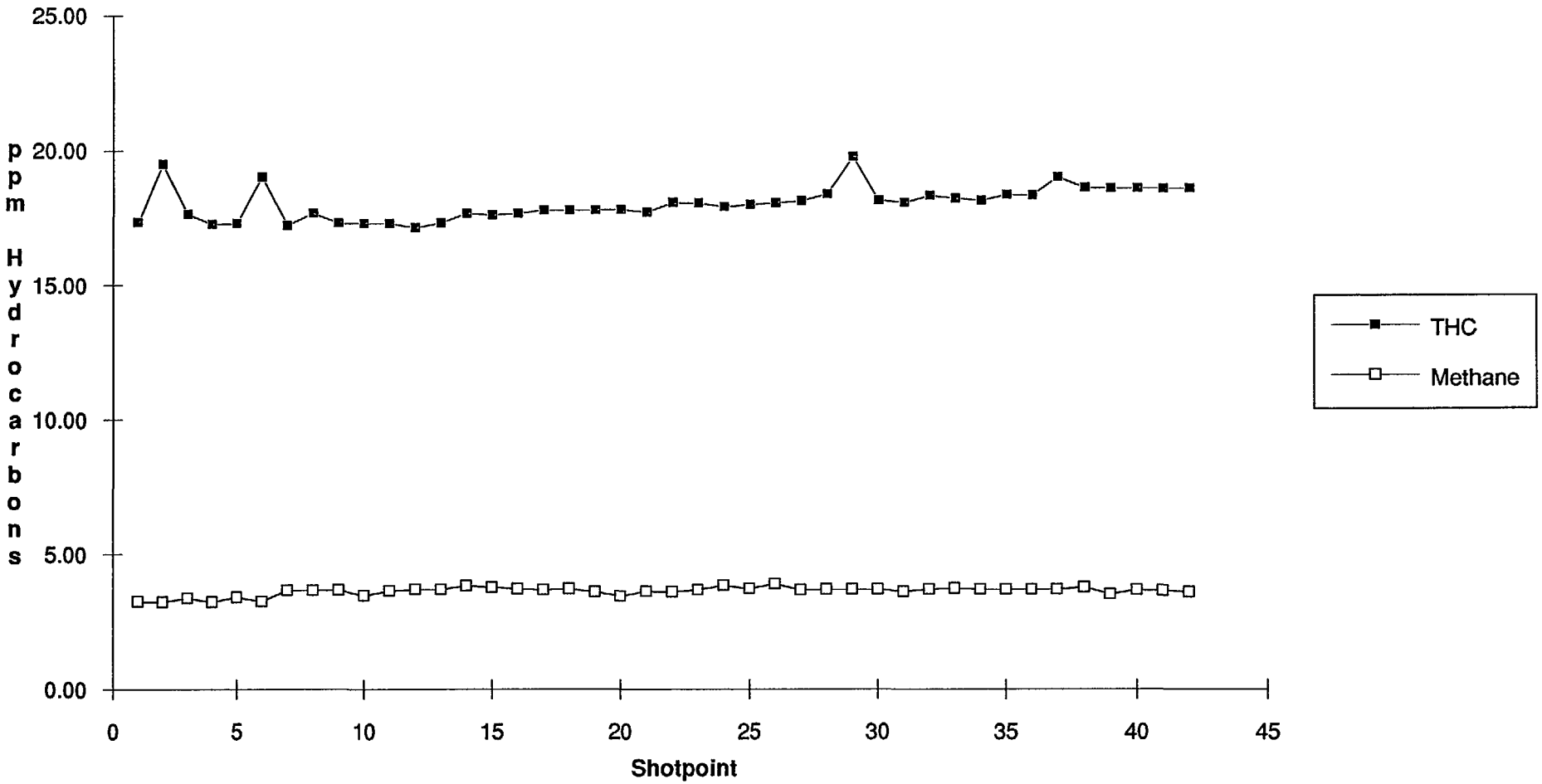
| | Shotpoint | Date | Time | Latitude | | Longitude | |
|---|---|---|---|---|---|---|---|
| Start | 1 | 25-Oct-90 | 12:19:27 | 19 | 30.260 | 116 | 26.799 |
| End | 42 | 25-Oct-90 | 13:41:29 | 19 | 35.347 | 116 | 31.900 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 18.027 | 3.628 | 0.013 | 0.098 | 0.019 | 0.035 | 0.003 | 0.000 | 0.000 | 0.089 | 0.000 | 0.000 | 0.985 |
| Std. Dev. | 0.614 | 0.166 | 0.001 | 0.005 | 0.011 | 0.022 | 0.010 | 0.002 | 0.000 | 0.020 | 0.002 | 0.000 | 0.442 |
| Minimum | 17.138 | 3.222 | 0.011 | 0.087 | 0.008 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.576 |
| Maximum | 19.765 | 3.910 | 0.016 | 0.107 | 0.050 | 0.092 | 0.049 | 0.013 | 0.000 | 0.114 | 0.016 | 0.000 | 2.559 |

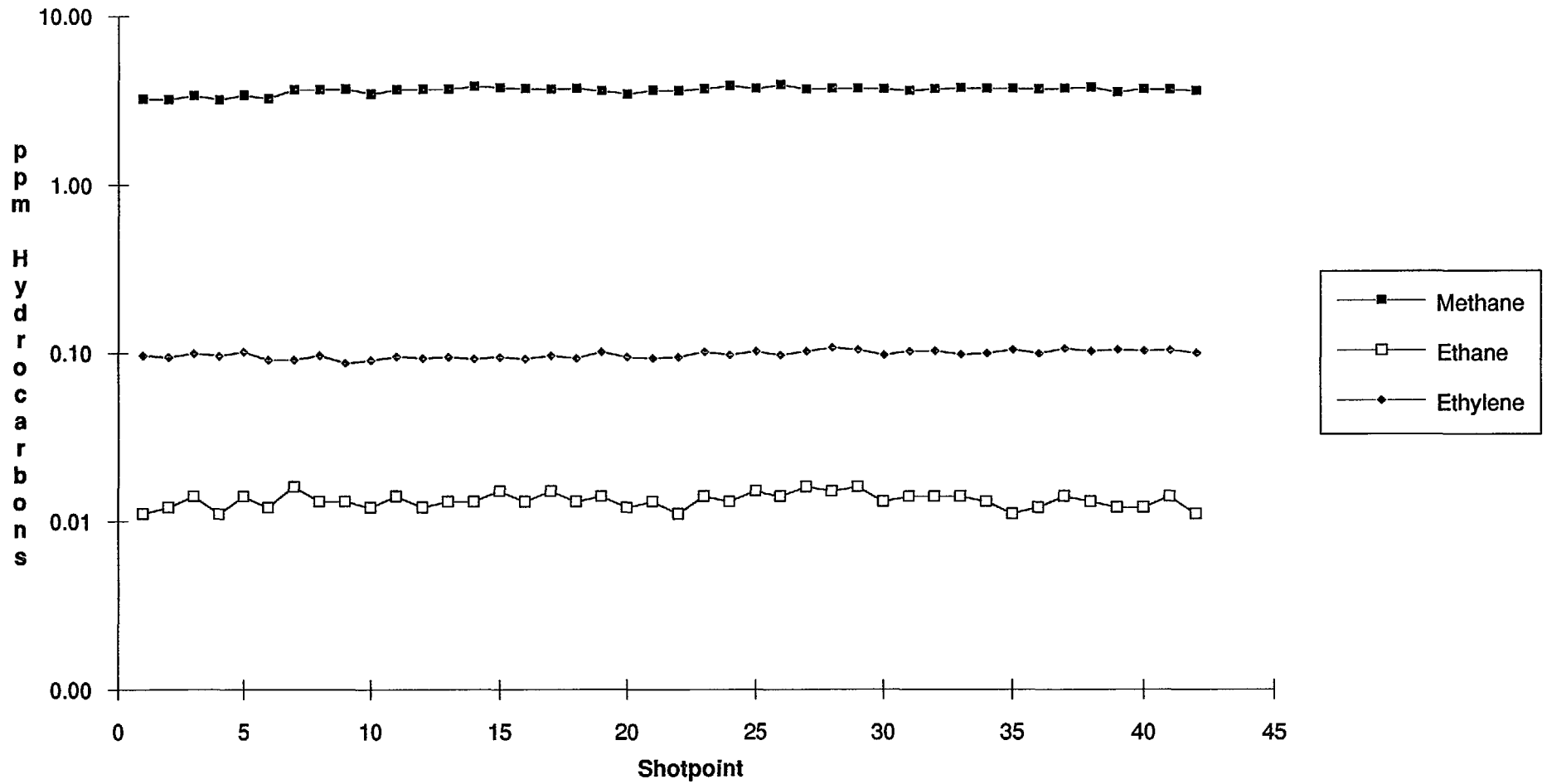
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 53.177 | 24.499 | 68.736 | 84.736 | 16.000 |
| Std. Dev. | 0.152 | 0.193 | 8.053 | 9.829 | 3.350 |
| Minimum | 52.930 | 24.130 | 60.894 | 72.996 | 12.000 |
| Maximum | 53.460 | 24.870 | 82.212 | 111.212 | 29.000 |

Notes No anomalies

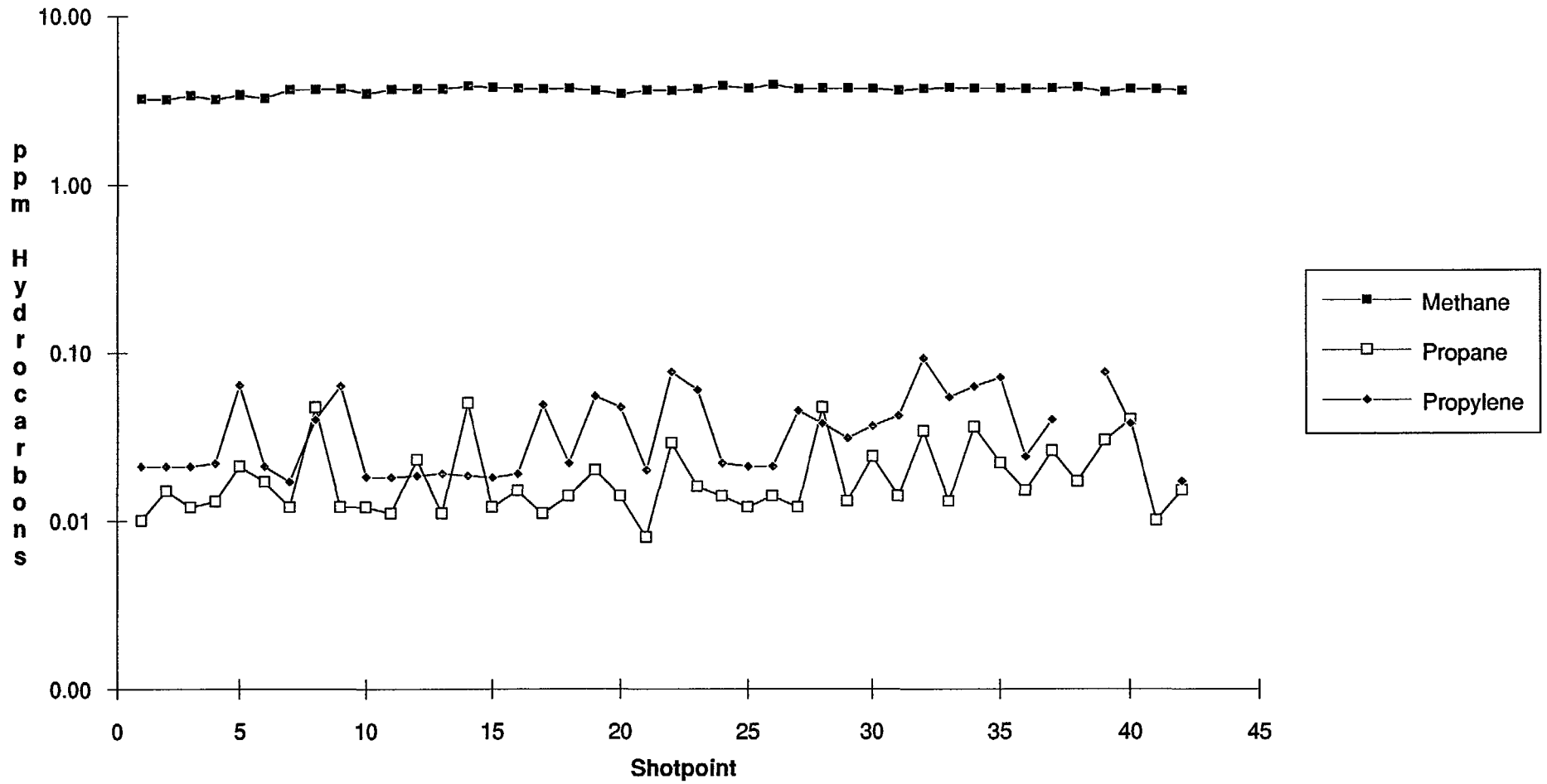
# Line 97009 THC, Methane



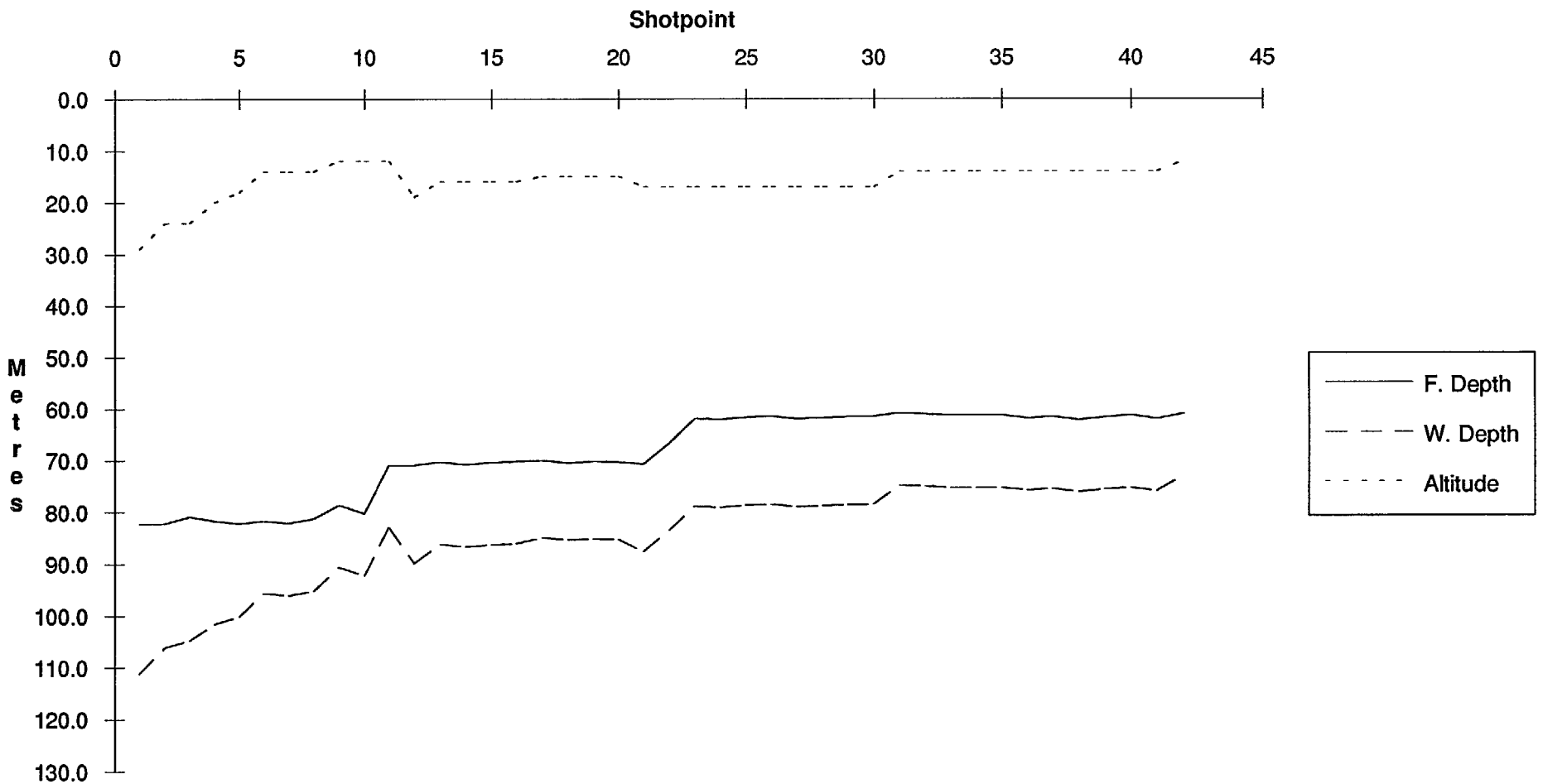
# Line 97009 Methane, Ethane, Ethylene



# Line 97009 Methane, Propane, Propylene



# Line 97009 Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 97010 |
| No. of Shotpoints | 83 |

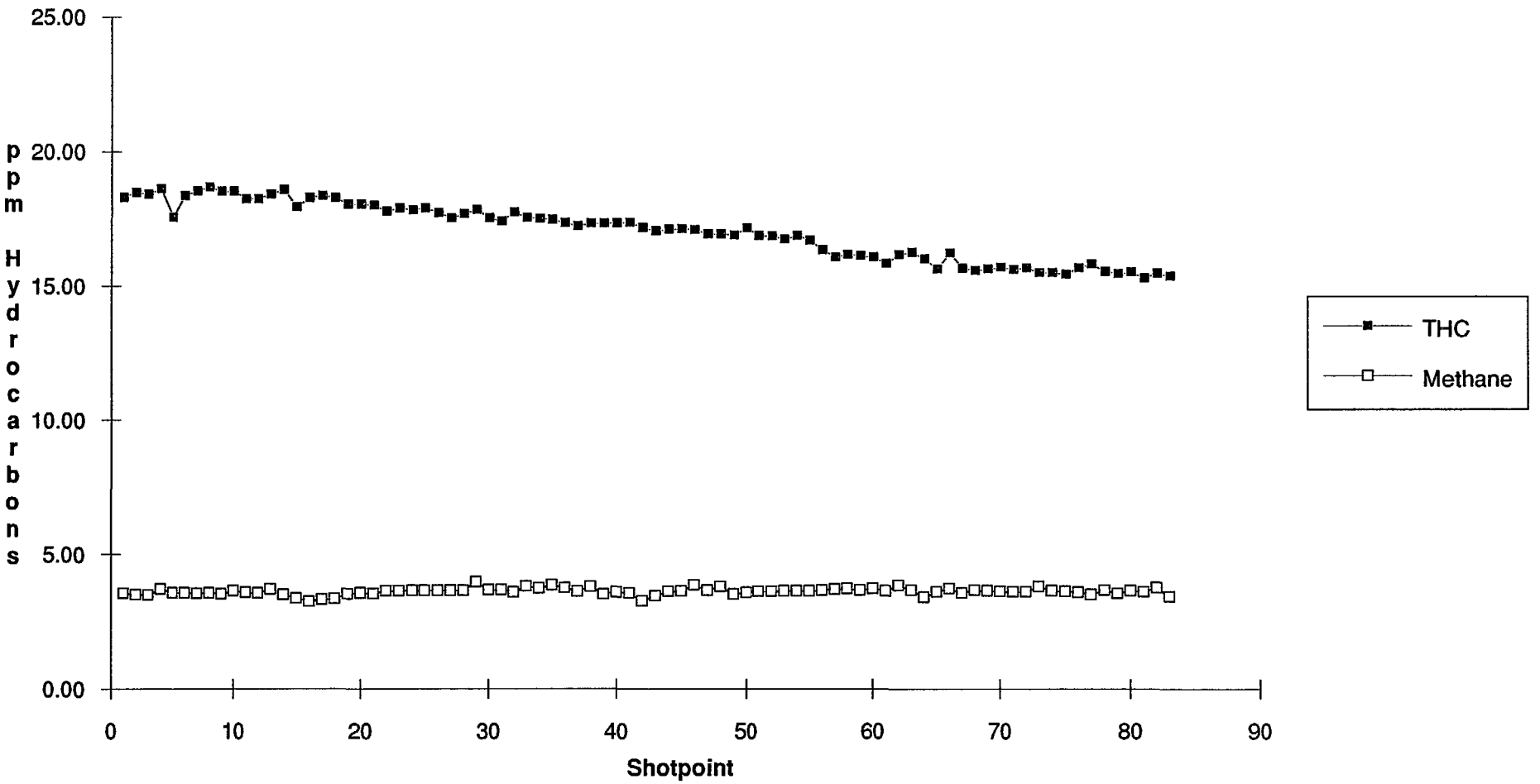
| | Shotpoint | Date | Time | Latitude | | Longitude | |
|---|---|---|---|---|---|---|---|
| Start | 1 | 25-Oct-90 | 15:42:42 | 19 | 39.851 | 116 | 30.204 |
| End | 83 | 25-Oct-90 | 18:26:44 | 19 | 26.015 | 116 | 29.386 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 17.047 | 3.619 | 0.013 | 0.097 | 0.019 | 0.034 | 0.010 | 0.001 | 0.000 | 0.087 | 0.000 | 0.000 | 1.189 |
| Std. Dev. | 1.050 | 0.126 | 0.002 | 0.010 | 0.014 | 0.020 | 0.022 | 0.006 | 0.000 | 0.040 | 0.002 | 0.000 | 0.850 |
| Minimum | 15.293 | 3.254 | 0.009 | 0.079 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.295 |
| Maximum | 18.690 | 3.982 | 0.018 | 0.127 | 0.065 | 0.098 | 0.085 | 0.039 | 0.000 | 0.240 | 0.022 | 0.000 | 4.032 |

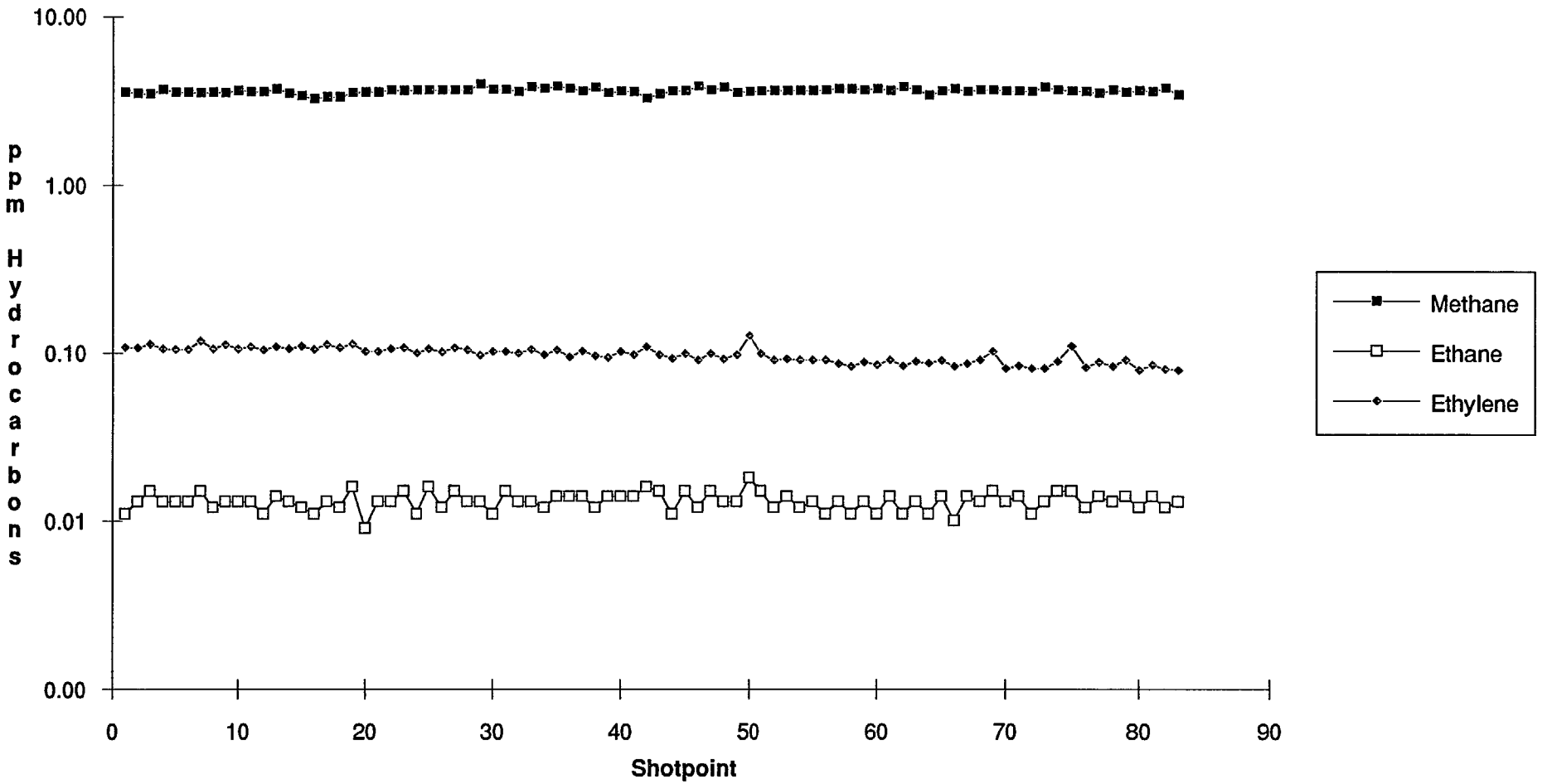
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 53.057 | 24.379 | 73.178 | 86.323 | 13.145 |
| Std. Dev. | 0.264 | 0.243 | 20.205 | 19.875 | 2.159 |
| Minimum | 52.620 | 23.880 | 46.104 | 59.104 | 11.000 |
| Maximum | 53.460 | 24.820 | 110.364 | 126.160 | 19.000 |

Notes No anomalies.

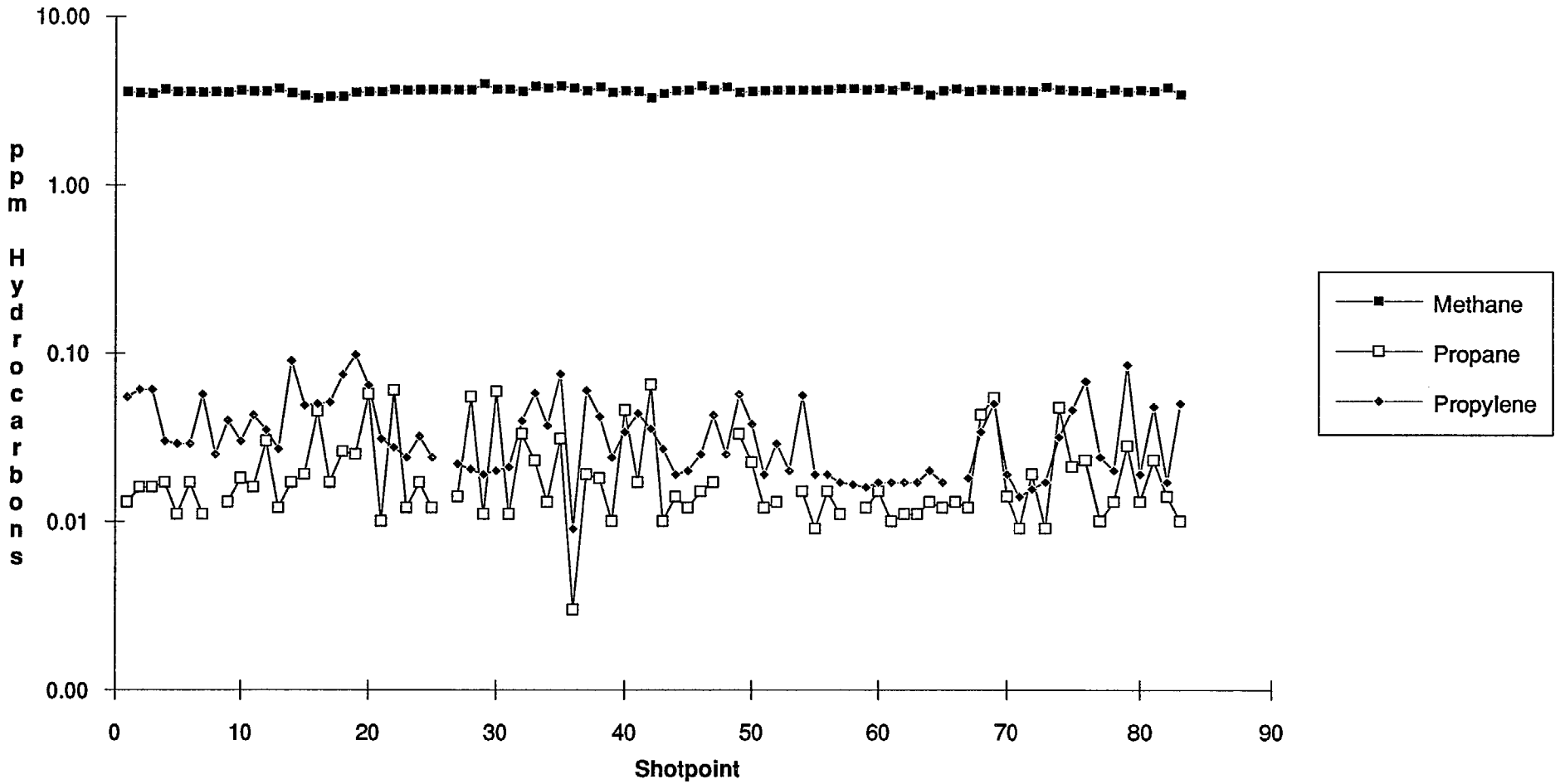
# Line 97010 THC, Methane



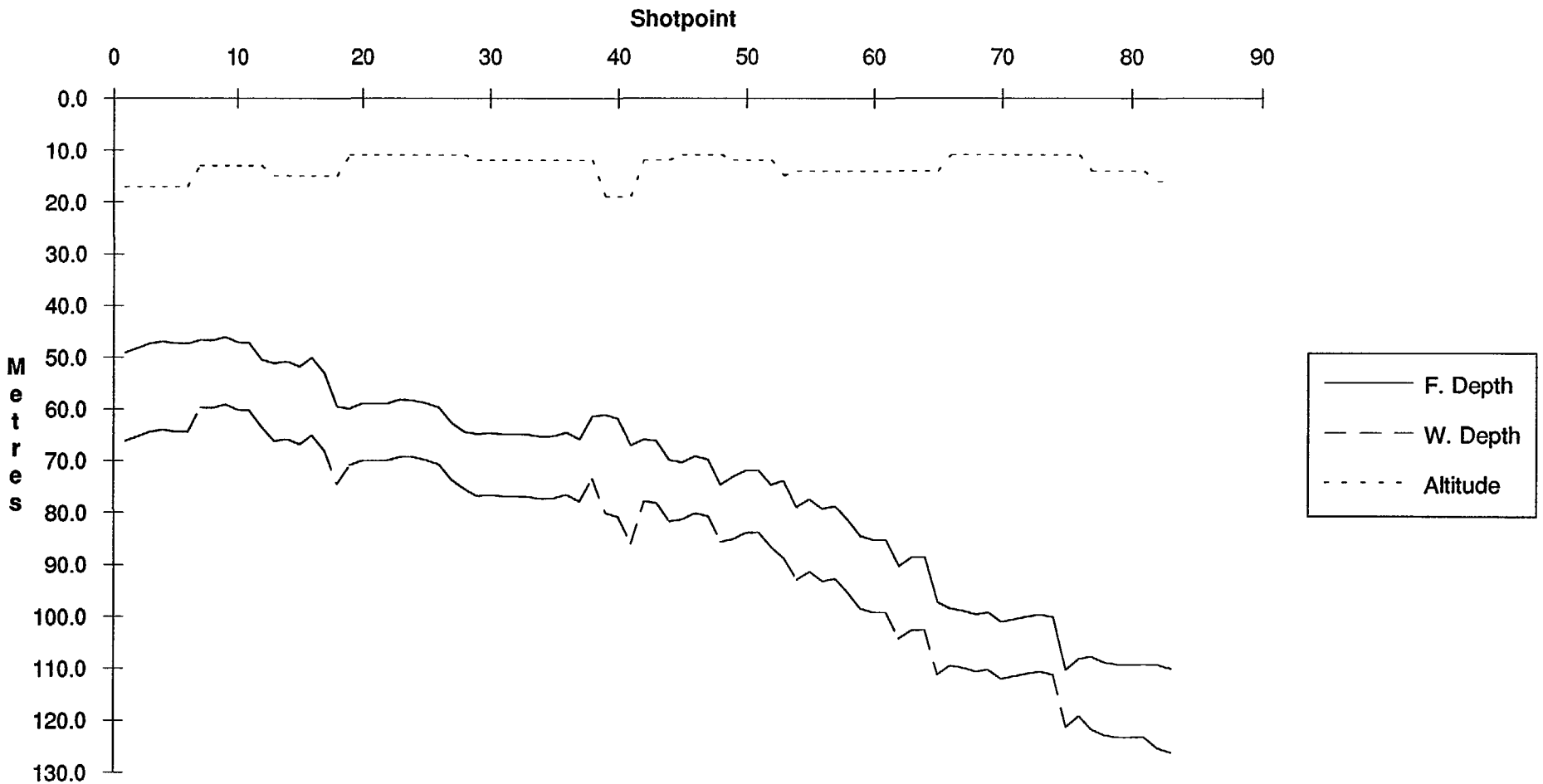
# Line 97010 Methane, Ethane, Ethylene



# Line 97010 Methane, Propane, Propylene



# Line 97010 Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 97011 |
| No. of Shotpoints | 34 |

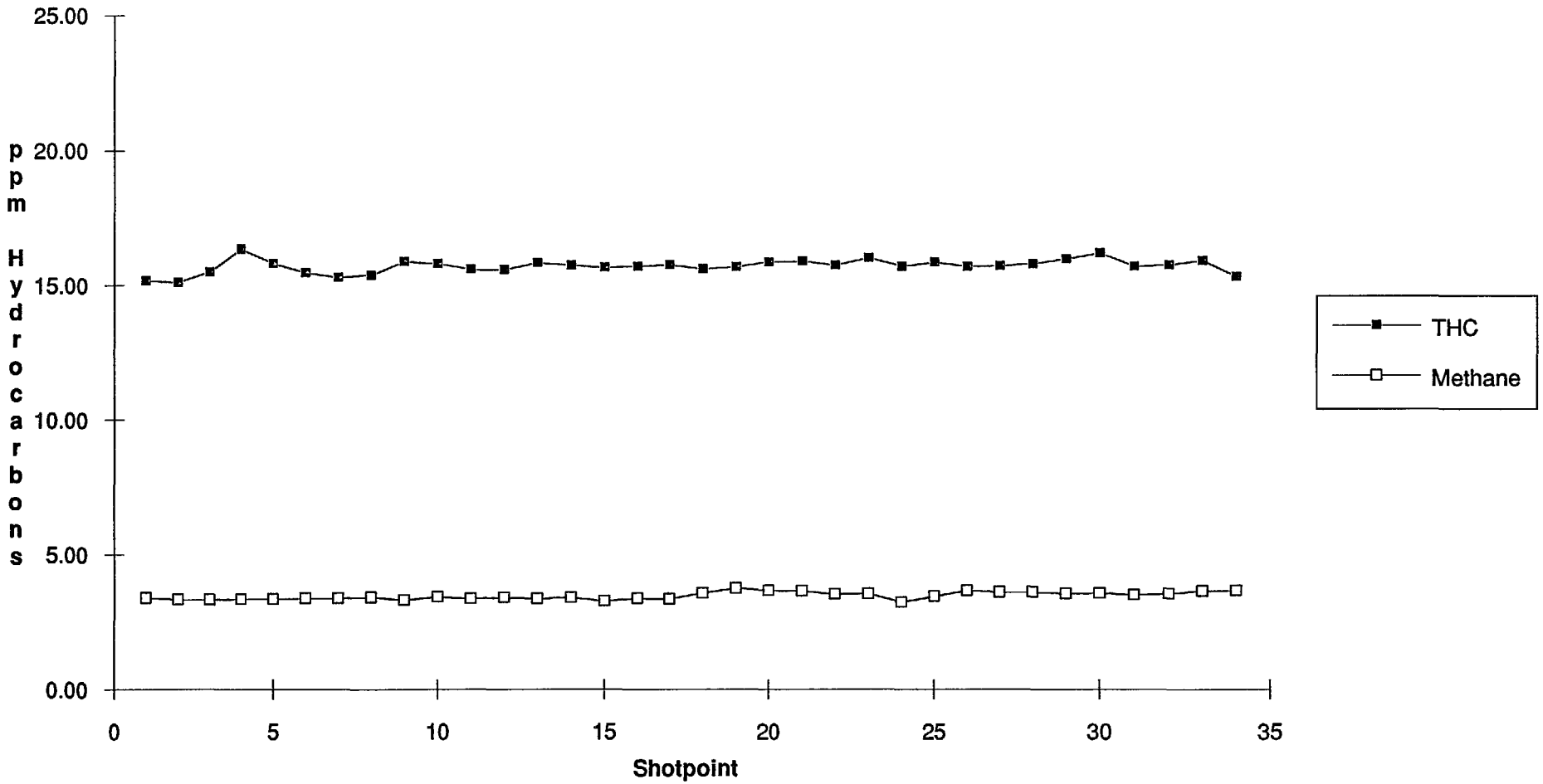
| | Shotpoint | Date | Time | Latitude | | Longitude | |
|---|---|---|---|---|---|---|---|
| Start | 1 | 25-Oct-90 | 20:17:56 | 19 | 27.132 | 116 | 28.505 |
| End | 34 | 25-Oct-90 | 21:24:02 | 19 | 28.121 | 116 | 34.166 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 15.704 | 3.468 | 0.012 | 0.091 | 0.019 | 0.026 | 0.005 | 0.000 | 0.000 | 0.065 | 0.000 | 0.000 | 1.025 |
| Std. Dev. | 0.263 | 0.135 | 0.001 | 0.007 | 0.014 | 0.015 | 0.014 | 0.000 | 0.000 | 0.017 | 0.000 | 0.000 | 0.607 |
| Minimum | 15.100 | 3.239 | 0.010 | 0.071 | 0.007 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.570 |
| Maximum | 16.342 | 3.746 | 0.014 | 0.115 | 0.065 | 0.067 | 0.064 | 0.000 | 0.000 | 0.112 | 0.000 | 0.000 | 2.687 |

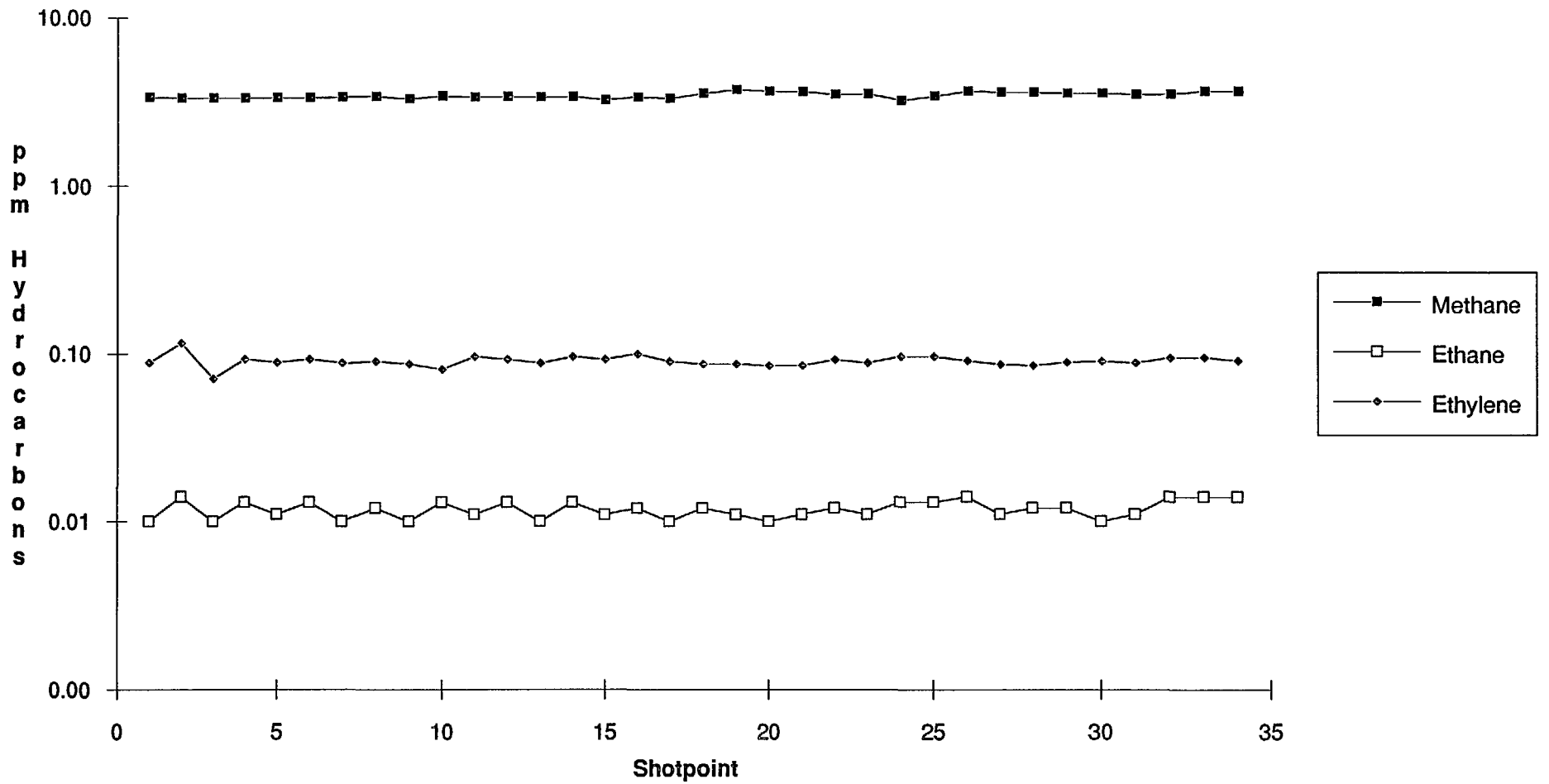
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 52.783 | 24.202 | 91.518 | 108.283 | 16.765 |
| Std. Dev. | 0.059 | 0.142 | 4.316 | 5.102 | 1.075 |
| Minimum | 52.610 | 23.960 | 76.704 | 91.704 | 15.000 |
| Maximum | 52.900 | 24.400 | 95.676 | 112.676 | 18.000 |

Notes No anomalies.

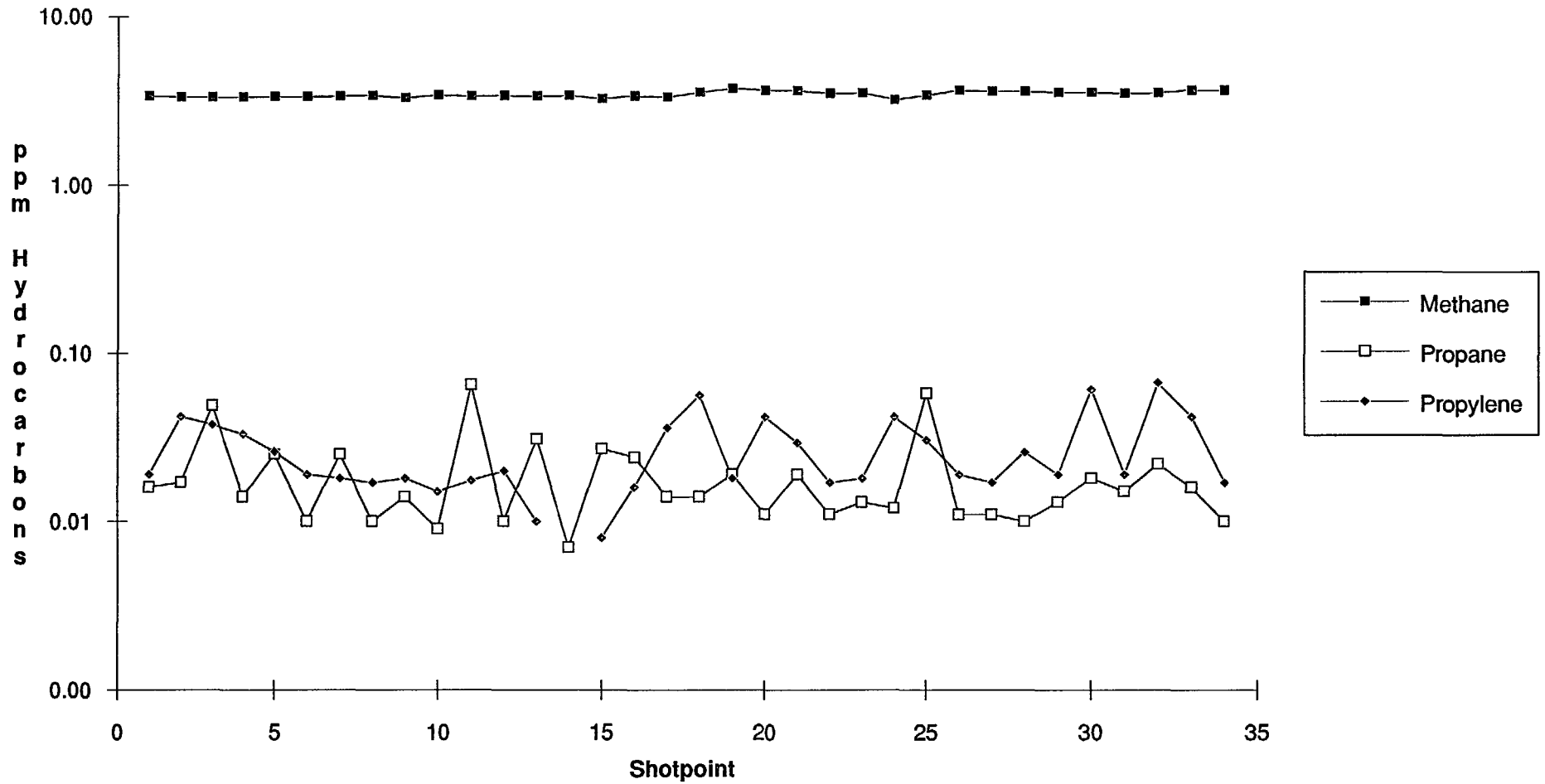
# Line 97011 THC, Methane



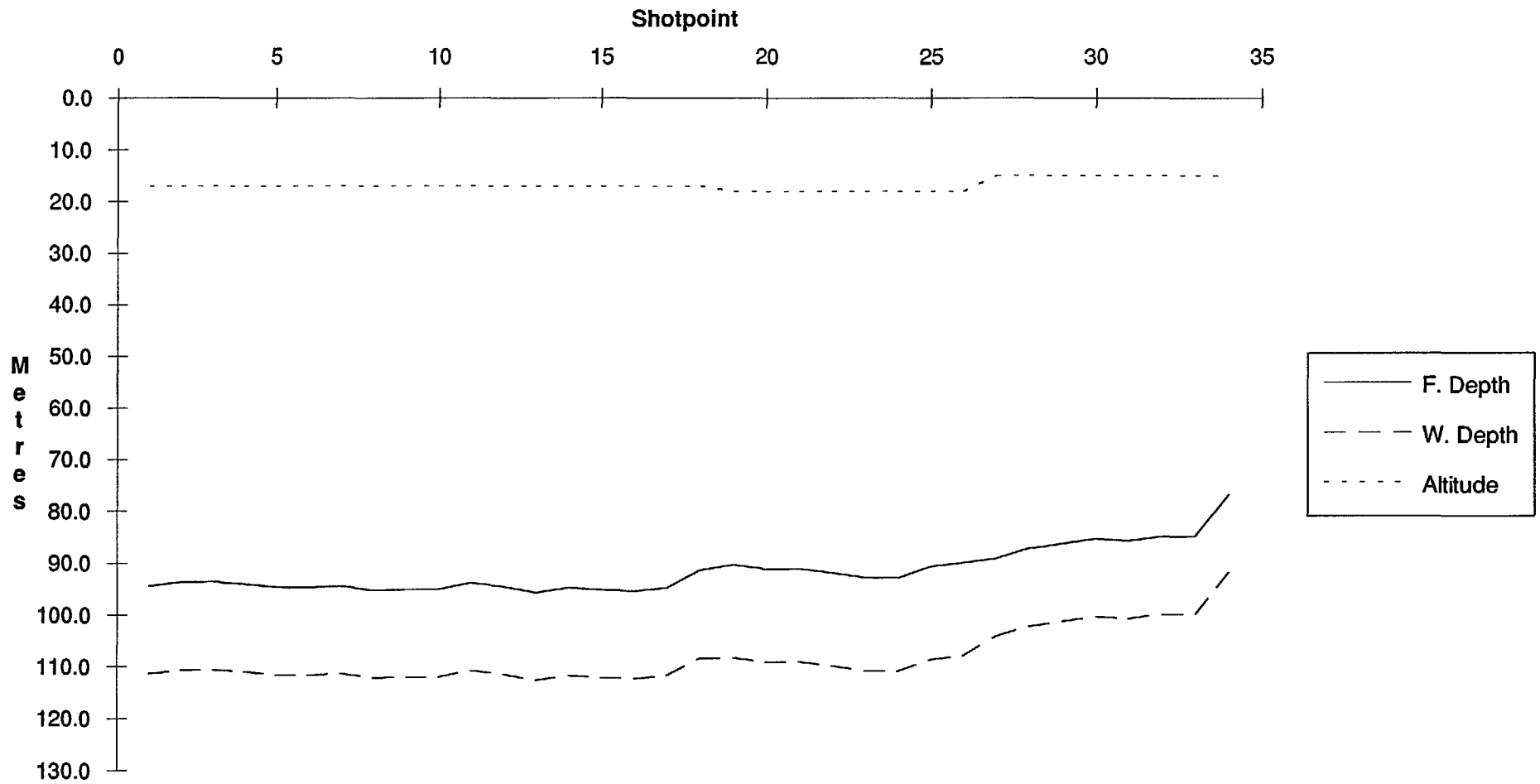
# Line 97011 Methane, Ethane, Ethylene



## Line 97011 Methane, Propane, Propylene



# Line 97011 Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 97012 |
| No. of Shotpoints | 41 |

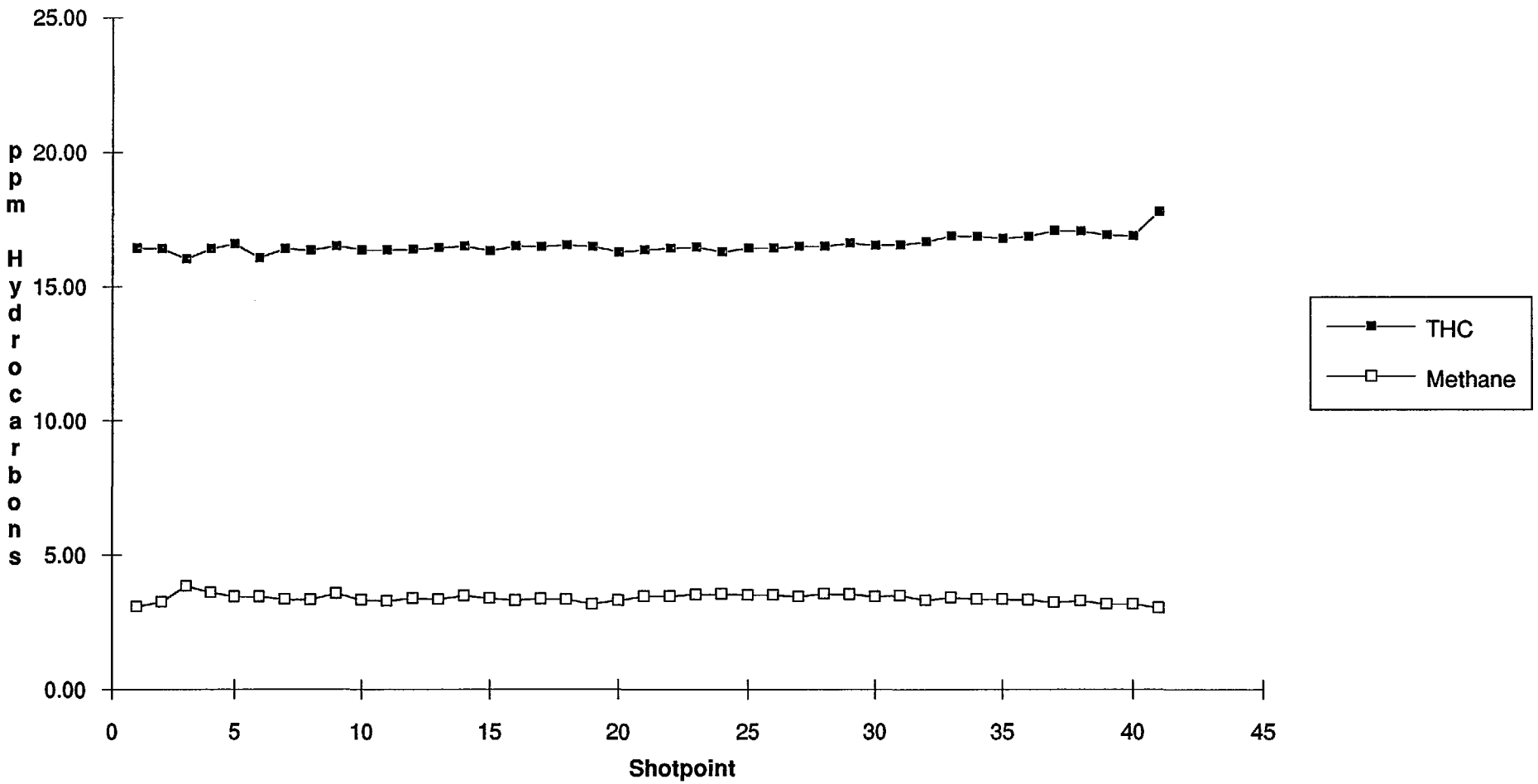
| | Shotpoint | Date | Time | Latitude | | Longitude | |
|---|---|---|---|---|---|---|---|
| Start | 1 | 25-Oct-90 | 23:10:14 | 19 | 28.197 | 116 | 34.072 |
| End | 41 | 26-Oct-90 | 00:30:26 | 19 | 33.476 | 116 | 38.692 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 16.554 | 3.385 | 0.012 | 0.100 | 0.017 | 0.032 | 0.009 | 0.002 | 0.000 | 0.090 | 0.000 | 0.000 | 1.183 |
| Std. Dev. | 0.305 | 0.151 | 0.001 | 0.006 | 0.011 | 0.019 | 0.019 | 0.010 | 0.000 | 0.024 | 0.000 | 0.000 | 0.740 |
| Minimum | 16.033 | 3.031 | 0.009 | 0.090 | 0.008 | 0.019 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.601 |
| Maximum | 17.798 | 3.835 | 0.016 | 0.122 | 0.070 | 0.091 | 0.073 | 0.047 | 0.000 | 0.126 | 0.000 | 0.000 | 3.881 |

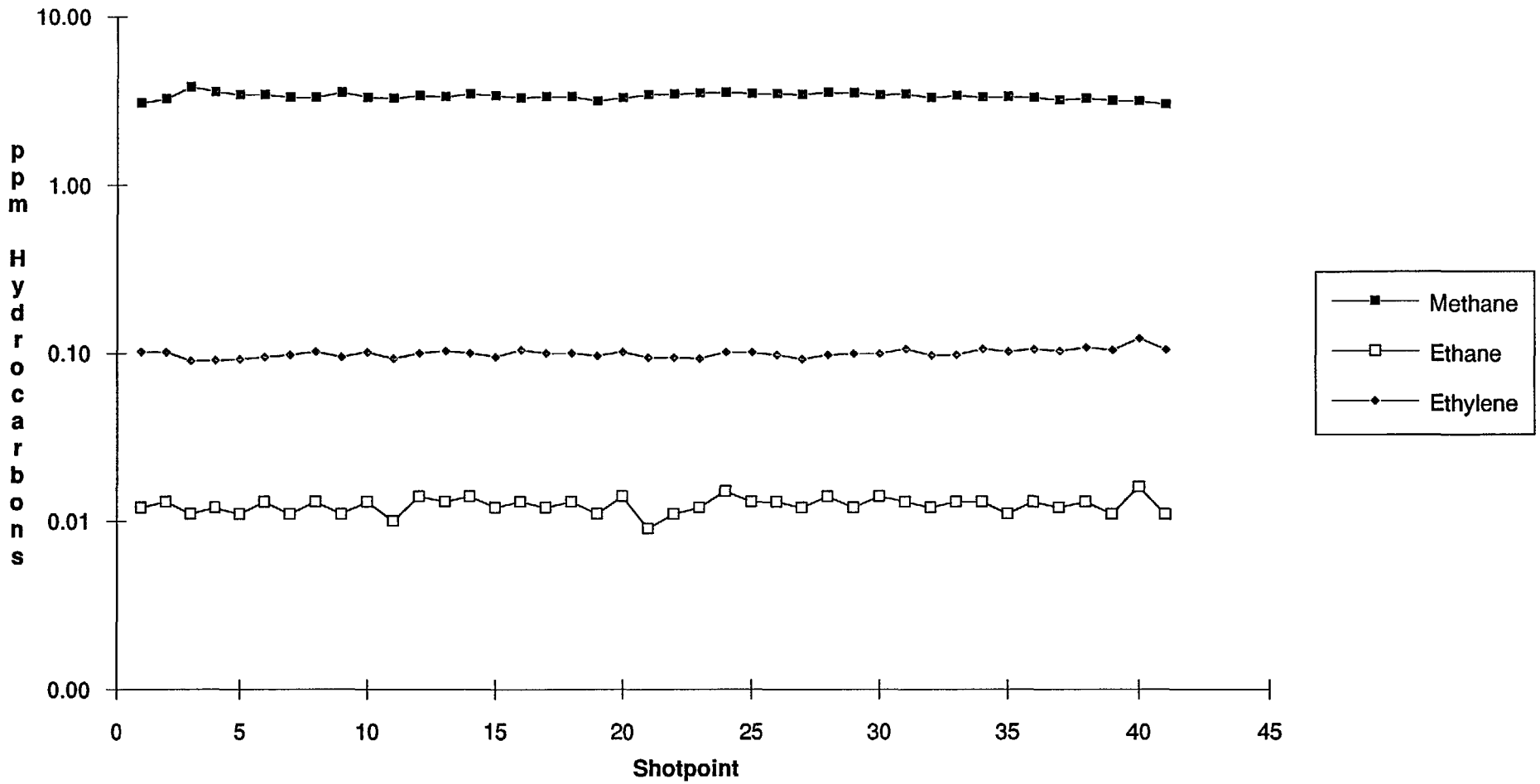
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 53.812 | 25.056 | 60.225 | 74.908 | 14.683 |
| Std. Dev. | 0.239 | 0.273 | 9.948 | 8.849 | 2.392 |
| Minimum | 53.530 | 24.460 | 46.818 | 61.328 | 11.000 |
| Maximum | 54.450 | 25.660 | 78.030 | 94.030 | 17.000 |

Notes No anomalies.

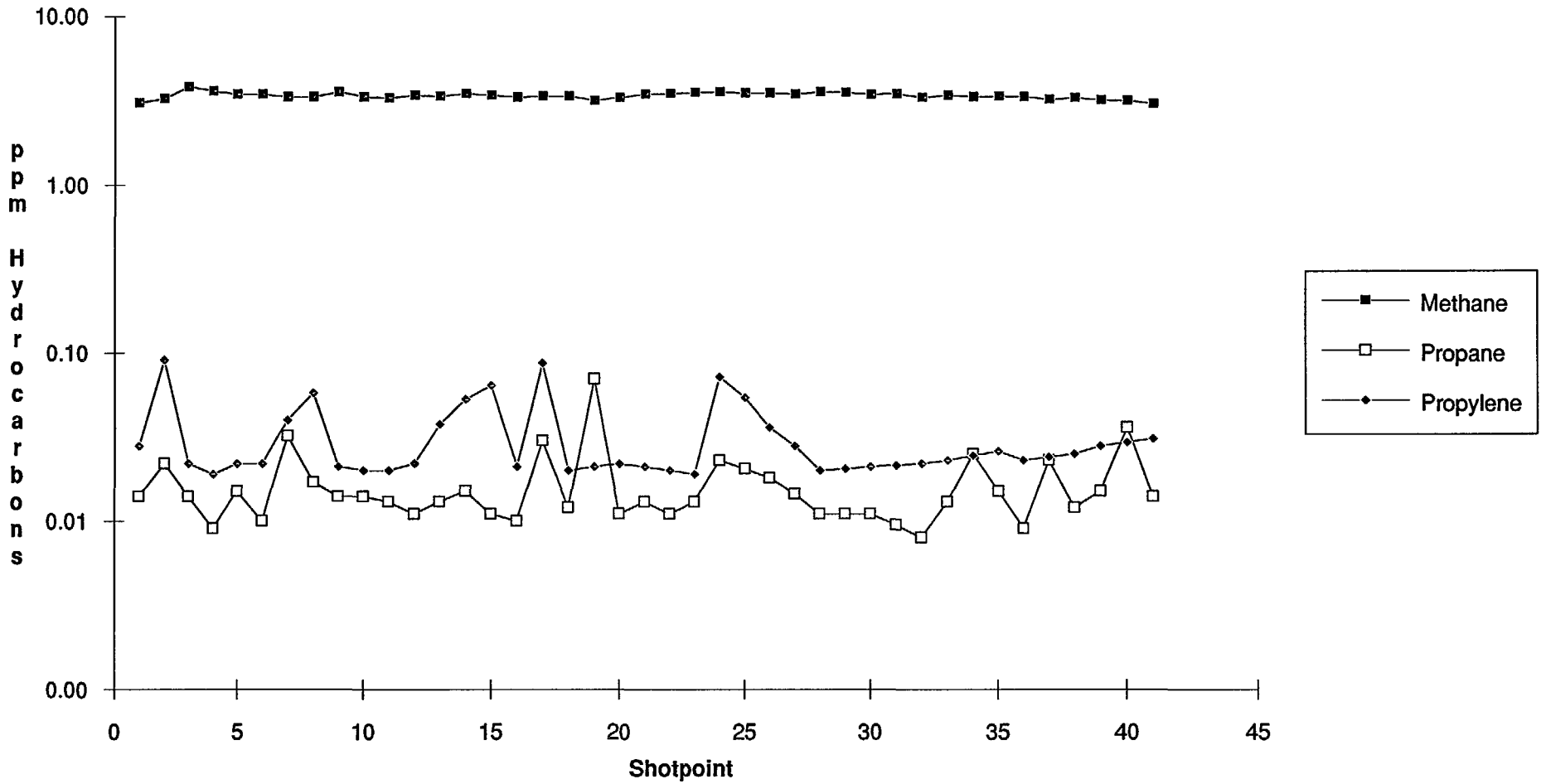
# Line 97012 THC, Methane



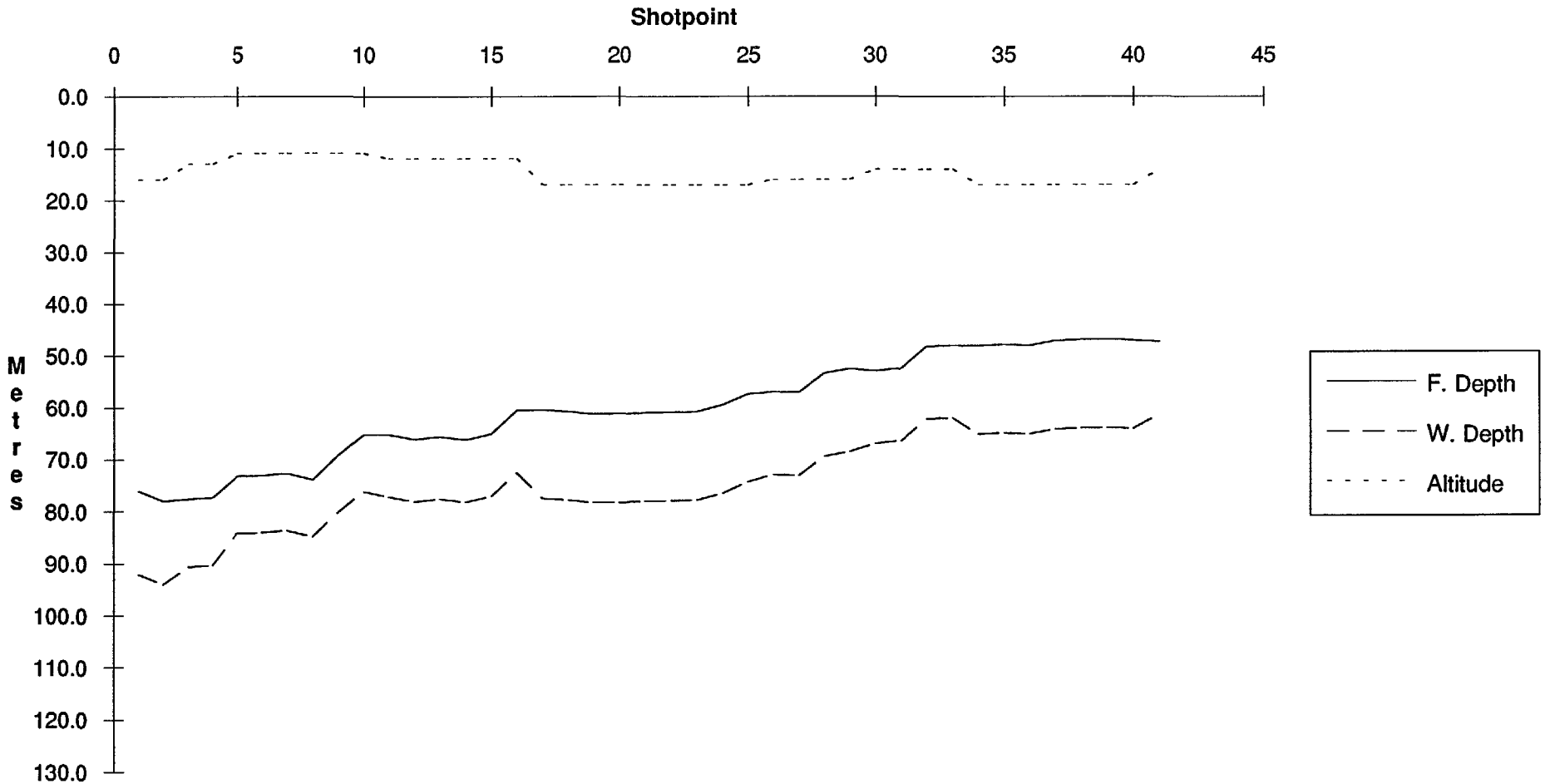
# Line 97012 Methane, Ethane, Ethylene



# Line 97012 Methane, Propane, Propylene



# Line 97012 Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 97013 |
| No. of Shotpoints | 36 |

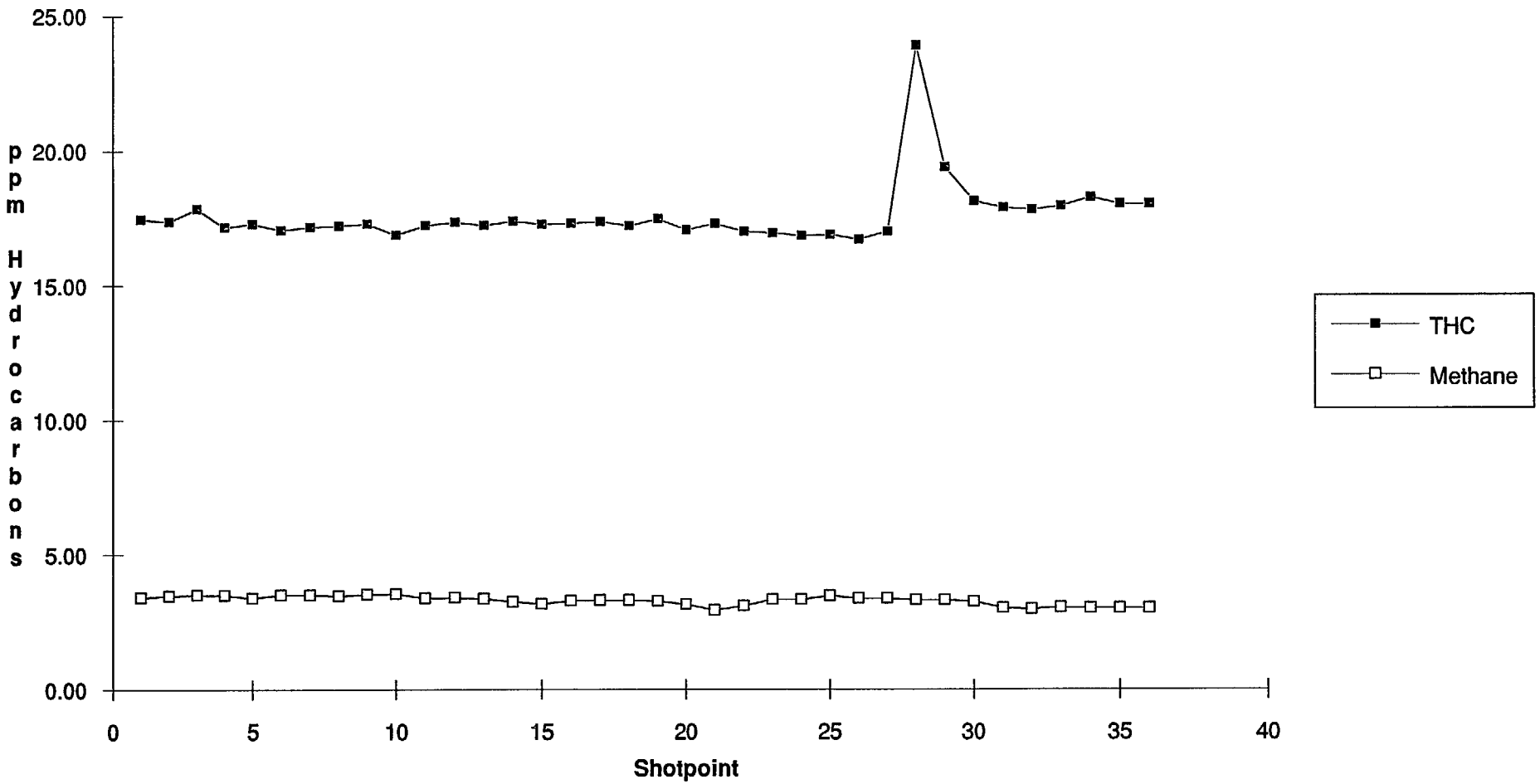
| | Shotpoint | Date | Time | Latitude | | Longitude | |
|---|---|---|---|---|---|---|---|
| Start | 2 | 26-Oct-90 | 02:10:29 | 19 | 33.286 | 116 | 38.025 |
| End | 37 | 26-Oct-90 | 03:20:40 | 19 | 27.671 | 116 | 36.468 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 17.602 | 3.290 | 0.012 | 0.100 | 0.018 | 0.031 | 0.007 | 0.000 | 0.000 | 0.100 | 0.000 | 0.000 | 1.106 |
| Std. Dev. | 1.194 | 0.182 | 0.002 | 0.004 | 0.011 | 0.016 | 0.015 | 0.002 | 0.000 | 0.032 | 0.000 | 0.000 | 0.617 |
| Minimum | 16.714 | 2.942 | 0.009 | 0.090 | 0.003 | 0.017 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.543 |
| Maximum | 23.892 | 3.538 | 0.015 | 0.107 | 0.043 | 0.069 | 0.050 | 0.009 | 0.000 | 0.194 | 0.000 | 0.000 | 3.203 |

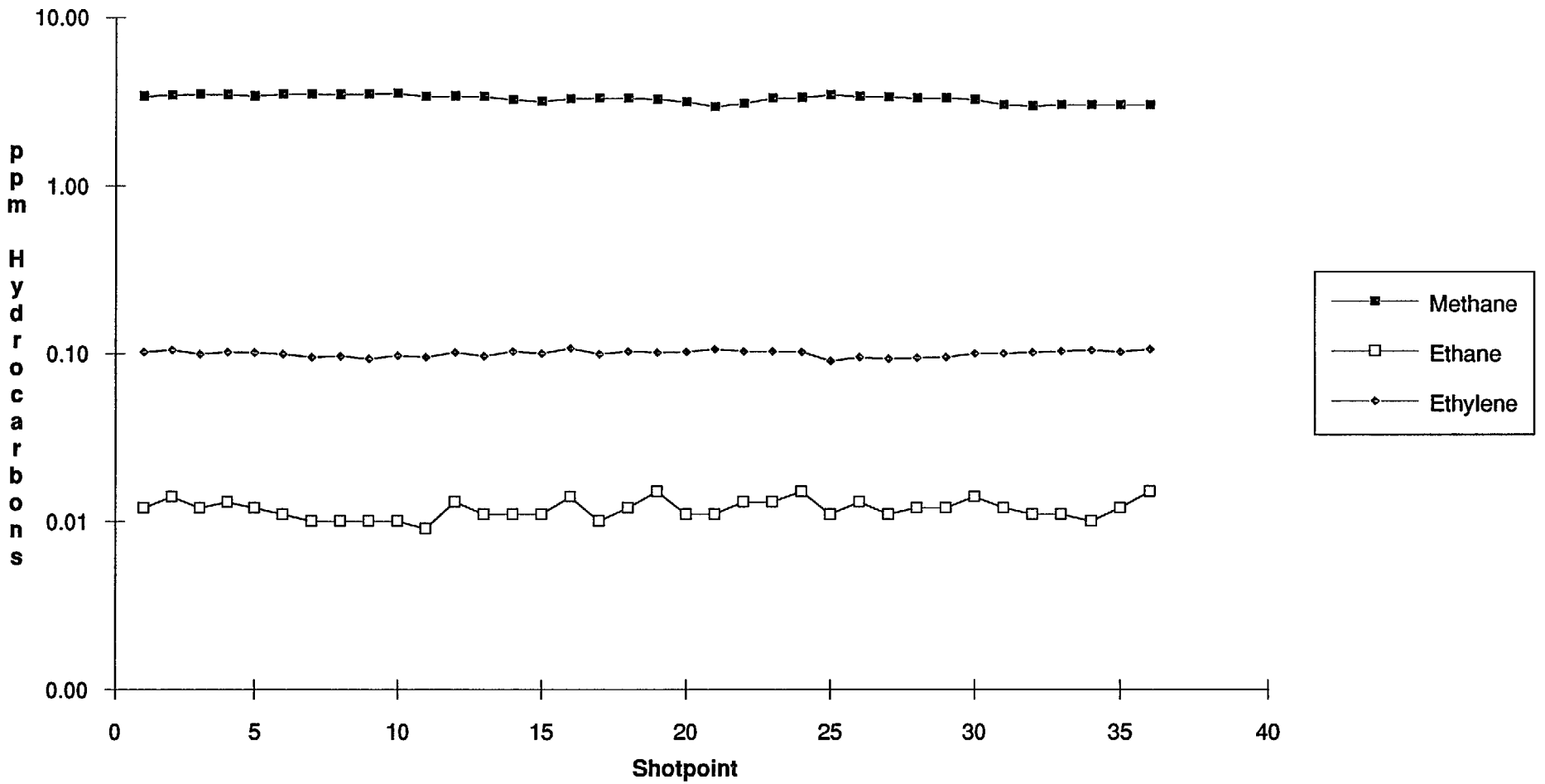
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 54.661 | 25.814 | 59.234 | 72.623 | 13.389 |
| Std. Dev. | 0.216 | 0.253 | 8.481 | 7.449 | 2.749 |
| Minimum | 54.370 | 25.310 | 46.206 | 61.206 | 10.000 |
| Maximum | 55.080 | 26.350 | 72.318 | 87.318 | 18.000 |

Notes **Minor THC spike between shotpoints 28 to 30**

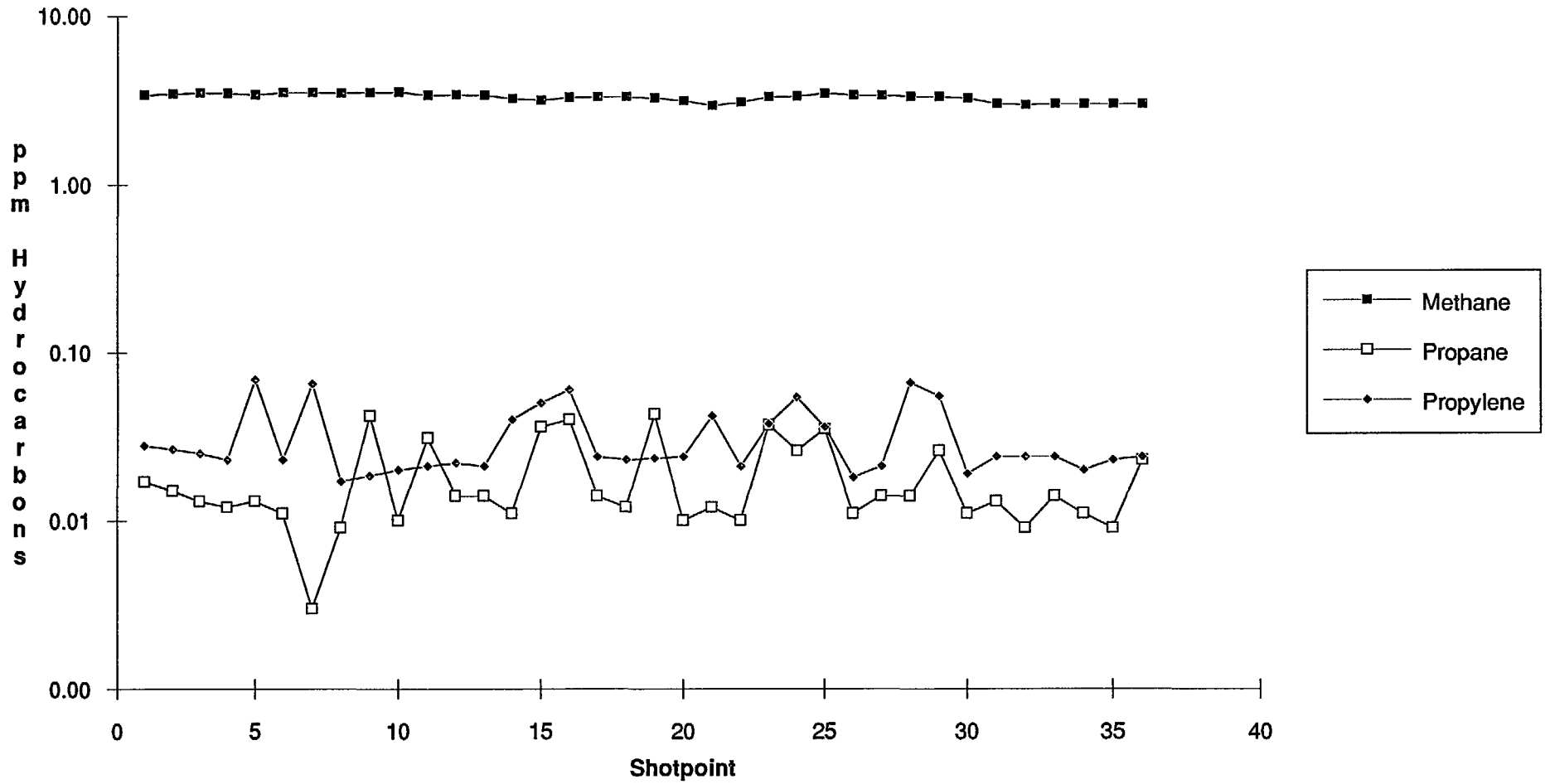
# Line 97013 THC, Methane



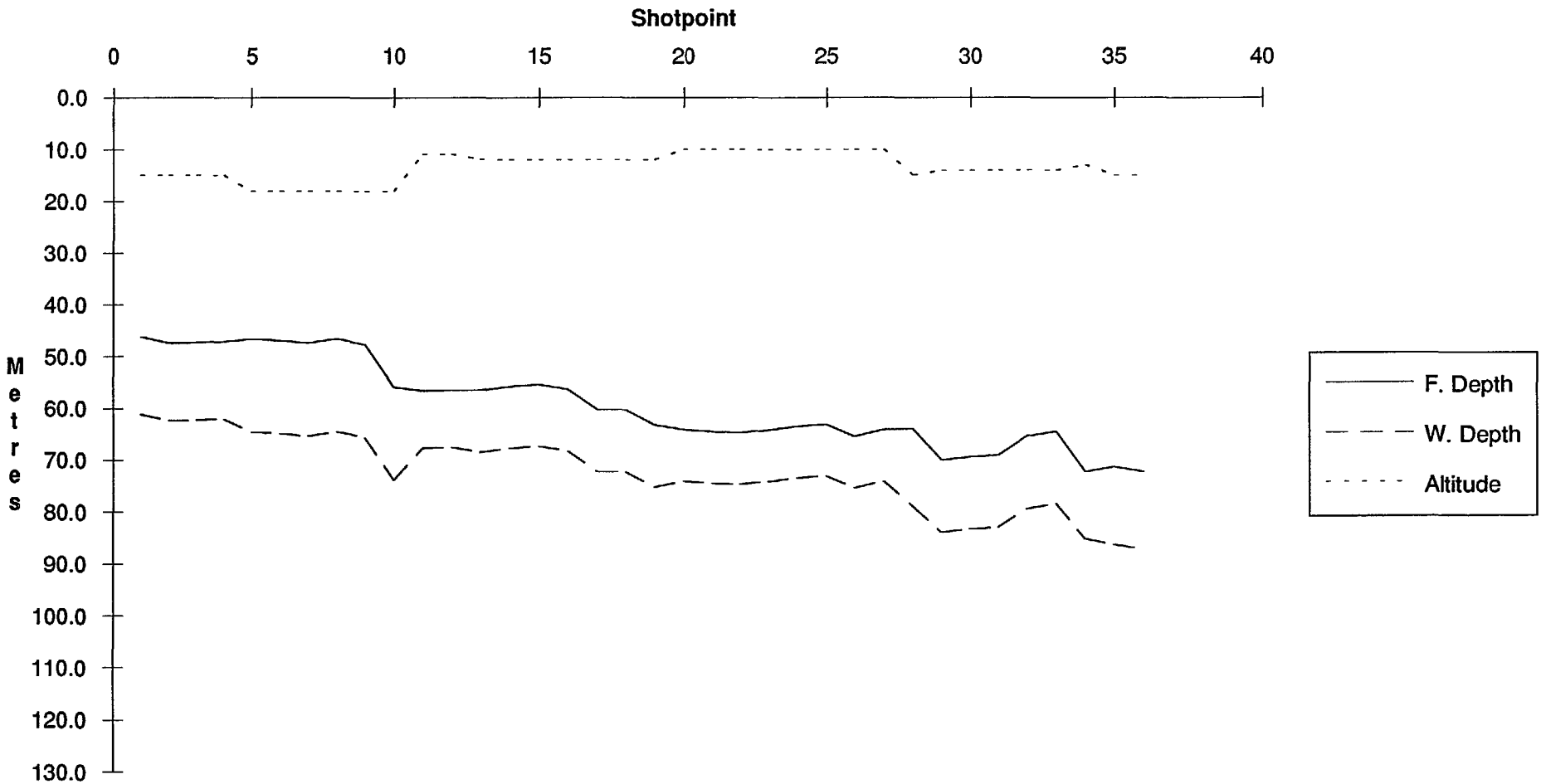
## Line 97013 Methane, Ethane, Ethylene



# Line 97013 Methane, Propane, Propylene



# Line 97013 Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 97021 |
| No. of Shotpoints | 67 |

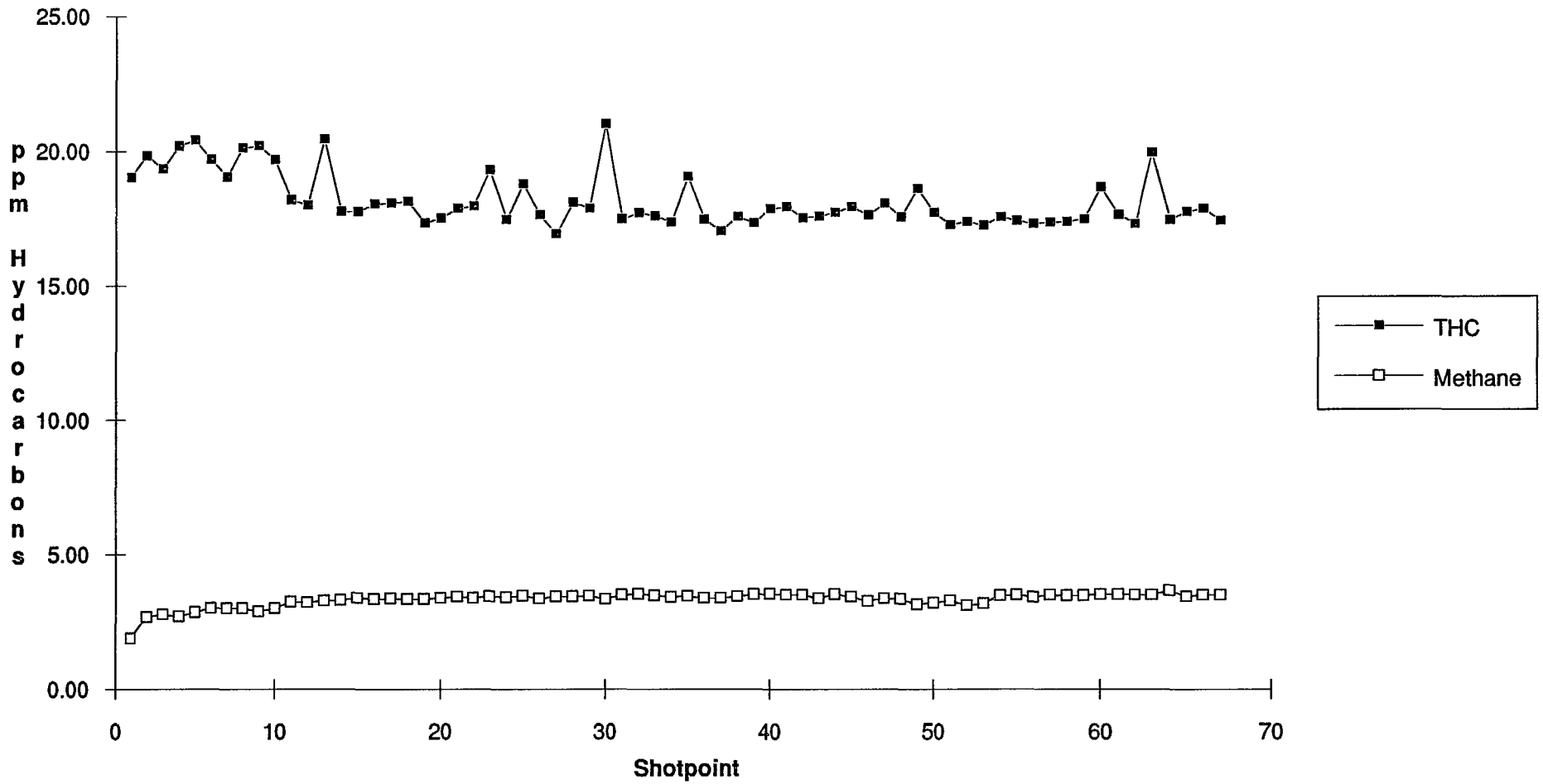
| | Shotpoint | Date | Time | Latitude | | Longitude | |
|---|---|---|---|---|---|---|---|
| Start | 1 | 27-Oct-90 | 12:55:10 | 19 | 29.708 | 116 | 31.660 |
| End | 68 | 27-Oct-90 | 15:22:40 | 19 | 37.749 | 116 | 21.406 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 18.173 | 3.318 | 0.012 | 0.083 | 0.019 | 0.033 | 0.006 | 0.000 | 0.000 | 0.054 | 0.018 | 0.000 | 1.117 |
| Std. Dev. | 0.996 | 0.277 | 0.004 | 0.009 | 0.017 | 0.021 | 0.020 | 0.003 | 0.000 | 0.015 | 0.005 | 0.000 | 0.842 |
| Minimum | 16.943 | 1.895 | 0.004 | 0.032 | 0.000 | 0.012 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.315 |
| Maximum | 21.021 | 3.661 | 0.041 | 0.110 | 0.084 | 0.087 | 0.089 | 0.025 | 0.000 | 0.084 | 0.029 | 0.000 | 4.011 |

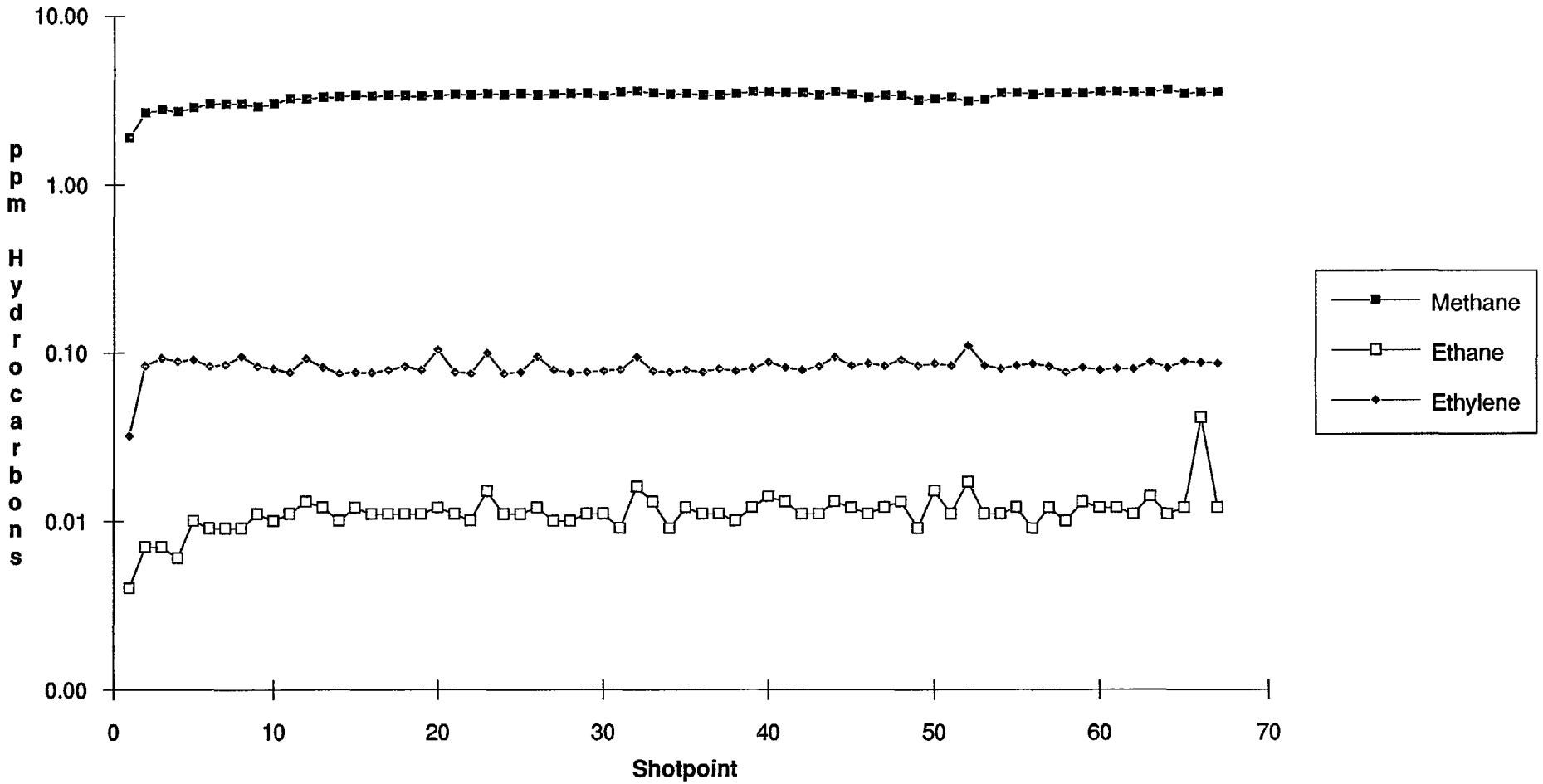
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 52.889 | 24.188 | 68.325 | 84.176 | 15.851 |
| Std. Dev. | 0.195 | 0.258 | 7.315 | 4.583 | 4.117 |
| Minimum | 52.700 | 23.790 | 52.836 | 73.610 | 11.000 |
| Maximum | 53.540 | 24.980 | 76.908 | 91.706 | 25.000 |

Notes No anomalies.

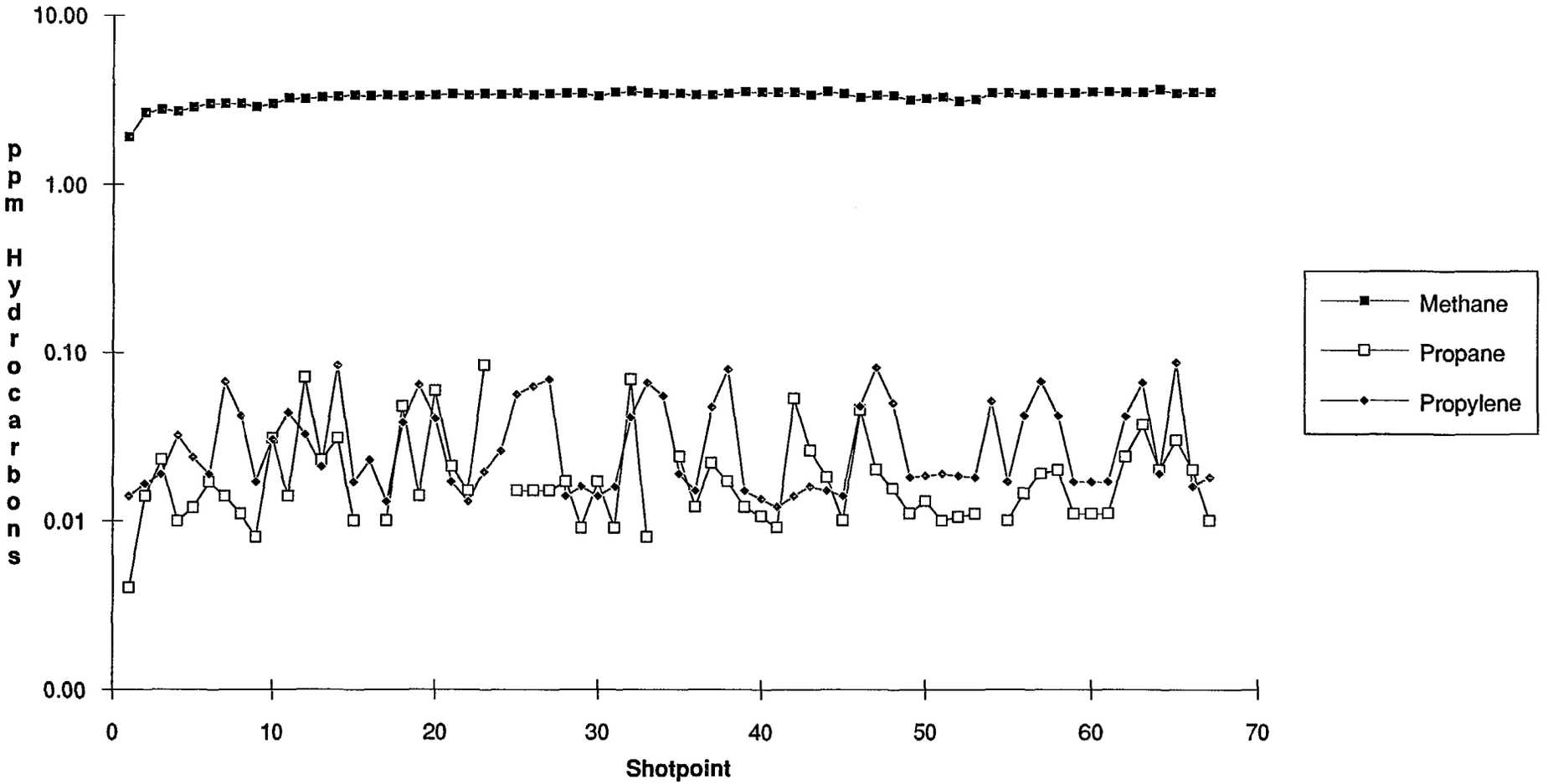
# Line 97021 THC, Methane



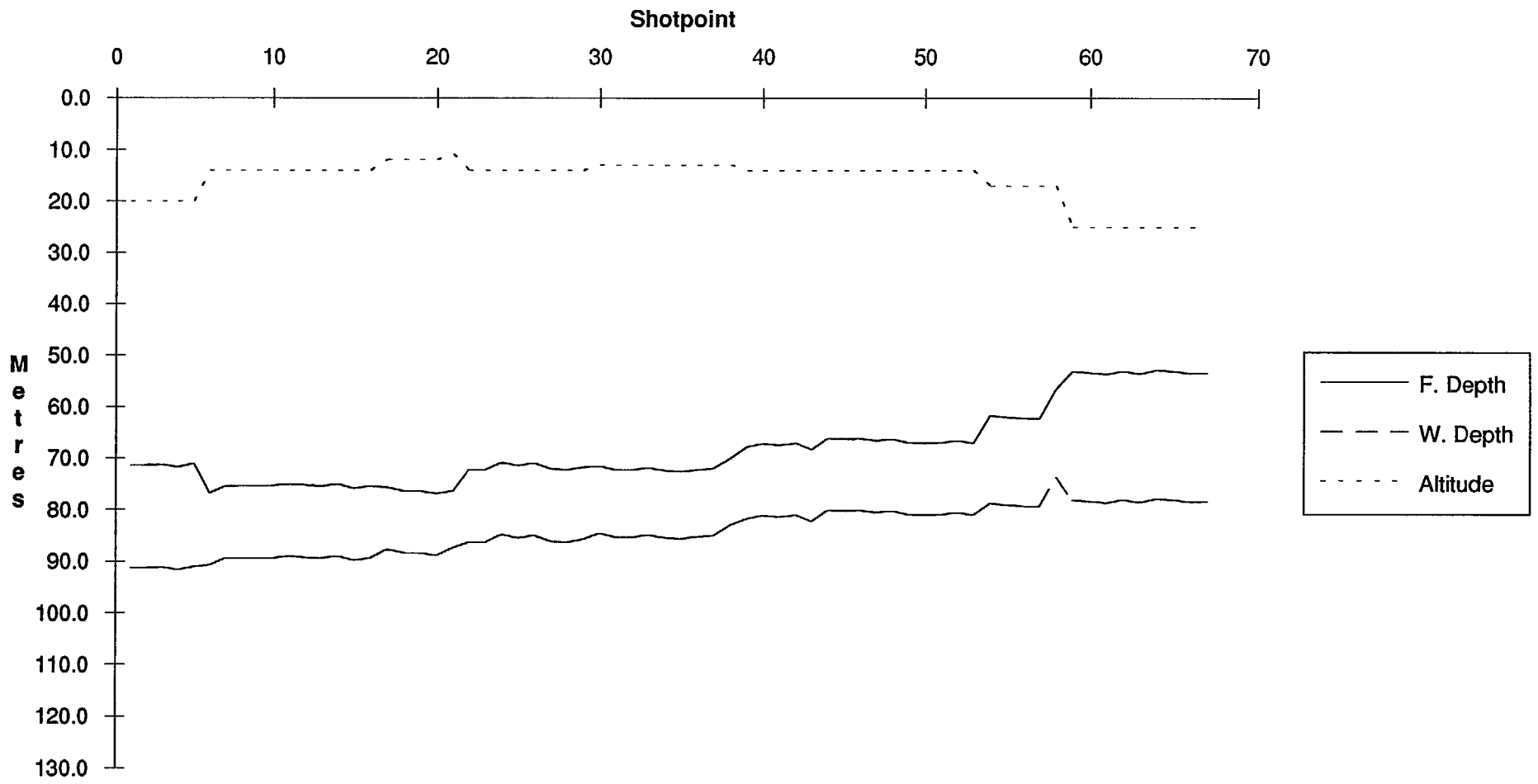
# Line 97021 Methane, Ethane, Ethylene



## Line 97021 Methane, Propane, Propylene



# Line 97021 Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 97022 |
| No. of Shotpoints | 62 |

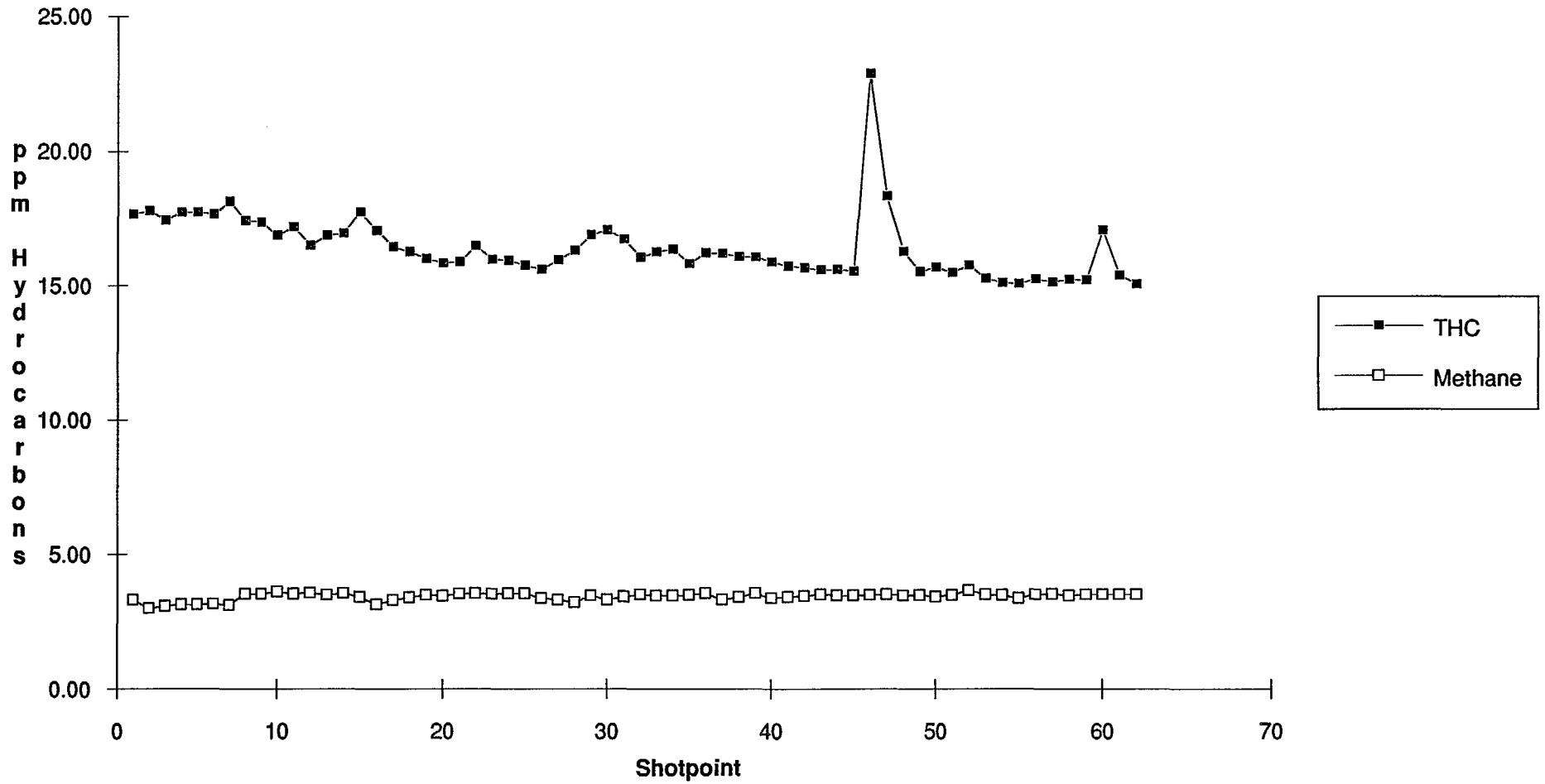
| | Shotpoint | Date | Time | Latitude | | Longitude | |
|---|---|---|---|---|---|---|---|
| Start | 1 | 27-Oct-90 | 17:10:47 | 19 | 39.197 | 116 | 22.870 |
| End | 62 | 27-Oct-90 | 19:12:50 | 19 | 29.158 | 116 | 20.690 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 16.412 | 3.424 | 0.012 | 0.089 | 0.027 | 0.034 | 0.013 | 0.000 | 0.000 | 0.055 | 0.000 | 0.000 | 1.498 |
| Std. Dev. | 1.197 | 0.140 | 0.002 | 0.008 | 0.021 | 0.021 | 0.025 | 0.002 | 0.000 | 0.023 | 0.002 | 0.000 | 1.096 |
| Minimum | 15.044 | 2.998 | 0.009 | 0.076 | 0.000 | 0.008 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.296 |
| Maximum | 22.865 | 3.658 | 0.022 | 0.113 | 0.080 | 0.090 | 0.096 | 0.013 | 0.000 | 0.106 | 0.016 | 0.000 | 4.923 |

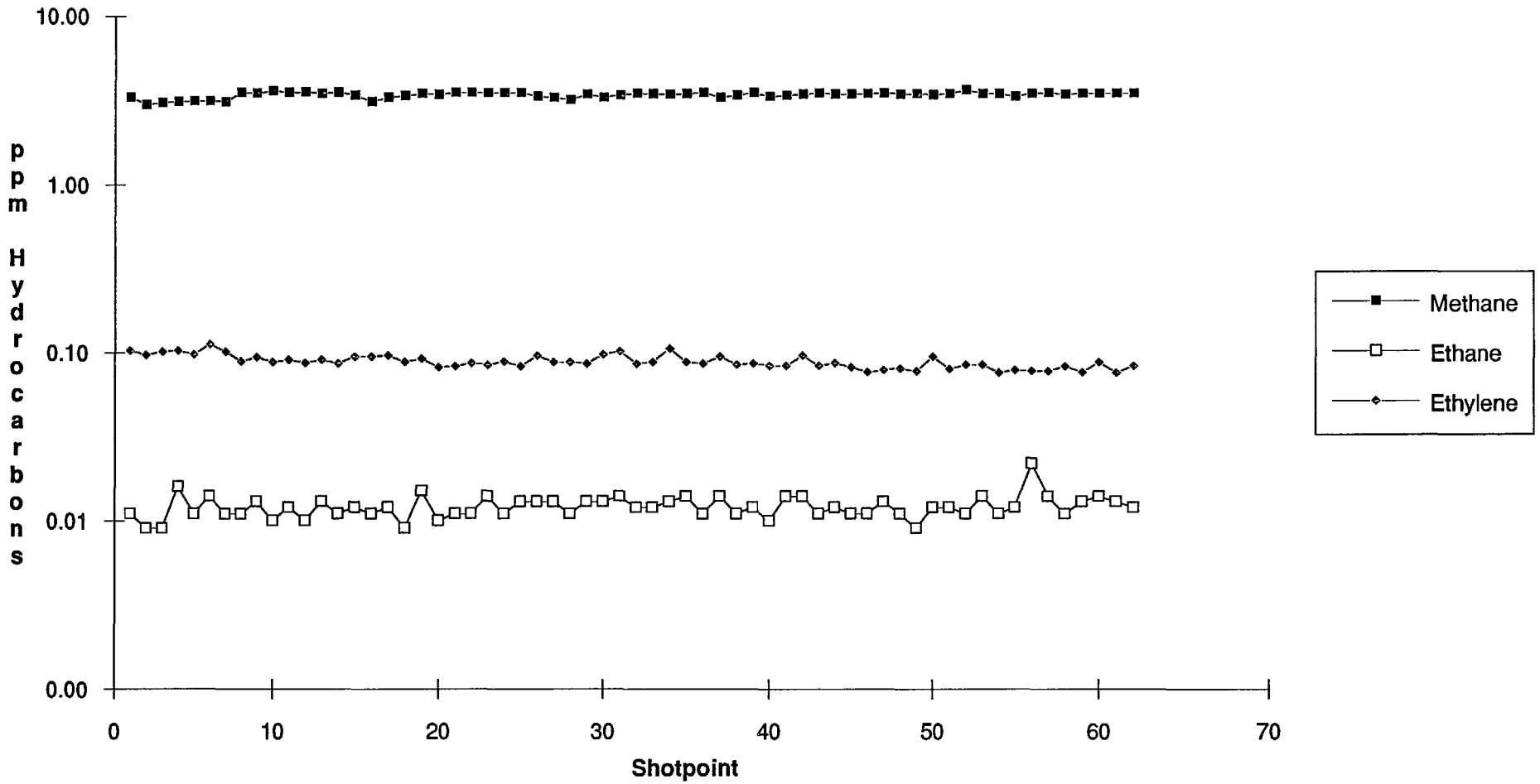
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 52.452 | 23.789 | 81.656 | 96.720 | 15.065 |
| Std. Dev. | 0.274 | 0.293 | 15.784 | 17.041 | 3.900 |
| Minimum | 52.050 | 23.230 | 55.896 | 68.202 | 10.000 |
| Maximum | 53.020 | 24.460 | 102.918 | 121.184 | 22.000 |

Notes Small THC anomaly right over Montague 1 well location.

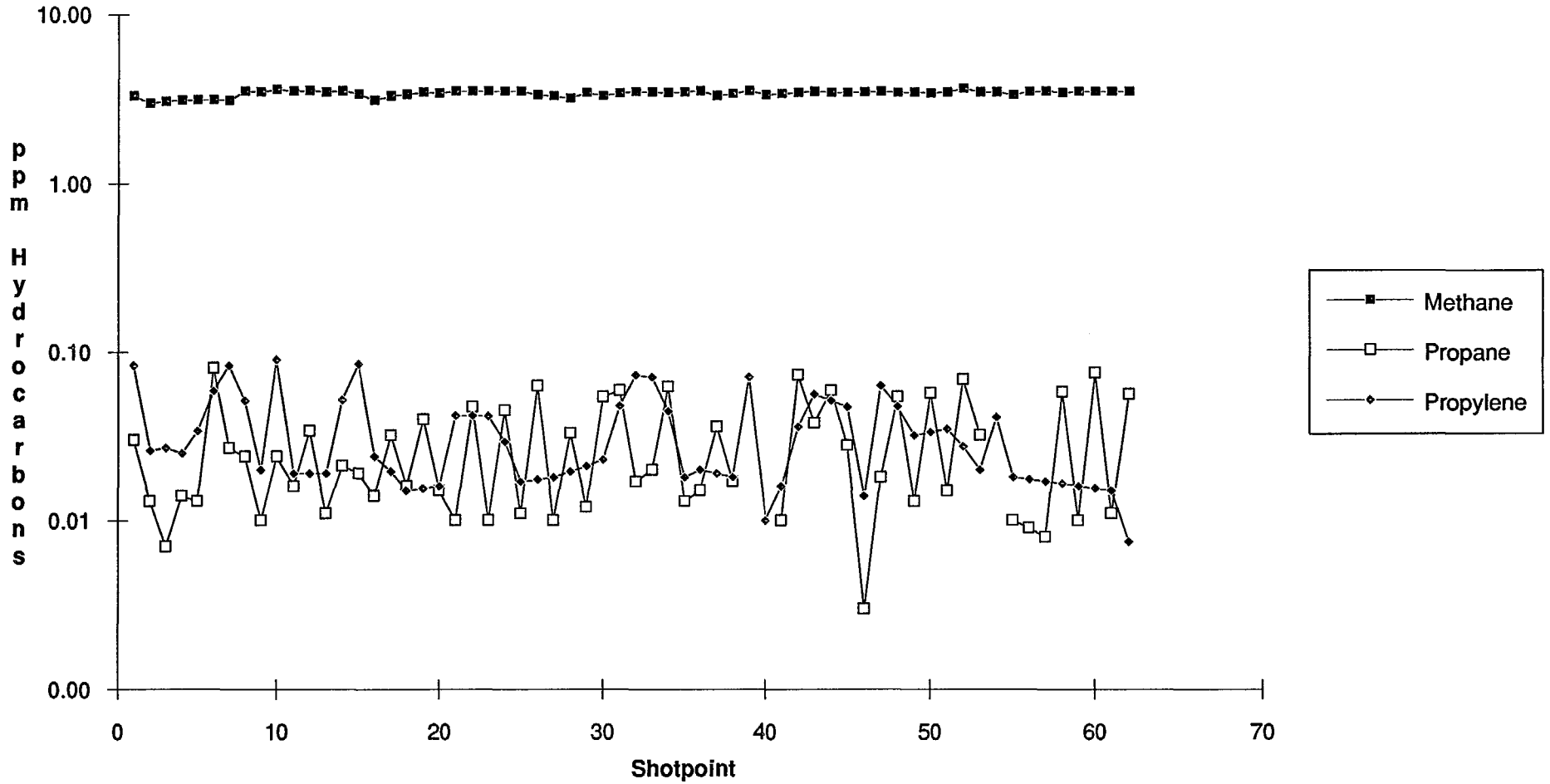
# Line 97022 THC, Methane



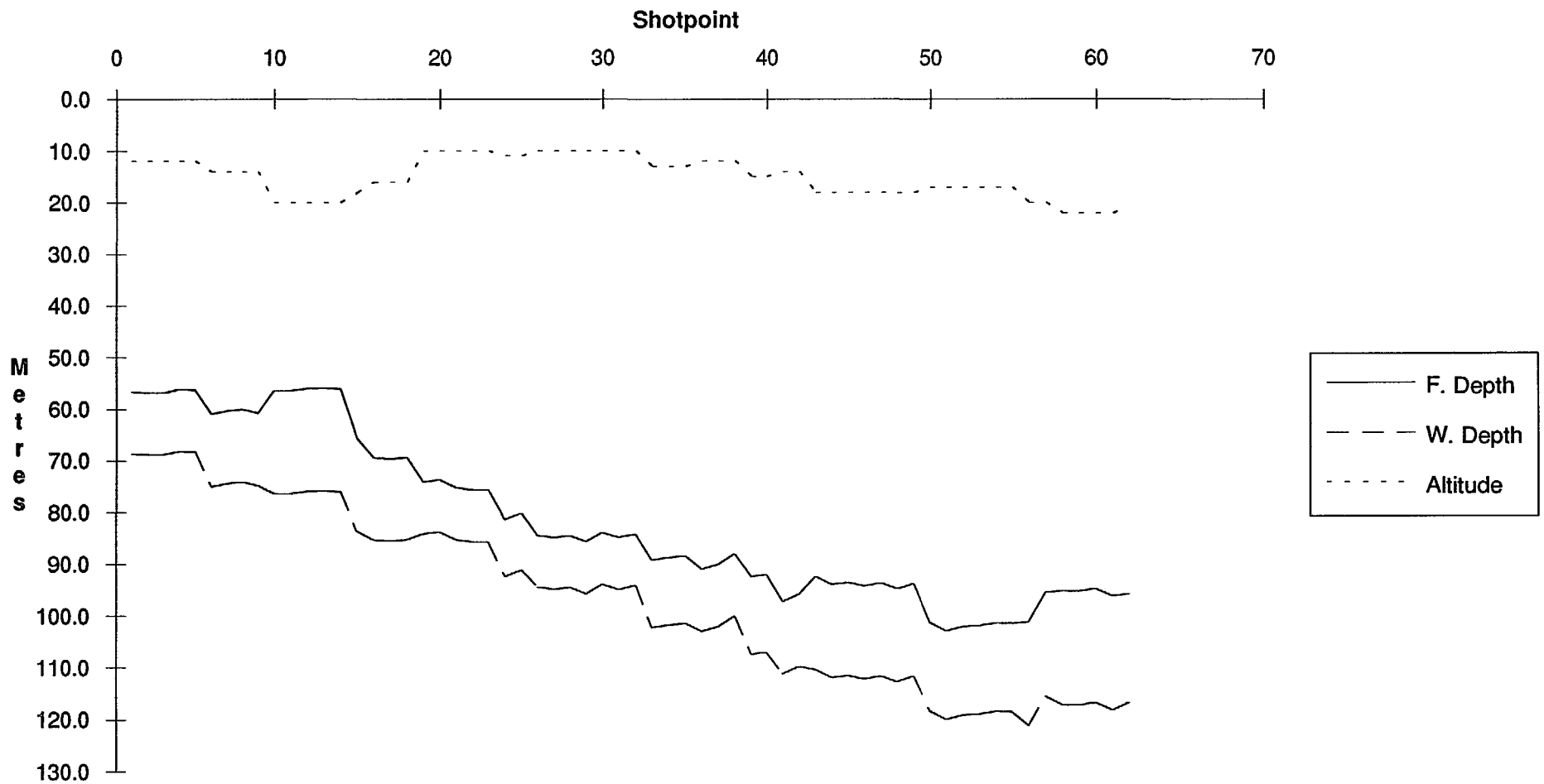
# Line 97022 Methane, Ethane, Ethylene



# Line 97022 Methane, Propane, Propylene



# Line 97022 Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 97023 |
| No. of Shotpoints | 85 |

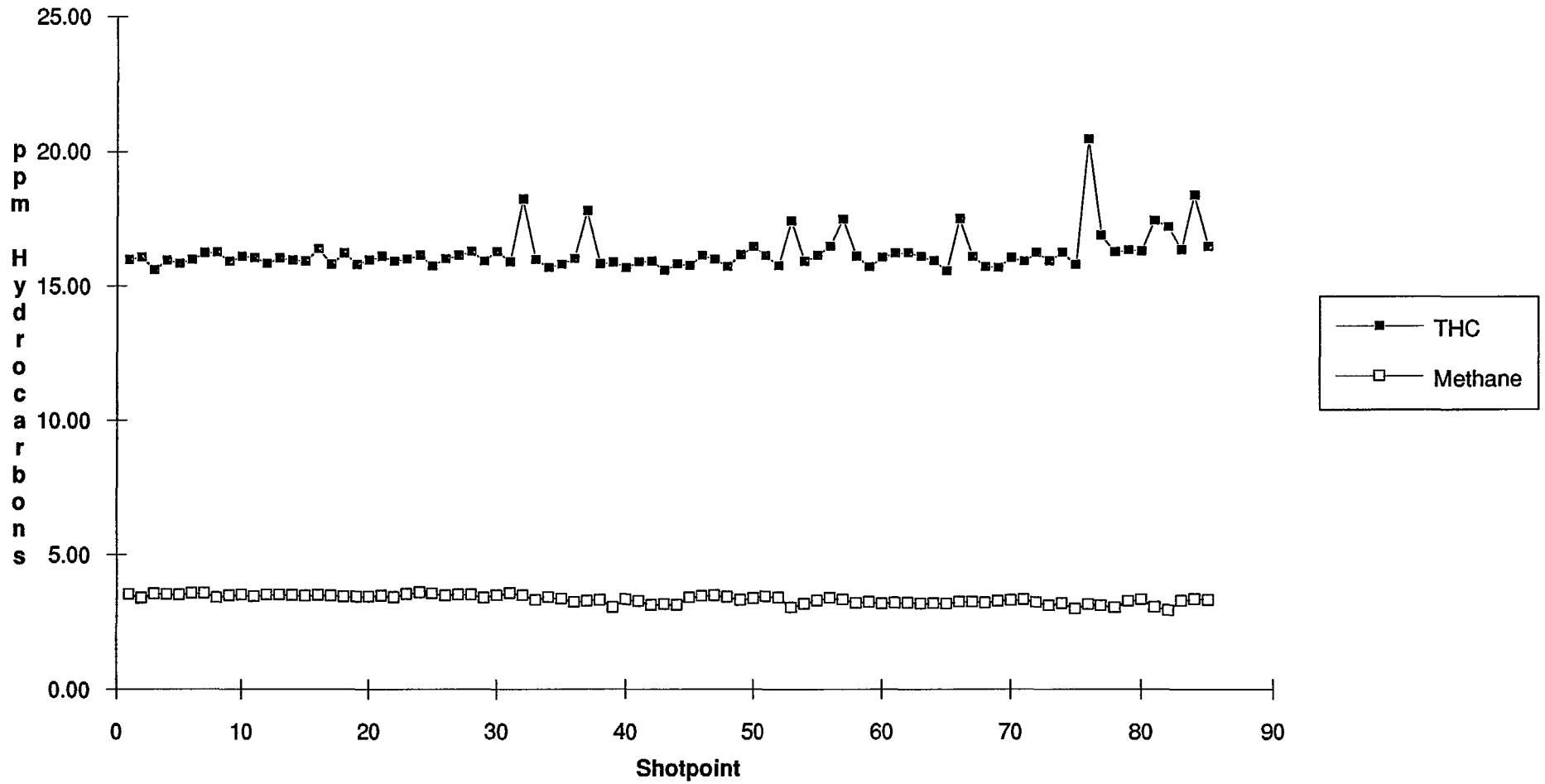
| | Shotpoint | Date | Time | Latitude | | Longitude | |
|---|---|---|---|---|---|---|---|
| Start | 1 | 27-Oct-90 | 21:26:09 | 19 | 33.883 | 116 | 24.037 |
| End | 85 | 28-Oct-90 | 00:14:16 | 19 | 32.354 | 116 | 38.880 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 16.220 | 3.334 | 0.011 | 0.089 | 0.019 | 0.036 | 0.002 | 0.001 | 0.000 | 0.063 | 0.000 | 0.000 | 0.987 |
| Std. Dev. | 0.721 | 0.158 | 0.001 | 0.007 | 0.016 | 0.023 | 0.010 | 0.009 | 0.000 | 0.018 | 0.002 | 0.000 | 0.547 |
| Minimum | 15.560 | 2.932 | 0.008 | 0.081 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.263 |
| Maximum | 20.457 | 3.579 | 0.015 | 0.132 | 0.074 | 0.093 | 0.062 | 0.066 | 0.000 | 0.102 | 0.016 | 0.000 | 2.549 |

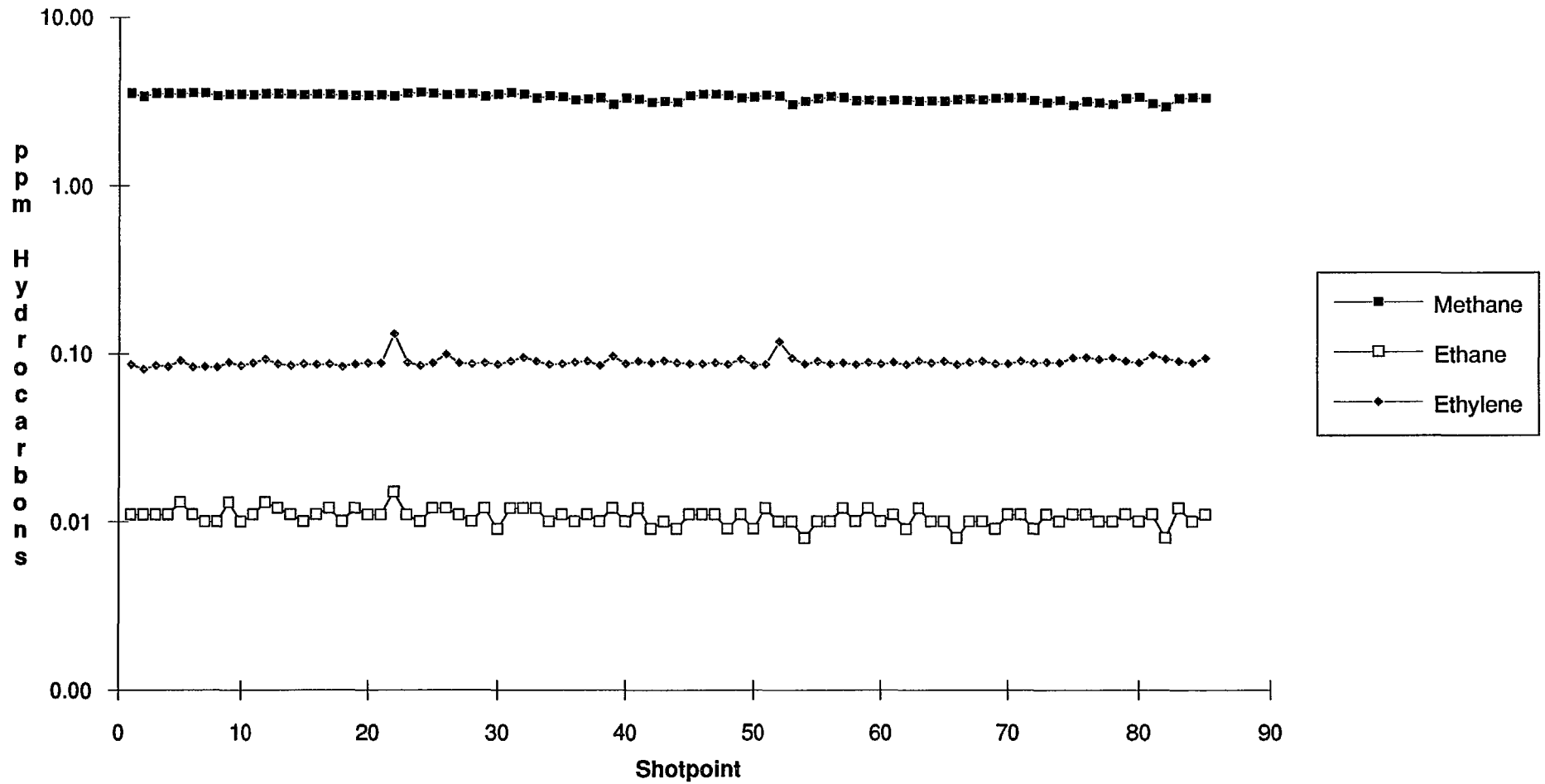
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 52.645 | 23.966 | 62.294 | 78.318 | 16.024 |
| Std. Dev. | 0.389 | 0.372 | 8.201 | 6.941 | 2.076 |
| Minimum | 52.120 | 23.340 | 48.246 | 64.246 | 13.000 |
| Maximum | 53.520 | 24.790 | 78.438 | 91.438 | 18.000 |

Notes No anomalies.

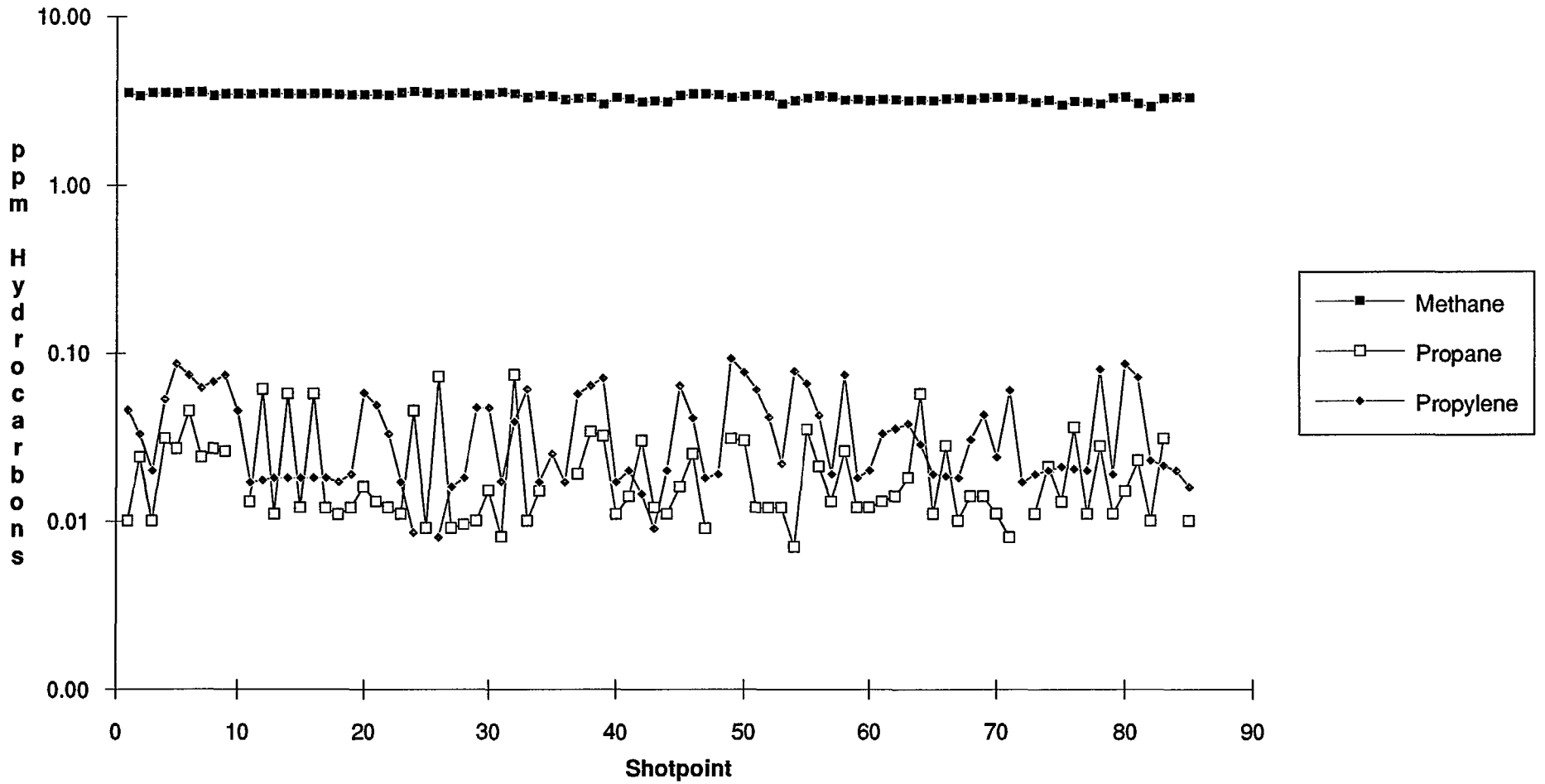
# Line 97023 THC, Methane



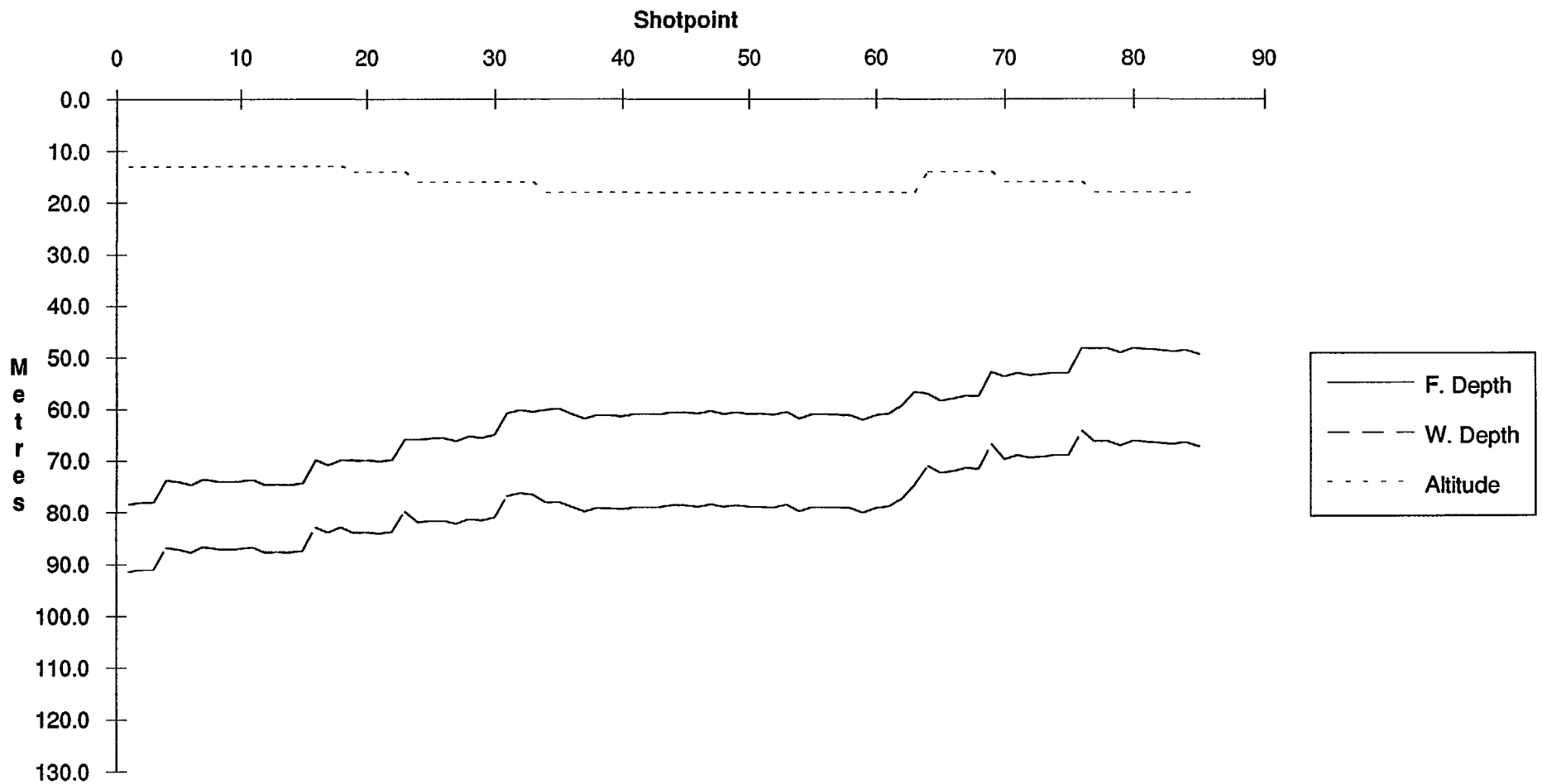
# Line 97023 Methane, Ethane, Ethylene



# Line 97023 Methane, Propane, Propylene



# Line 97023 Depths, Altitude



Line Summary

| | |
|---|---|
| Line Number | 97024 |
| No. of Shotpoints | 43 |

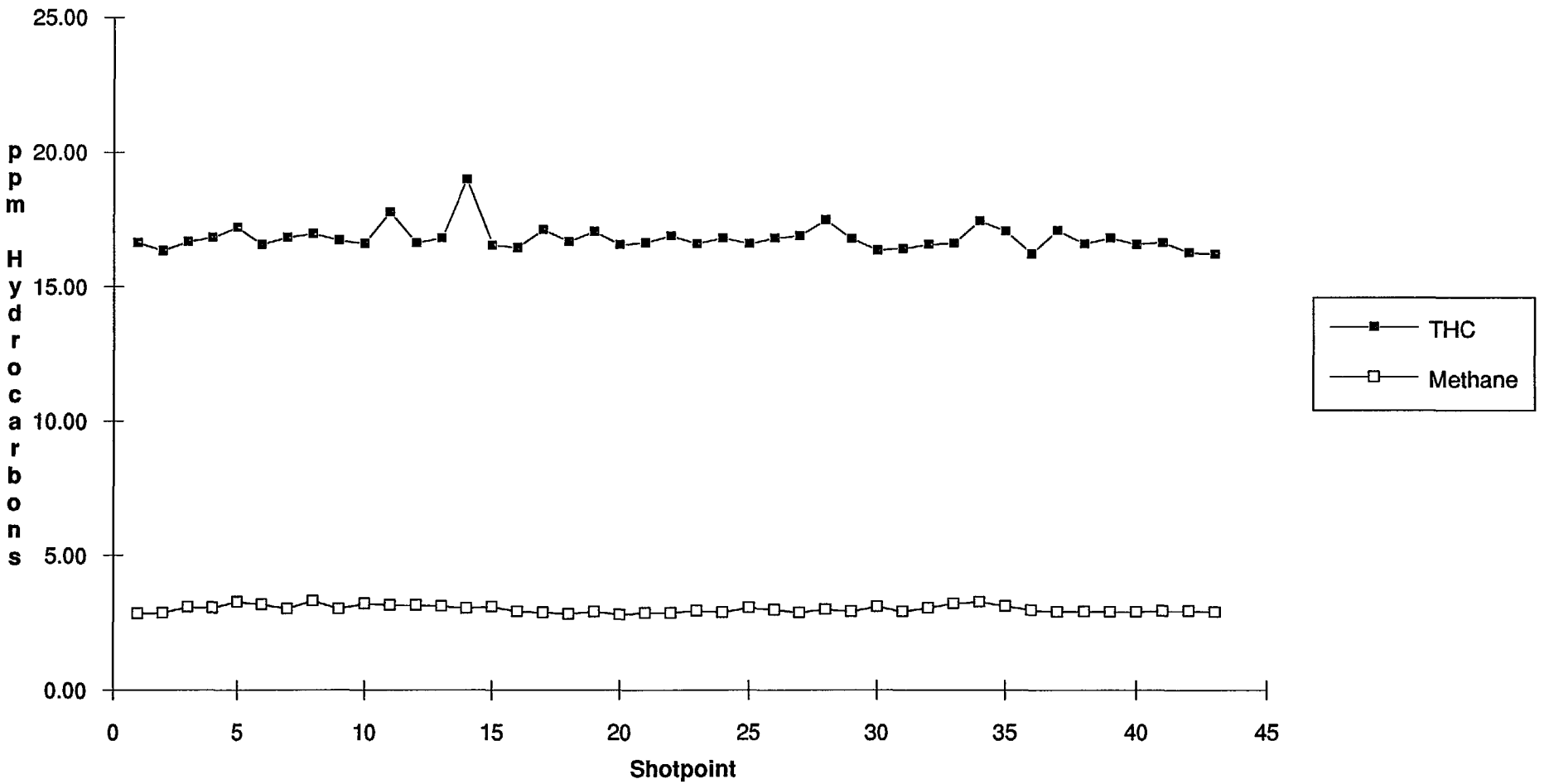
| | Shotpoint | Date | Time | Latitude | | Longitude | |
|---|---|---|---|---|---|---|---|
| Start | 1 | 28-Oct-90 | 02:18:40 | 19 | 33.323 | 116 | 37.472 |
| End | 43 | 28-Oct-90 | 03:42:53 | 19 | 26.784 | 116 | 39.920 |

| | THC | Methane | Ethane | Ethylene | Propane | Propylene | i-Butane | n-Butane | i-Pentane | n-Pentane | i-Hexane | n-Hexane | %Wetness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 16.790 | 2.998 | 0.010 | 0.097 | 0.016 | 0.041 | 0.003 | 0.000 | 0.000 | 0.087 | 0.000 | 0.000 | 0.931 |
| Std. Dev. | 0.476 | 0.135 | 0.001 | 0.004 | 0.011 | 0.025 | 0.010 | 0.000 | 0.000 | 0.021 | 0.000 | 0.000 | 0.464 |
| Minimum | 16.205 | 2.797 | 0.007 | 0.090 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.274 |
| Maximum | 18.998 | 3.305 | 0.013 | 0.110 | 0.057 | 0.097 | 0.049 | 0.000 | 0.000 | 0.105 | 0.000 | 0.000 | 2.387 |

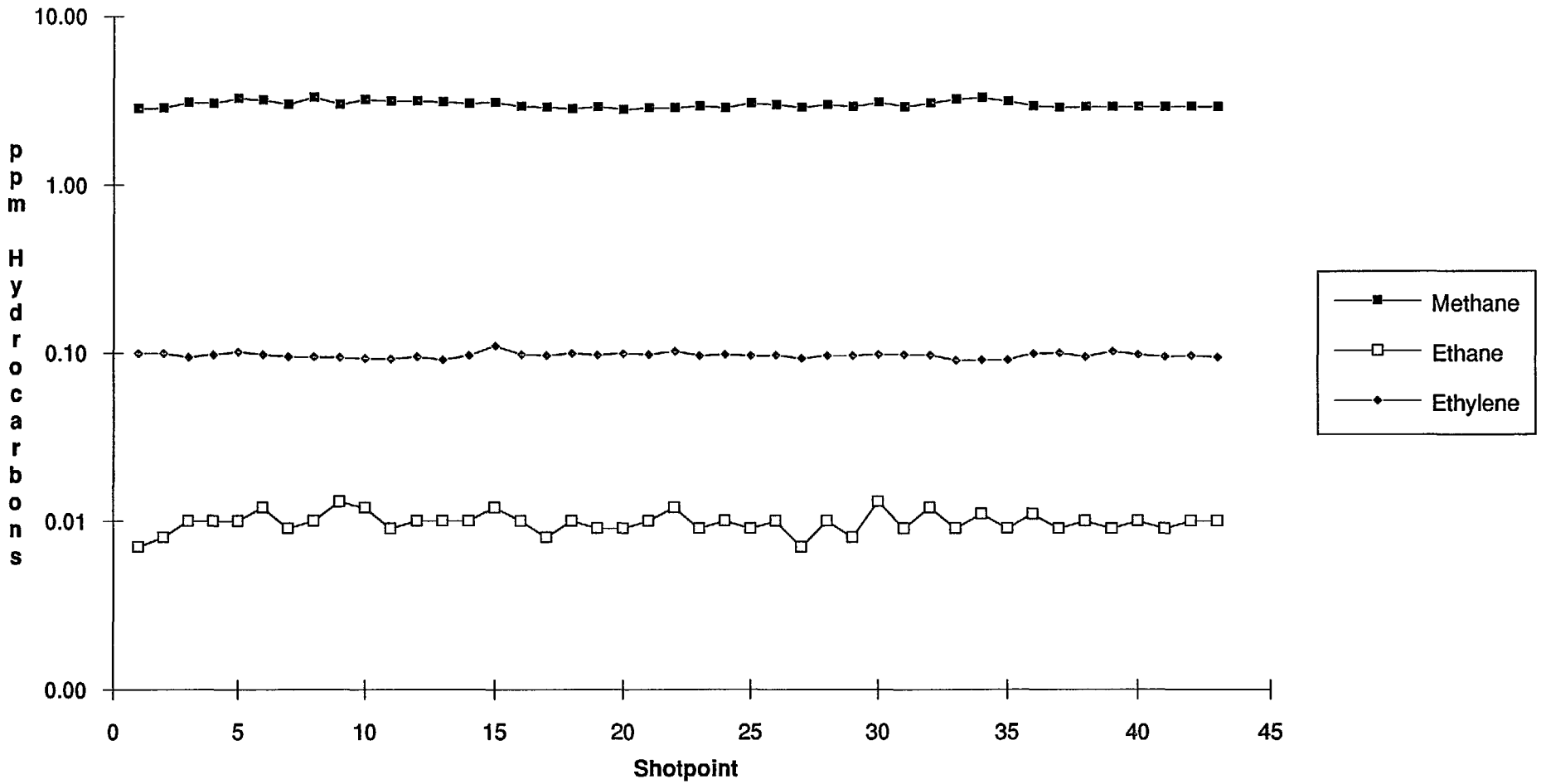
| | Cond. | Temp. | F. Depth | W.Depth | Altitude |
|---|---|---|---|---|---|
| Mean | 54.726 | 25.809 | 59.661 | 73.428 | 13.767 |
| Std. Dev. | 0.131 | 0.188 | 10.359 | 11.295 | 2.277 |
| Minimum | 54.510 | 25.470 | 48.144 | 64.122 | 12.000 |
| Maximum | 54.960 | 26.160 | 86.802 | 102.802 | 20.000 |

Notes No anomalies.

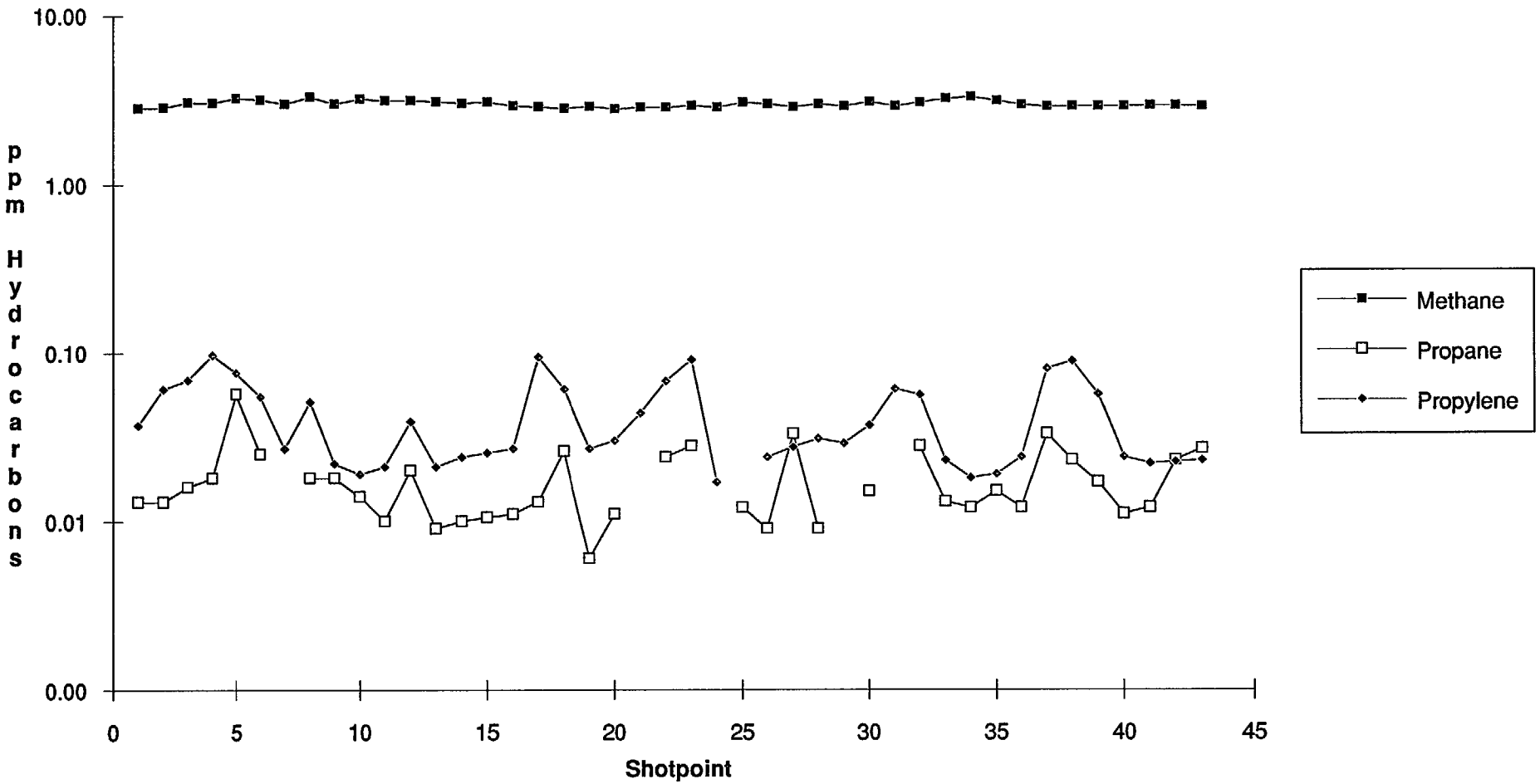
# Line 97024 THC, Methane



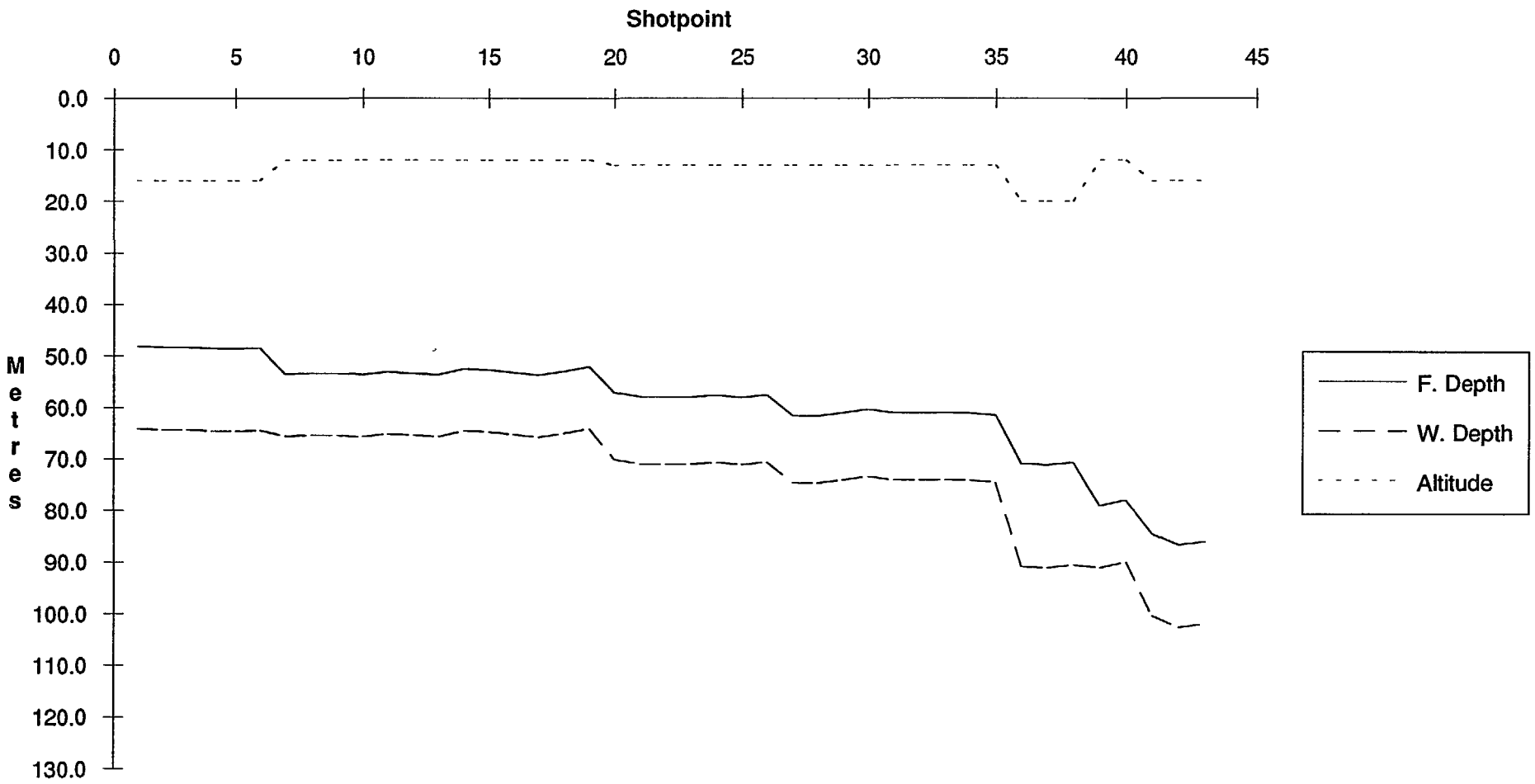
# Line 97024 Methane, Ethane, Ethylene



## Line 97024 Methane, Propane, Propylene



# Line 97024 Depths, Altitude



# APPENDIX II

# DHD methodology

Direct hydrocarbon detection in bottom-water (DHD) is accomplished with the equipment schematically shown in Figure II-1. The equipment comprises four major components.

(1) The over-the-side gear includes a towed 'fish' fitted with a submersible pump which delivers seawater to the geochemical laboratory on the ship via a hollow cable. A conductivity/temperature/depth sensor (CTD) in the 'fish' measures the depth of the 'fish' as well as the temperature and salinity of the seawater (to relate the depth of sampling to the depth of the thermocline, to detect hydrographic 'fronts', and to detect sub-seafloor freshwater aquifers that may drain through sedimentary layers from the continent). A sonar measures and continuously displays the altitude of the 'fish' above the seafloor allowing the operator to maintain the 'fish' at an altitude of about 10 m.

(2) A hollow cable (consisting of medical grade nylon tubing wrapped with insulated conductors which both transmit power to the fish and relay CTD and sonar data from the 'fish') delivers bottom-water to the geochemical laboratory. The tubing and conductors are wrapped in a stainless steel braid. Plastic fairings, which are attached to the cable to reduce frictional drag, allow the 'fish' to be towed almost directly beneath the ship.

(3) The analytical equipment includes a gas extraction unit and gas chromatographs connected in parallel to measure the concentrations of a variety of ($C_1$-$C_8$) hydrocarbons extracted from the seawater. The total hydrocarbon concentrations are measured every 30 seconds or at a ship speed of 5 knots, a distance of about 75 m on the seafloor. The light hydrocarbons ($C_1$-$C_4$) are measured at 2 minute intervals (approximately 300 m on the seafloor), whereas the $C_5$-$C_8$ hydrocarbons are measured every 8 minutes (approximately 1200 m). Sub-samples of extracted gas may be taken and stored for subsequent shore-based isotopic analyses.

(4) The data acquisition system is PC based: all data is displayed, edited and stored in a database for plotting at sea.

The towed 'fish' is deployed over the port side from the *Rig Seismic*. Echo sounder data and GPS navigation are displayed in the laboratory and these, together with the side scan sonar, provide clues to the locations of surface expressions of gas seeps on the seafloor. All data are recorded continuously so that any hydrocarbon anomalies in the water column

can be quickly recognised and additional measurements (or samples can be collected) if appropriate.

Detector sensitivity is < 10 parts per billion in the stripped head-space sample. Calibrations were conducted on a daily basis and were within 10% for the entire program and system blanks were less than 2 ppm for methane and 5 ppb for $C_{2+}$ compounds. The following parameters are measured:

| Parameter | Units | Equipment Used |
|---|---|---|
| Total Hydrocarbon (THC) | ppm | Shimadzu GC with FID Detector using 6" Glass bead column |
| Methane | ppm | Shimadzu GC with FID Detector using 42" Activated alumina column |
| Ethane | ppm | " |
| Ethylene | ppm | " |
| Propane | ppm | " |
| Propylene | ppm | " |
| i-Butane | ppm | " |
| n-Butane | ppm | " |
| i-Pentane | ppm | Shimadzu GC with FID Detector using 30 Megabore DB1 column |
| n-Pentane | ppm | " |
| i-Hexane | ppm | Shimadzu GC with FID Detector using 30 Megabore DB1 column |
| n-Hexane | ppm | " |
| Water Depth | Metres | On-board Echo sounders |
| Fish Altitude | metres | Water Depth minus Fish Depth |
| Conductivity | mmhos/cm | Conductivity Meter |
| Water Temperature | °Celsius | Temperature thermistor |
| Fish Depth | d-bar | Pressure transducer |

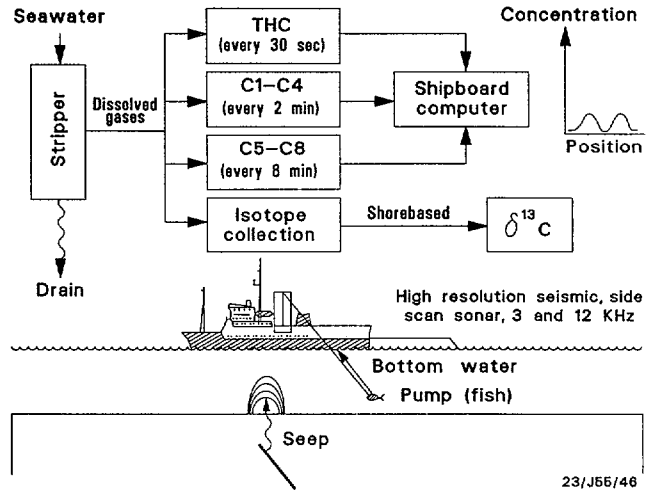



**Figure II -1.** Schematic of the geochemical equipment aboard *Rig Seismic* for the continuous profiling of hydrocarbons in seawater: the bottom-water DHD technique.

# APPENDIX III

# Interpretative methodology

The DHD equipment installed on *Rig Seismic* can be used for measuring hydrographic, environmental or petroliferous parameters. The light hydrocarbon data ($C_1$ to $C_6$) contained in this report can be produced by a variety of sources. These sources include biological activity associated with the degradation of organic matter in seawater and near-surface sediments and reservoired petroleum products (oil, gas and condensate). The aim of the data interpretation is to determine the origin (biogenic or thermogenic) of the light hydrocarbon gases measured, and via a variety of cross-plots of molecular and isotopic compositions of gases, to infer the 'source' (dry gas, gas-condensate or liquids) of detected seepage.

**Light Hydrocarbons In Seawater**

Light ($C_1$-$C_4$) and intermediate ($C_5$-$C_8$) hydrocarbons are present in seawater and sediments principally as a result of the following three processes.

(1) **Thermogenic processes.** The effect of heat on organic matter (catagenesis and metagenesis) buried to depths of several kilometres in sedimentary basins produces thermogenic hydrocarbons (Hunt 1979; Tissot and Welte 1984). The products of these reactions include methane and the saturated ($C_2$-$C_8$) hydrocarbons, which are the hydrocarbons mostly analysed in surface geochemical techniques. Some of the thermogenic hydrocarbons migrate to the surface, either directly from source rocks (primary migration) or indirectly, from gas, gas-condensate or liquid reservoirs (secondary migration). Hydrocarbons may migrate kilometres to permeate the near-surface sediments and seep into the overlying bottom-water resulting in thermogenic anomalies.

(2) **Biological processes.** Hydrocarbons are produced microbially and photochemically in seawater. In addition, during early diagenesis, a variety of hydrocarbons are produced by the activities of microbial organisms during aerobic and anaerobic destruction of organic matter which occurs primarily in the top few tens of metres of sediments. The products of these reactions include methane and minor quantities of both saturated and unsaturated hydrocarbons (Hunt 1979; Claypool & Kvenvolden 1983 and references cited therein). The presence of the unsaturated hydrocarbons, which are only produced biochemically (Primrose & Dilworth 1976; Claypool & Kvenvolden 1983), provides one criteria to distinguish between biogenic and thermogenic hydrocarbons.

These compounds produced *in situ* generally occur in low concentrations as background hydrocarbons in seawater (Claypool & Kvenvolden 1983). However, high concentrations of biogenically-produced hydrocarbons may accumulate in relatively shallow-buried sediments and seep into the overlying water, resulting in biogenic anomalies (Brooks et al. 1974; Bernard et al. 1976).

(3) **Anthropogenic processes**. Man's activities can introduce anthropogenically-sourced hydrocarbons into the marine environment. Anthropogenic hydrocarbons may be of a thermogenic origin (e.g., ship spills, refined petroleum products used in industrial processes) or a biogenic origin (such as those produced from urban sewage when excessive loads of organic matter are dumped into the sea and degraded microbially).

The concentrations of *in situ* biogenic (ie., background) light hydrocarbons in seawater are generally an order of magnitude lower than those in the underlying seafloor sediments (Claypool & Kvenvolden 1983). Consequently, it is relatively easier to detect migrated thermogenic hydrocarbons in seawater (low background concentration) than in seafloor sediments (high and variable background concentrations). Herein, lies one perceived advantage in the use of bottom-water DHD compared with sediment geochemistry in offshore petroleum exploration.

The bottom-water DHD technique is dependent upon hydrocarbons migrating from hydrocarbon reservoirs or petroleum source rocks to the seafloor. Although the exact mechanism(s) of migration may be variable or even unknown, some form of vertical migration, as evidenced by the many observations of seepage (eg., Brooks et al. 1974; Bernard et al. 1976; Reed & Kaplan 1977; Cline & Holmes 1977; Nelson et al. 1978; Reitsma et al. 1978; Brooks et al. 1979; Kvenvolden et al. 1979; Kvenvolden & Field 1981; Hovland & Judd 1988) does occur (via porous sediments, fault planes and microfissures etc). It is generally accepted that migration by diffusion is not important (Leythaeuser etal., 1982; Reitsma et al. 1981; Whelan et al. 1984) although bubble ebullition from saturated solution, oil and gas transport in solution in carbon dioxide and advective processes involving basinal fluids are all likely mechanisms (eg., Kvenvolden & Claypool 1980; Hunt 1984; Sweeney 1988; Hovland & Judd 1988).

## Data interpretation: the mixing model

The detection of seepage requires that anomalous concentrations of hydrocarbons be distinguished from the background inventory of hydrocarbons. Thermogenic hydrocarbons

that seep into the bottom-waters mix with the background concentration of hydrocarbons. One approach to defining anomalies and distinguishing seep hydrocarbons from background hydrocarbons requires that a mean background concentration be defined (either statistically or graphically), and this mean concentration is then subtracted from the measured concentrations. Because of variability in the background concentrations, this approach may be problematic, particularly where seepage is weak and the anomalies are very subtle.

Our initial approach is to review the data on a line-by-line basis and compare measured concentrations with the regional background. Then, a variety of hydrocarbon cross-plots are constructed, particularly that where methane is plotted versus percent hydrocarbon wetness (wetness % = [SUM($C_2$-$C_4$)/SUM($C_1$-$C_4$)] x100) to delineate seepage. The rationale behind this plot (Figure III-1) is that different hydrocarbon 'sources' eg., biogenic versus thermogenic gas, condensate and liquids, can be distinguished on the basis of differences in their light hydrocarbon molecular compositions (Hunt 1979; Tissot & Welte 1984; Claypool & Kvenvolden 1983). In this model background hydrocarbons plot in a narrow range towards the left origin (low concentrations), while end-member 'source' hydrocarbons ie., hydrocarbons from either oil-prone, condensate-prone or gas-prone source rocks or reservoirs, plot to the right (high concentrations).

As the hydrocarbons in bottom-waters represent mixtures of the end-member background (low) and 'source' (high) concentrations, the trends between the end-members in these plots are indicative of the 'source' of the hydrocarbons comprising the anomalies. For example, when the % hydrocarbon wetness increases with increasing methane concentration, the trend indicates that the anomaly was probably derived from a gas-condensate or oil-prone 'source'. In contrast, increasing methane concentrations, coupled with decreasing % hydrocarbon wetness, suggest that the anomaly was derived from a gas-prone thermogenic 'source' or is of a biogenic origin. This model cannot distinguish between biogenic and gas-prone thermogenic anomalies. Carbon isotope (eg., Fuex 1977; Bernard et al. 1977) and molecular compositional data are required to discriminate between biogenic gas and 'dry' thermogenic anomalies.

## Classification of anomalies

'Strong' (arbitrarily defined here as when some of the measured $C_1$-$C_4$ concentrations increase more than an order of magnitude above the background concentration) and 'moderate' thermogenic anomalies (some $C_1$-$C_4$ increase 5-10 fold above background) are obvious and are accompanied by large increases in individual $C_1$-$C_4$ hydrocarbons with no increase in the biogenic components (ethylene and propylene). 'Weak' anomalies

(individual $C_1$-$C_4$ is less than five-fold the background concentration) are more difficult to discern. In some cases, what appear to be weak anomalies may result from variations in the depth of the fish above the seafloor, a shoaling of the water depth, penetration of the fish above the local thermocline or combinations of these factors. In these cases, plotting the saturated hydrocarbon (methane, ethane, propane) concentrations against the 'fish' depth, seawater temperature and salinity, or against the biogenic hydrocarbons (ethylene, propylene), generally resolves apparent anomalies from those anomalies related to seepage.

A cross-plot of two compounds (eg., ethane vs. methane) indicates whether the compounds are being added to the natural hydrocarbons in an area. Positive trends on plots of one compound versus another indicate that both compounds are being added concurrently and thus, the source of the anomaly contains both compounds. Because a mixing trend is created by one hydrocarbon source supplying hydrocarbons to the background, all data on the same trend reflect the same source regardless of the absolute concentrations or absolute ratios. For example, an anomaly with ethane at 0.1 ppm would reflect the same hydrocarbon source as a second anomaly with ethane values at 1.0 ppm if the data from the two anomalies lie on the same mixing trend. Similarly, an anomaly with a wetness of 2% (oil-like) may actually represent a dry gas source if it falls on a mixing trend that has low wetness values at higher concentrations.

# Appendix III References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# APPENDIX IV

## General details: R.V. *Rig Seismic*

*Rig Seismic* is a seismic research vessel with dynamic positioning capability, chartered and equipped by AGSO to carry out the Continental Margins Program. The ship was built in Norway in 1982 and arrived in Australia to be fitted out for geoscientific research in October 1984. It is registered in Newcastle, New South Wales, and is operated for AGSO by the Federal Department of Transport and Communications.

| | | |
|---|---|---|
| Gross Registered Tonnage: | 1545 tonnes | |
| Length, overall: | 72.5 m | |
| Breadth: | 13.8 m | |
| Draft: | 6.0 m | |
| Engines: | Main: Norma KVMB-12 | 2640 HP/825 rpm |
| | Aux: 3x Caterpillar | 564 HP/482 KVA |
| | 1x Mercedes | 78 HP/56 KVA |
| | Shaft generator: | AVK 1000KVA; 440 V/60 Hz |
| Side Thrusters: | | 2 forward, 1 aft, each 600 HP |
| Helicopter Deck: | | 20 m diameter |
| Accommodation: | | 39 single cabins and hospital |

### Scientific equipment

*General*

Raytheon echo sounders: 3.5 Khz (2 KW) and 12 Khz (2 KW)

Geometrics G801/803 magnetometer/gradiometer

Bodenseewerk Geosystem KSS-31 marine gravity meter

E.G. & G. model 990 side scan sonar

Nichiyu Giken Kogyo model NTS-11Au heatflow probe

*Navigation*

Trimble Differential GPS System

Magnavox T-set Global Positioning System

Magnavox MX 1107RS and MX 1142 transit satellite receivers

Magnavox MX 610D and Raytheon DSN 450 dual axis sonar dopplers
Arma Brown and Robertson gyro-compasses; plus Ben paddle log

# Cruise narrative

*Rig Seismic* departed from Fremantle at approximately 1830 hours on Thursday, October 18, 1990 and steamed to the the vicinity of WA-28p in the northern Dampier Sub-Basin off Western Australia. The ship arrived in the vicinity of the Angel gas field at approximately 0730 hours on Monday October 22, 1990. The next 48 hours were spent balancing the seismic cable and testing the seismic acquisition system. During this period, water column geochemical (direct hydrocarbon detection [DHD]) data were acquired in a loose grid over the Wanaea and Angel fields (see Table 1). Contemporaneous seismic and DHD acquisition began at 0800 hours on Wednesday, October 24, 1990 (Table 2). Data acquisition was completed at 1150 am on Sunday October 28, 1990, by which stage a total of 491 km of seismic and 531 km of DHD data had been acquired. *Rig Seismic* then sailed to Dampier Harbour, arriving at approximately 730 pm.

# Systems performance

The primary navigation system was a Trimble differential GPS system with a base station at King Bay near Dampier, Western Australia. Additional navigational systems on board included GPS, transit satellite and sonar doppler (Appendix 2). All navigation systems performed well. The only problem with the DHD acquisition system was the rather noisy nature of the propane data.

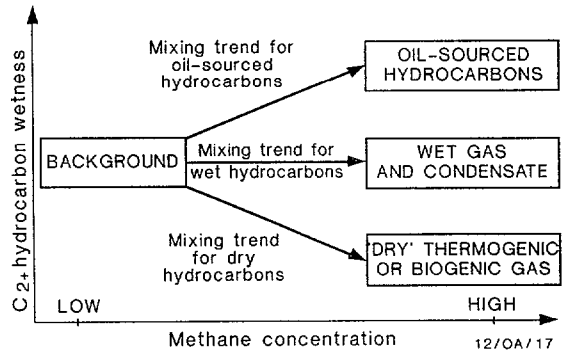
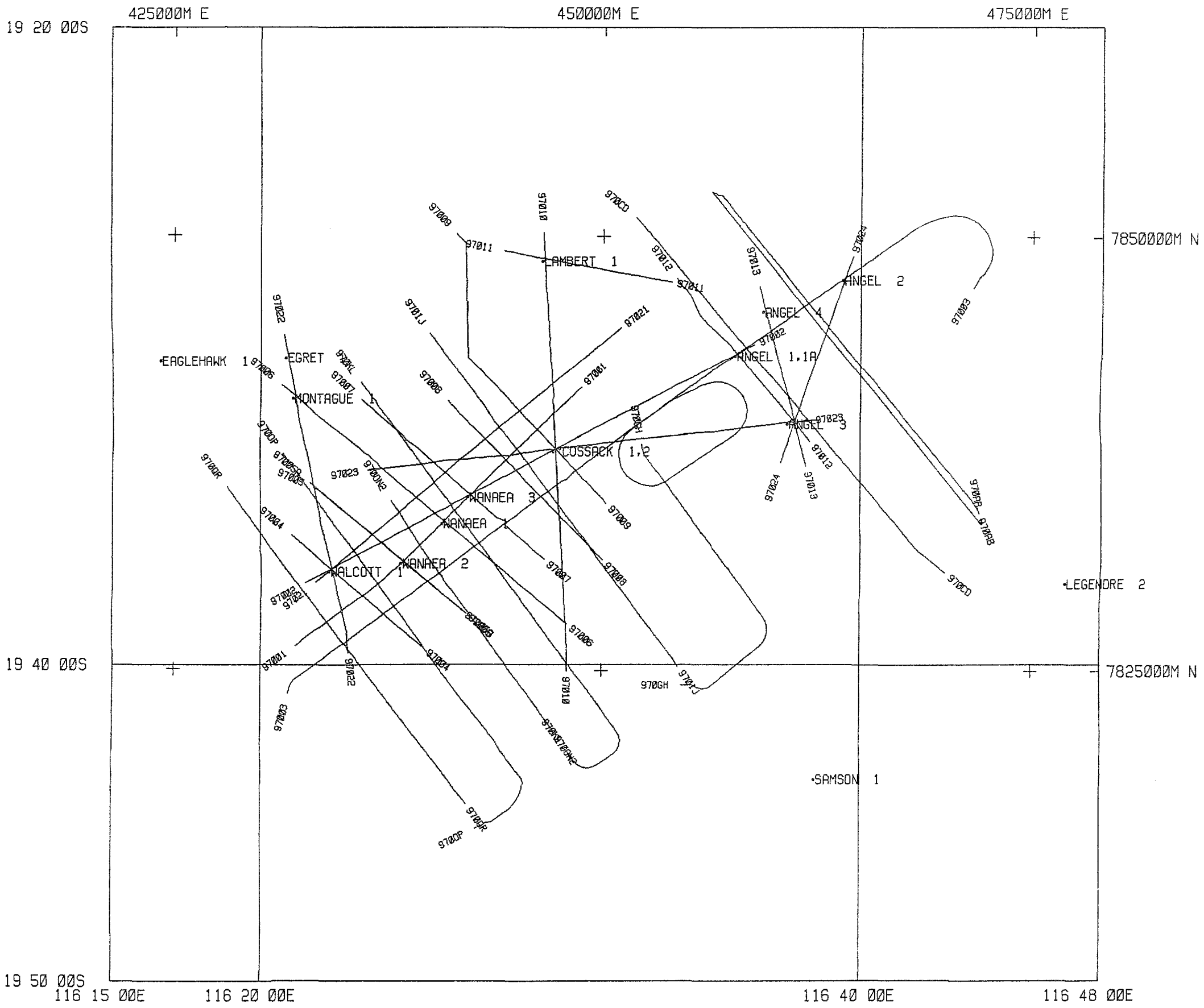



**Figure III-1.** Cross-plot of methane versus hydrocarbon wetness, showing the general decrease in wetness with increasing methane for gas-prone or biogenic sources. Conversely, oil-prone sources are indicated by increasing wetness with increasing wetness with increasing methane. Gas-condensate sources fall between the dry gas and oil-prone trends.

# DAMPIER SUB-BASIN




1:250000

0 5 10 15 20 25

KILOMETRES

0 2 4 6 8 10

MILES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 117 00 00E

| DHD SURVEY LINES | | |
|---|---|---|
| BMR DAMPIER SUB-BASIN<br>SURVEY 97 | | |
| S3BARDAM 7/6/92 J NEEDHAM | | |
| | | |

**Enclosure 1**