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BMR RECORD 1992/46
LIGHT HYDROCARBON GEOCHEMISTRY IN BOTTOM-WATERS OF THE ARAFURA SEA, NORTHERN AUSTRALIA

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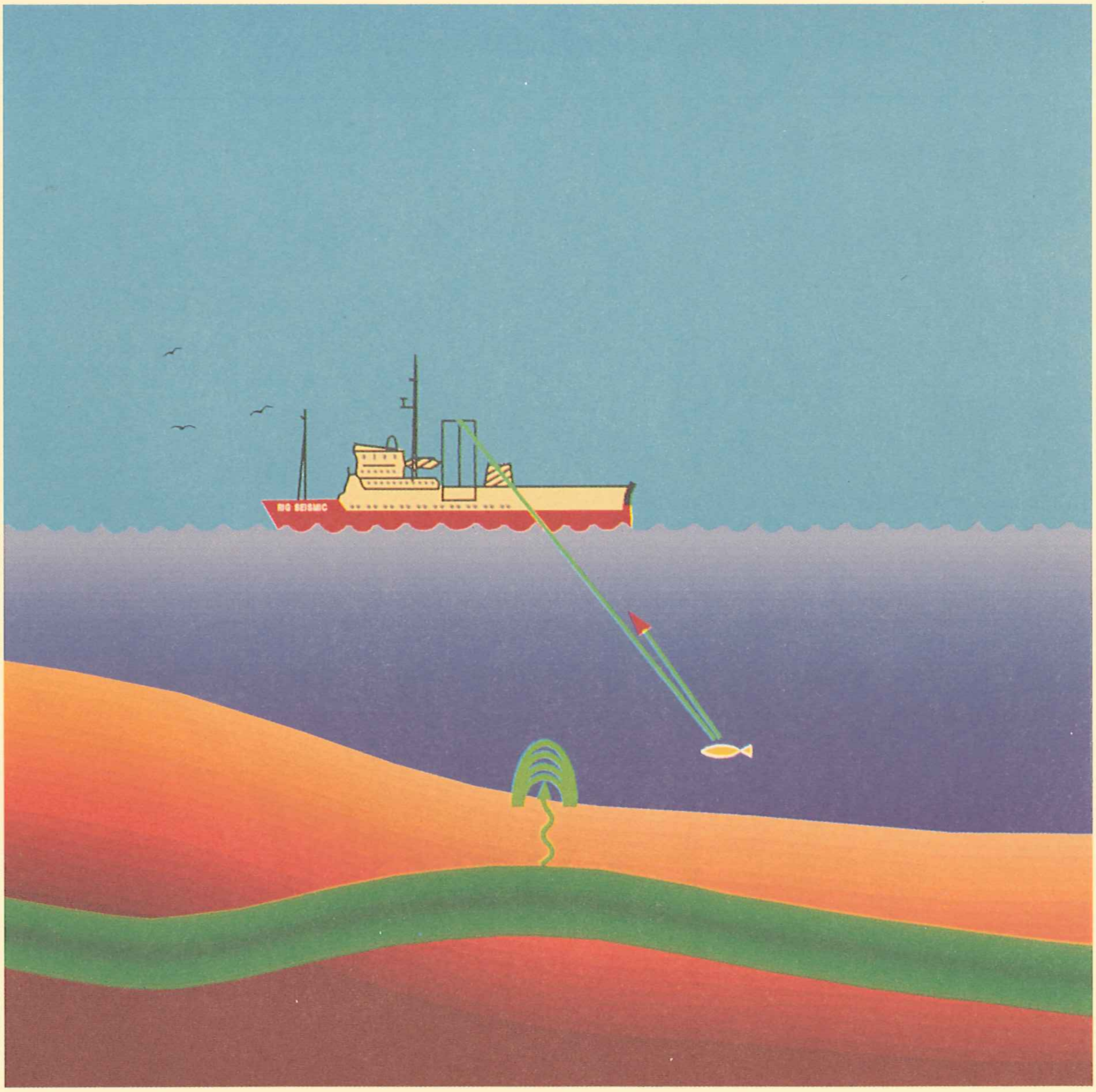

PROJECT 121.24

G. P. Bickford, D.T. Heggie and J.H. Bishop

MARINE GEOSCIENCE AND PETROLEUM GEOLOGY PROGRAM

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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS, AUSTRALIA

DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

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EXECUTIVE SUMMARY

During February-March 1990 the BMR conducted a combined seismic and DHD (Direct Hydrocarbon Detection) survey in the Arafura Sea of northern Australia. This survey was the second to employ the 'geochemical sniffer' (DHD) aboard Rig Seismic, and represented the first deployments of the geochemical equipment from amidships Rig Seismic. The purpose of these deployments were to develop the capability to collect underway, bottom-water geochemical data simultaneously with seismic reflection, gravity and magnetic data. The bottom-water geochemical data hence would complement existing remote sensed methods to aid in offshore exploration for hydrocarbons, and to provide new insights into concepts of hydrocarbon generation and migration. As such, the deployment of the equipment amidships Rig Seismic was successful and will become a permanent installation. However, some mechanical (deployment) and data collection difficulties resulted in some gaps and artefacts in the bottom-water DHD, and these are noted in the text. Some parts of the data have been heavily edited.

The survey collected approximately 1800 line-km of bottom-water DHD data and seismic reflection, gravity and magnetics data covering parts of the Money Shoals and Arafura Basins and the known extent of the Goulburn Graben.

Seven areas of anomalous light hydrocarbons (distinct from apparent local background) concentrations were detected during the survey. However, the anomalies are generally very weak (less than fivefold background), and some are evident as elevated concentrations persisting over relatively short distances (less than 10 kilometres e.g., survey lines 2, 4, and 6), while others appear as broad trends in concentration increases over distances of several tens of kilometres (e.g., survey lines 8 and 9).

The anomalies appear to fall into two classes. First, anomalies on survey lines 2, 4 and 6 have elevated concentrations of total hydrocarbons (THC), methane and trace amounts of ethane. These anomalies all have elevated concentrations of ethylene (the unsaturated hydrocarbon) and, as such, probably result from in-situ generation in the water column by microbial activities. These elevated levels of THC and methane (trace ethane) therefore probably do not represent seepage from the seafloor. There exists the possibility that these biogenic hydrocarbons are indirect indicators of very weak seepage, if seep hydrocarbons stimulate microbial activity in the water column, resulting in production of an unsaturated hydrocarbon anomaly.

Second, anomalies were detected on survey lines 8 and 9. These elevated levels of THC, methane and ethane (trace propane) were observed as trends - the highest concentrations being measured near Money Shoals 1 and Kulka 1. These increases in the saturated hydrocarbons (albeit very weak) were, however, not accompanied by increases in the unsaturated hydrocarbons, and may represent weak seepage of saturated hydrocarbons across the seafloor.

A cross-plot of methane versus hydrocarbon wetness suggests all anomalies are derived from 'dry' sources.

INTRODUCTION

Surface geochemistry and offshore exploration for hydrocarbons

The aim of surface geochemical techniques in offshore petroleum exploration is: (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. This 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 remains proprietary and the opinions expressed publicly, about surface 'sniffer' geochemical techniques, by the petroleum exploration community remain divided. Schiener et al. (1985) have commented 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. Those surveys were all located in southeastern Australia, specifically in: (1) the Duntroon Basin, for Getty Oil Development Company Ltd. in 1983, (2) the Otway Basin (Sprigg 1986) for Ultramar Australia in 1981, and (3) two small surveys in the Gippsland Basin for Esso Exploration and Production, Australia Inc., in 1983.

The Bureau of Mineral Resources (BMR), as part of the Continental Margins Program, and a joint Agreement with Transglobal Environmental Geoscience (TEG) of Leucadia California (Heggie et al., 1990), has been conducting surface geochemical (bottom-water DHD and sediment [hydrocarbon-headspace] geochemistry) surveys on parts of the Australian continental margin since 1989. 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, and will be, carried out by the Rig Seismic (and occasionally on other vessels) around the Australian continental margin. These data are both integrated with each other, and also with sediment geochemical data which may sometimes be collected during the surveys.

The geochemical analysis system (Direct Hydrocarbon Detection or DHD) that has been installed aboard the BMR's research vessel "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 C1-C8 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 deals with the results obtained from DHD acquisition in the Arafura Sea on BMR Survey 94 (February-March 1990). This Record combines a basic and preliminary interpretation with the data release.

THE ARAFURA SEA: Previous Work and Objectives

Early Exploration

The Arafura Basin is the most extensive of the basins underlying the shallow Arafura Sea, and contains sediments of Cambrian to Permo-Triassic age. The west-northwest-trending Goulburn Graben within the Arafura Basin contains up to 10 kilometres of Palaeozoic sediments (Bradshaw etal., 1990). A short exploration phase from 1981 to 1986 led to partial delineation of the basin sediments and structure, which has been recently reviewed (Petroconsultants, 1989).

Six exploration wells in the basin have all been sited on structural targets along the Goulburn Graben, and most of the modern seismic coverage is within the Goulburn Graben. The majority of the Cambrian and Permo-Triassic sequences remain untested and extensive areas of the basin outside the graben are virtually unexplored.

The survey collected new seismic reflection (simultaneously with surface geochemical (DHD), magnetic and gravity data), both across and along the Goulburn Graben (to acquire new information on the deep structure within the Graben), with tie lines from the graben northward toward the Australian-Indonesian border; with infill seismic in the eastern part of the Arafura basin, and with a seismic tie-line to near Lower Palaeozoic outcrop to the northeast of the Wessel Islands (Napier etal., 1991).

A map of the Arafura Sea showing the major structural features and the seismic and DHD data acquisition lines is shown in Figure 1. The 30 day survey took place during February-March 1990.

The principal objectives of the program were:-

- to investigate the architecture of the Goulburn Graben in the central and western ends of the basin

- to complete a framework of essential reconnaissance in the sparsely explored and little known eastern portion of the Arafura Sea

- to contribute to an evaluation of hydrocarbon prospectivity in the Arafura Sea region, with surface geochemical techniques via measurements of the distributions and concentrations of light hydrocarbons in bottom-waters (Direct Hydrocarbon Detection).

ARAFURA SEA: DHD RESULTS

The work program in the Arafura Sea consisted of 16 lines with a total survey length of approximately 1800 km. DHD data were collected from 15 lines.

This section summarises, in a preliminary way, the key aspects of the DHD data. The survey results are presented in the line summary sheets (Appendix 1), which show the beginning and end of each line, and the light hydrocarbon characteristics of each survey line. The distributions of the C1 to C4 hydrocarbons (and fish depth) along each line are summarised in Appendix 1.

An overview of the DHD data is summarised in Figures 2-37. The survey area has been arbitrarily divided into western and eastern sectors.

Western Arafura Sea (survey lines 1-9)

Several weak (<5-fold background concentrations) discrete anomalies were detected on these survey lines (Figures 2-17). The approximate locations of these anomalies are marked on Figure 1. Total hydrocarbon concentrations (THC), sum C1-C4 and methane anomalies were found on survey line 2 (1 anomaly), line 4 (2 anomalies), and line 6 (2 anomalies), see Figures 2 - 4. The highest concentrations of THC (< 25 ppm) were about two-fold typical background concentrations (approx. 10 ppm) in this area. Similarly, highest methane (approximately 25 ppm) were about five-fold typical background levels (<5 ppm). In all cases these elevated concentrations were accompanied by trace increases in ethane (Fig. 5), with no significant changes in propane (Fig. 7). However, the increases in methane and ethane were accompanied by about two-to-fivefold increases in the unsaturated hydrocarbon, ethylene (Fig. 6). Propylene concentrations remain near background (0.04 ppm; Fig.8). Trace levels of butanes were detected on survey lines 2,3 and 6 (Fig.9), but these are not accompanied by increases in other saturated hydrocarbons; the data are very noisy and probably do not represent seepage. The anomalies in sum C1-C4 hydrocarbons on survey lines 2,4 and 6 are accompanied by small but detectable decreases in hydrocarbon wetness values (Fig. 10).

As an indication of the relative abundances of various hydrocarbons, the ratio of methane/ethane (Fig. 11), ethane/propane (Fig. 12) and the Bernard parameter (methane/ethane+propane Fig. 13) are included.

The highest concentrations of THC on survey lines 7-9 (Fig. 14) (< 30ppm) were about three-fold background concentrations (approx. 10ppm). Increases in methane were measured (Fig. 16) up to about 16 ppm (about four-fold background concentrations of 4-5 ppm) and are accompanied by increases in ethane, from background levels of about 0.02 ppm, to maximum concentration of about 0.045 ppm

(Fig. 17). The highest concentrations of methane and ethane were measured toward the western end of the Goulburn Graben, at the end of survey line 8 (approaching Money Shoal-1) and the beginning of line 9. (Figs. 16,17). Survey line 1 (which contains a break in data acquisition because of seismic and DHD system problems), ties Kulka 1 to Money Shoal 1. Methane values of about 15ppm were measured at the end of this line (near Money Shoal 1), values of <10ppm were also measured. Significantly, the increases in ethane were not accompanied by increases in the unsaturated ethylene (Fig. 18). Similarly, but less convincing, propane levels increase very slightly, from < 0.02 ppm to levels of about 0.05 ppm (Fig. 19) in the western part of the Goulburn Graben. Propylene concentrations do not vary significantly between survey lines 7 and 9 (Fig 20). Occasional trace occurrences of i-butanes were detected on line 9, although at these levels the data are very noisy and near the detection levels (<10ppb) of the equipment (Fig. 21). Wetness values are typically <1% on survey lines 7-9 (Fig. 22), and towards Money Shoal 1 and Kulka-1, (survey lines 8 and 9), the increases in methane and ethane are accompanied by small, but detectable decreases in wetness to values less than 0.6 %. Ratios of methane/ethane (Fig. 23), ethane/propane (Fig. 24) and the Bernard parameter (methane/ethane+propane, Fig. 25) are included.

Eastern Arafura Sea (survey lines 10-16)

Highest concentrations of THC in this sector of the survey were measured on survey line 13 (Fig. 14), up to about 30 ppm. Survey line 13 is in the eastern-most sector of the survey area in shallow water near the Wessels Islands. The THC values are as high as those measured on lines 2,4 and 6, further to the west. These increases in THC are not however accompanied by increases in sum C1-C4, methane, ethane or propane (Figs. 15, 16, 17, 19).

THC, methane, ethane and propane concentrations, on the other survey lines in the eastern sector (lines 14-16; Figs 26-37) are low and do not show any significant variations between survey lines. Occasional trace occurrences of n-butanes were found on survey lines 14 and 15 (Fig. 33), but these were not accompanied by increases in other (C1-C3) saturated hydrocarbons (Figs. 28-32). Hydrocarbon wetness values are generally less than 1%, except on survey line 15 (Fig. 34). The ratios of methane/ethane (Fig. 35), ethane/propane (Fig. 36) and the Bernard parameter (methane/ethane+propane, Fig. 37) are included.

Hydrocarbon 'source'.

The following brief discussion, is a preliminary interpretation of hydrocarbon 'source'. The low levels of hydrocarbons found during the survey preclude a more definitive analysis of the data. The elevated levels of THC and methane (accompanied by trace increases in ethane) found on survey lines 2, 4 and 6, are north of the Goulburn Graben (Fig. 1). The methane increases, above background, were the highest recorded during the survey, with values recorded up to 24 ppm. A plot of methane versus hydrocarbon wetness (for survey lines 1-7) is shown in Figure 38. Background wetness values are about 1% (or less) and at high methane concentrations (up to about 20 - 25 ppm) wetness values decrease and approach 0.4 %. This result suggests, according to the cross-plot model and criteria outlined in Appendix III, and Figure III-1, that these weak anomalous concentrations of methane, accompanied by decreasing wetness values represent either biogenic or 'dry' thermogenic gas.

The presence of saturated hydrocarbons in seawater may result from additions of thermogenic hydrocarbons, which have migrated from sub-seafloor hydrocarbon accumulations into the bottom-waters, or be produced by in-situ biogenic reactions associated with microbial activities (Claypool and Kvenvolden, 1983). Biogenic production of the light hydrocarbon, ethane, is also accompanied by the production of ethylene. The presence of anomalous ethylene concentrations, therefore, suggests in-situ biogenic production of hydrocarbons. In contrast, an absence of the unsaturated ethylene - but anomalous levels of ethane - suggests migrated thermogenic hydrocarbons. Inspection of Figures, 4-6 (survey lines 1-6), indicates the anomalous levels of THC, methane and ethane on these lines are also accompanied by higher levels of ethylene - suggesting that these anomalies result from the in-situ activities of microbial organisms.

The anomalies in sum C1-C4, methane, ethane and propane found on survey lines 8 and 9, which run along strike in the Goulburn Graben (Figs 15-17 and 19), indicate methane increases about four-fold, and ethane increases about twofold above background. These somewhat elevated levels of methane and ethane are also accompanied by slight decreases in wetness values (Fig. 22), and a cross-plot of methane versus percent hydrocarbon wetness (survey lines 7-13) shows decreasing wetness with increasing methane (Fig. 39), suggesting either biogenic (in-situ or migrated) gas or 'dry' thermogenic gas. However, in contrast to those anomalies noted on survey lines 2, 4 and 6 (north of the Goulburn Graben), these trends (line 8 and 9) are not accompanied by increases in ethylene or propylene (the unique biogenic components). This suggests these data represent migrated gas, either from a 'dry' thermogenic 'source' or possibly migrated biogenic gas.

On survey lines 14-16, a plot of methane (Fig. 40) versus percent hydrocarbon wetness generally indicates near constant wetness values (<1%) for less than two-fold changes in methane.

SUMMARY

Anomalous hydrocarbons were found in seven locations. A total of five discrete, but weak THC and methane anomalies (the strongest anomaly had THC and methane increase about two-fold above background concentrations) were detected. All of these anomalies were found near the boundary of, and to the north of, the Goulburn Graben. The strongest discrete anomalies were accompanied by increases in ethylene (a biogenically-produced hydrocarbon) and the molecular compositional data revealed decreasing hydrocarbon wetness with increasing methane concentrations, indicating that they were of either a dry thermogenic or a biogenic origin. No propane or C5-C8 hydrocarbons enrichments were associated with these anomalies. These data suggest that the anomalies are of an in situ biogenic origin, although they are relatively deep (>70 m water depth) in the water column.

On two survey lines (lines 8 and 9) which were run along strike within (line 8), or near, the northern boundary (line 9) of the Goulburn Graben, methane was consistently higher (> two-fold) to the west (toward Money Shoal 1 and Kulka 1) than in the eastern end of the Graben. Two-fold increases in ethane and minor increases in propane accompanied the increase in methane. These slightly elevated methane, ethane and propane concentrations were accompanied by decreases in hydrocarbon wetness values, suggesting 'dry' gas. However, these slightly elevated levels of saturated hydrocarbons are independent of the biogenic hydrocarbons (ethylene and propylene) suggesting that they may be of a thermogenic origin. However, the anomalies are so weak that any interpretation of their origin remains equivocal.

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LIST OF SURVEY PERSONNEL

Cruise Leader: P. Napier

Deputy Cruise Leader: A. Moore,

BMR Scientific Staff:

G. Bickford, E. Chudyk, G. Heal

BMR Technical Staff:

Kossatz, T. McNamara, D. Pryce, H. Reynolds, A. Warnes, D. Holdway, G. Burren, H. Hudson, G. Sparksman, C. Tindall, P. Attenborough, B. Dickinson, C. Dyke, C. Green, D. Sewter

LIST OF ENCLOSURES

Enclosure 1. Floppy disk with geochemical data in ASCII format.

Enclosure 2. Map showing DHD lines.

LIST OF FIGURES

Figure 1. Map of the Arafura Sea showing an outline of the Goulburn Graben and the geochemical survey lines. The locations of geochemical anomalies are highlighted.

Figure 2. Total hydrocarbons (THC) versus line number (survey lines 1-6).

Figure 3. Methane versus line number (survey lines 1-6).

Figure 4. Sum of C1-C4 hydrocarbons (survey lines 1-6).

Figure 5. Ethane versus line number (survey line 1-6).

Figure 6. Ethylene versus line number (survey lines 1-6).

Figure 7. Propane versus line number (survey lines 1-6).

Figure 8. Propylene versus line number (survey lines 1-6).

Figure 9. Butane versus line number (survey lines 1-6).

Figure 10. Percent hydrocarbon wetness versus line number (survey lines 1-6).

Figure 11. Ratio of C1/C2 versus line number (survey lines 1-6).

Figure 12. Ratio of C2/C3 versus line number (survey lines 1-6).

Figure 13. Bernard Parameter versus line number (survey lines 1-6).

Figure 14. THC versus line number (survey lines 7-13).

Figure 15. Sum of C1-C4 hydrocarbons versus line number (survey lines 7-13).

Figure 16. Methane versus line number (survey lines 7-13).

Figure 17. Ethane versus line number (survey lines 7-13).

Figure 18. Ethylene versus line number (survey lines 7-13).

Figure 19. Propane versus line number (survey lines 7-13).

Figure 20. Propylene versus line number (survey lines 7-13).

Figure 21. Butanes versus line number (survey lines 7-13).

Figure 22. Percent hydrocarbon wetness versus line number (survey lines 7-13).

Figure 23. Ratio of C1/C2 versus line number (survey lines 7-13).

Figure 24. Ratio of C2/C3 versus line number (survey lines 7-13).

Figure 25. Bernard Parameter versus line number (survey lines 7-13).

Figure 26. THC versus line number (survey lines 14-16).

Figure 27. Sum C1-C4 versus line number (survey lines 14-16).

Figure 28. Methane versus line number (survey lines 14-16).

Figure 29. Ethane versus line number (survey lines 14-16).

Figure 30. Ethylene versus line number (survey lines 14-16).

Figure 31. Propane versus line number (survey lines 14-16).

Figure 32. Propylene versus line number (survey lines 14-16).

Figure 33. Butanes versus line number (survey lines 14-16).

Figure 34. Percent hydrocarbon wetness versus line number (survey lines 14-16).

Figure 35. Ratio of C1/C2 versus line number (survey lines 14-16).

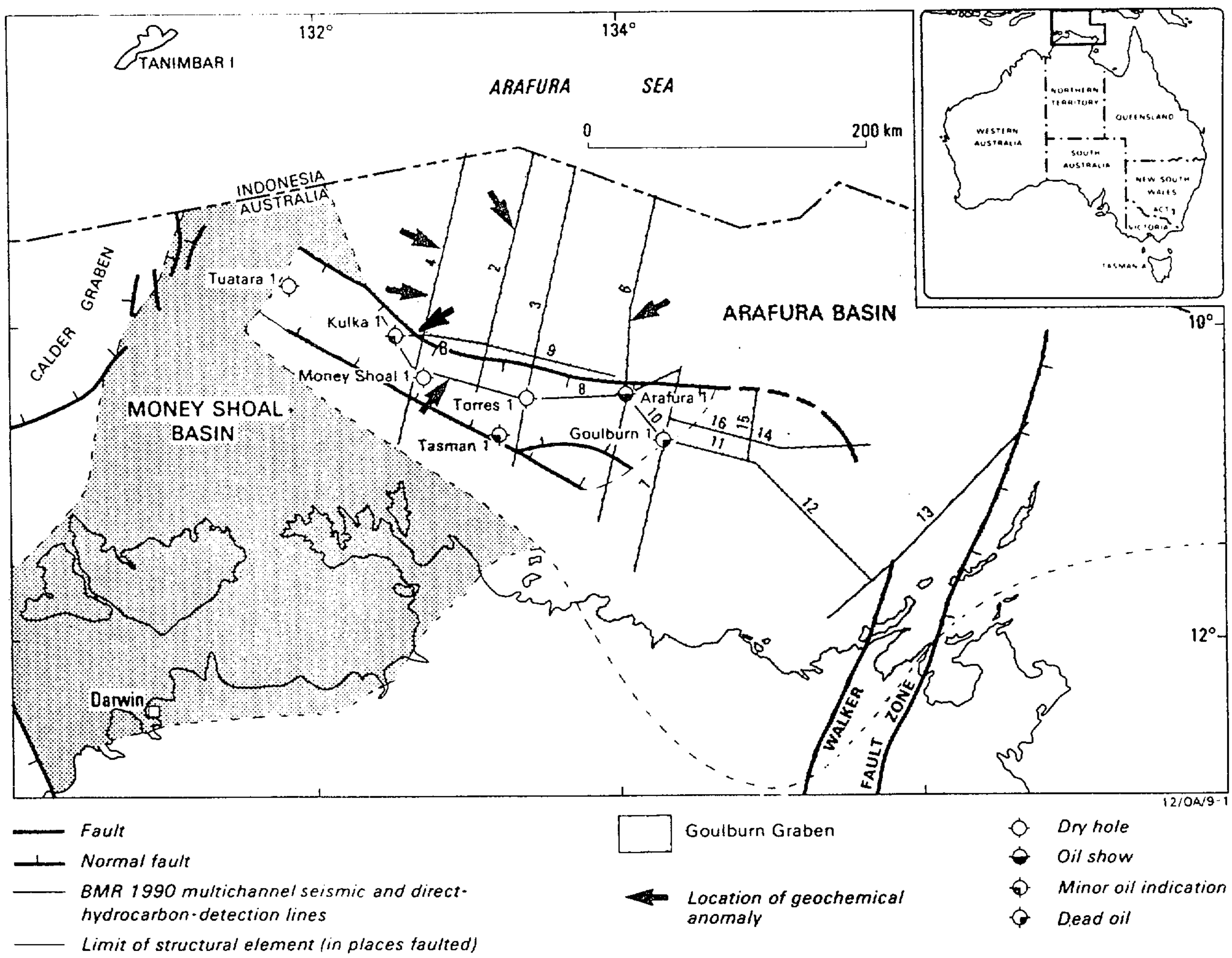
Figure 36. Ratio of C2/C3 versus line number (survey lines 14-16).

Figure 37. Bernard Parameter versus line number (survey lines 14-16).

Figure 38. Methane versus percent wetness (survey lines 1-6).

Figure 39. Methane versus percent wetness (survey lines 7-13).

Figure 40. Methane versus percent wetness (survey lines 14-16).



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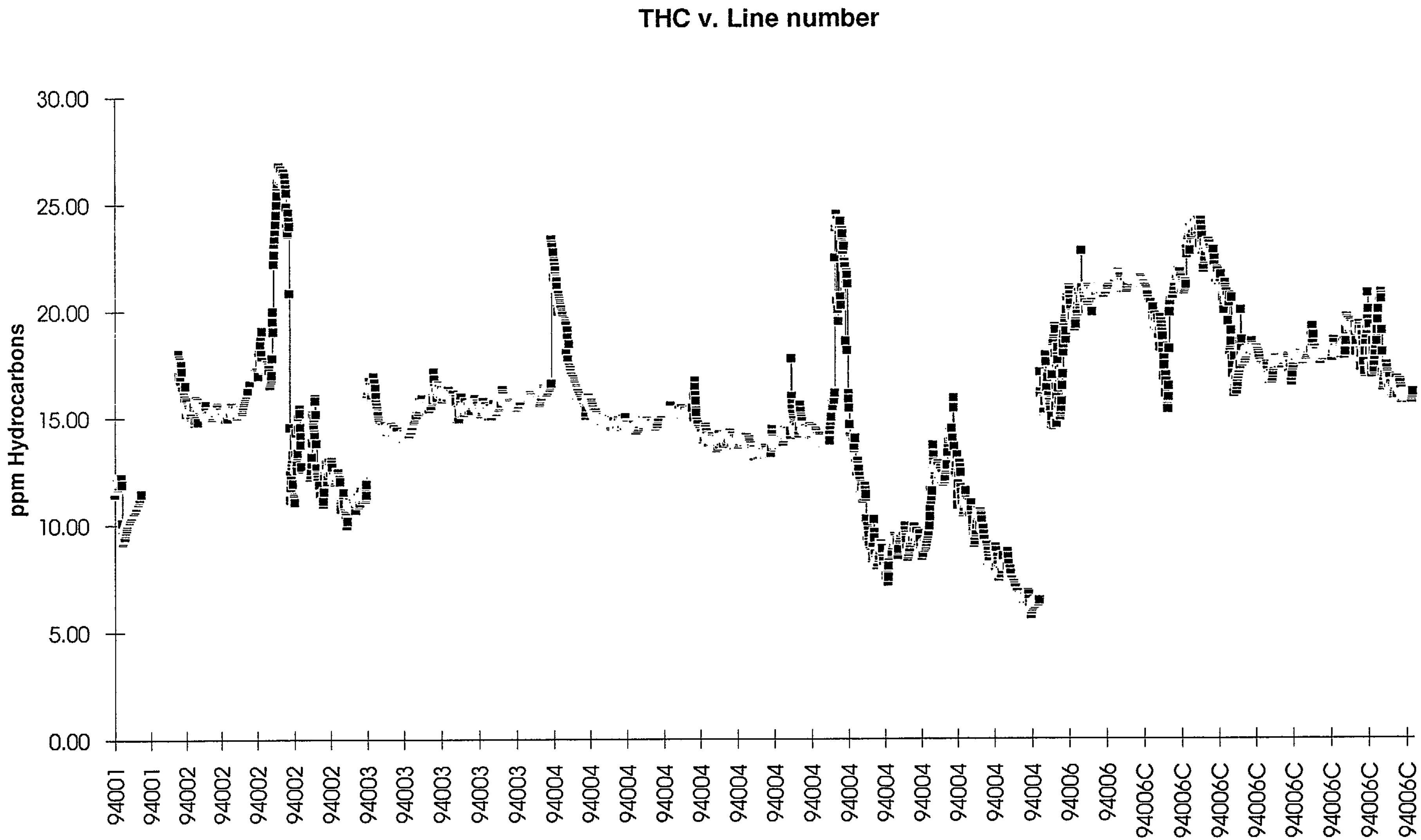


Figure 2. Total hydrocarbons (THC) versus line number (survey lines 1-6).

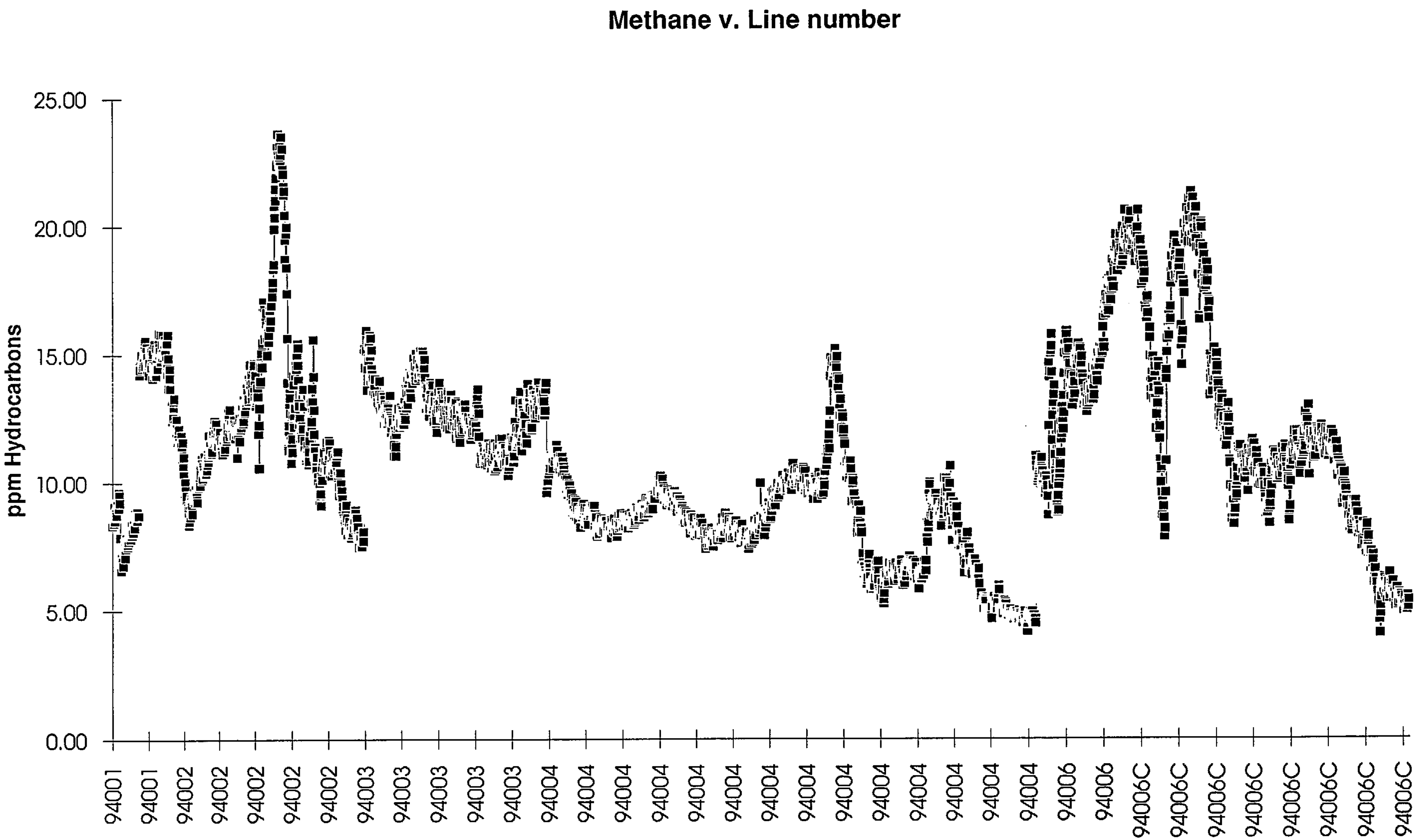


Figure 3. Methane versus line number (survey lines 1-6).

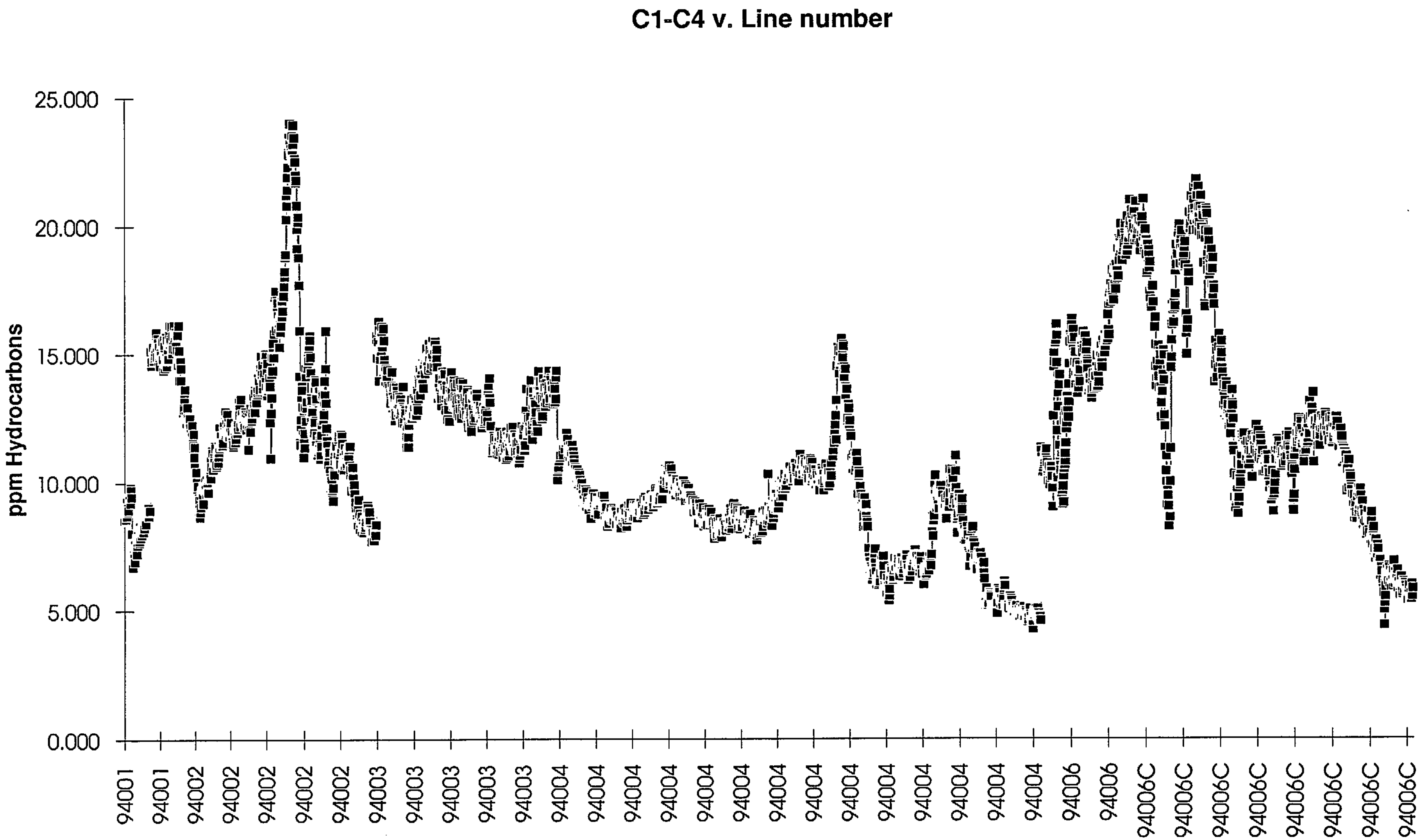


Figure 4. Sum of C1-C4 hydrocarbons (survey lines 1-6).

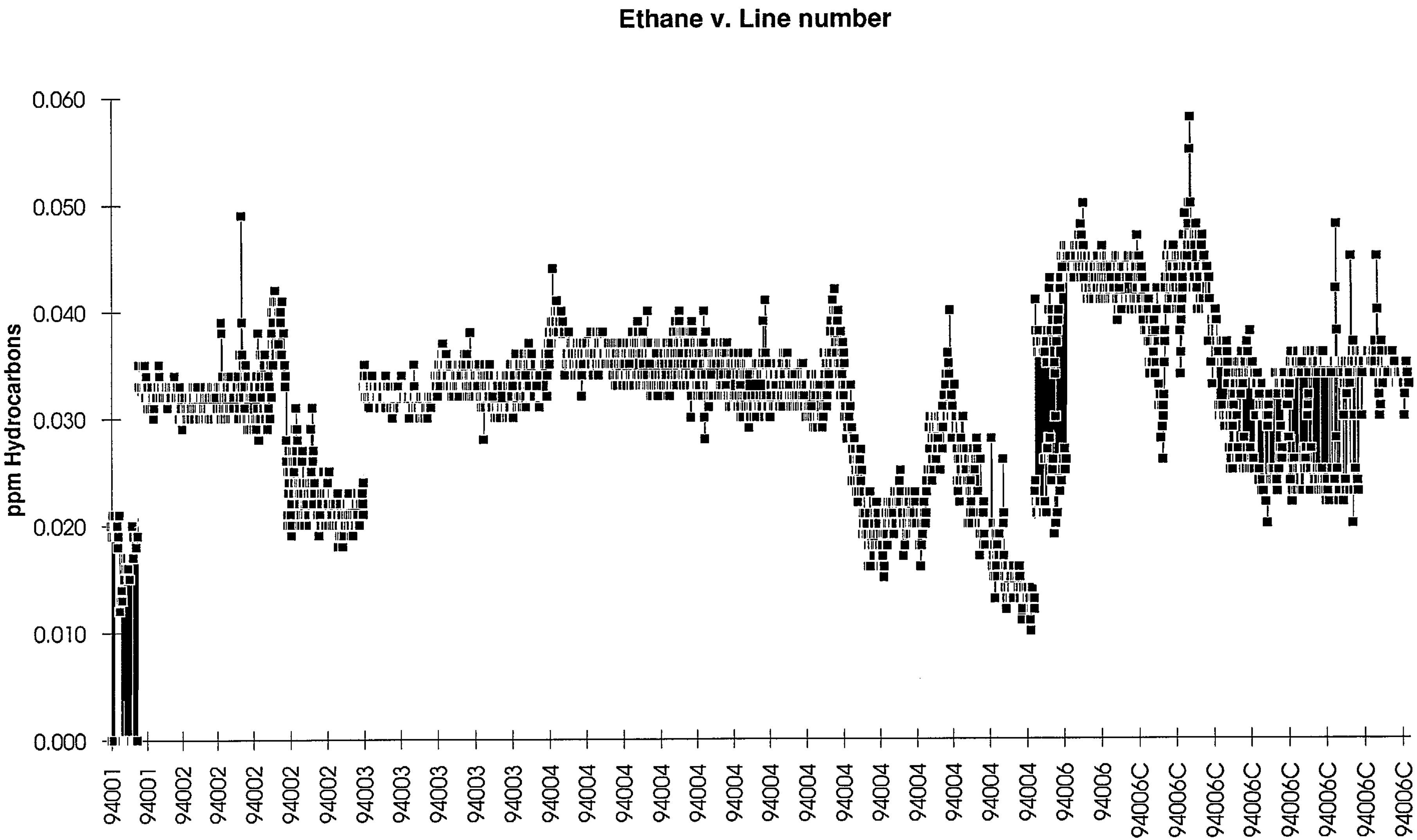


Figure 5. Ethane versus line number (survey line 1-6).

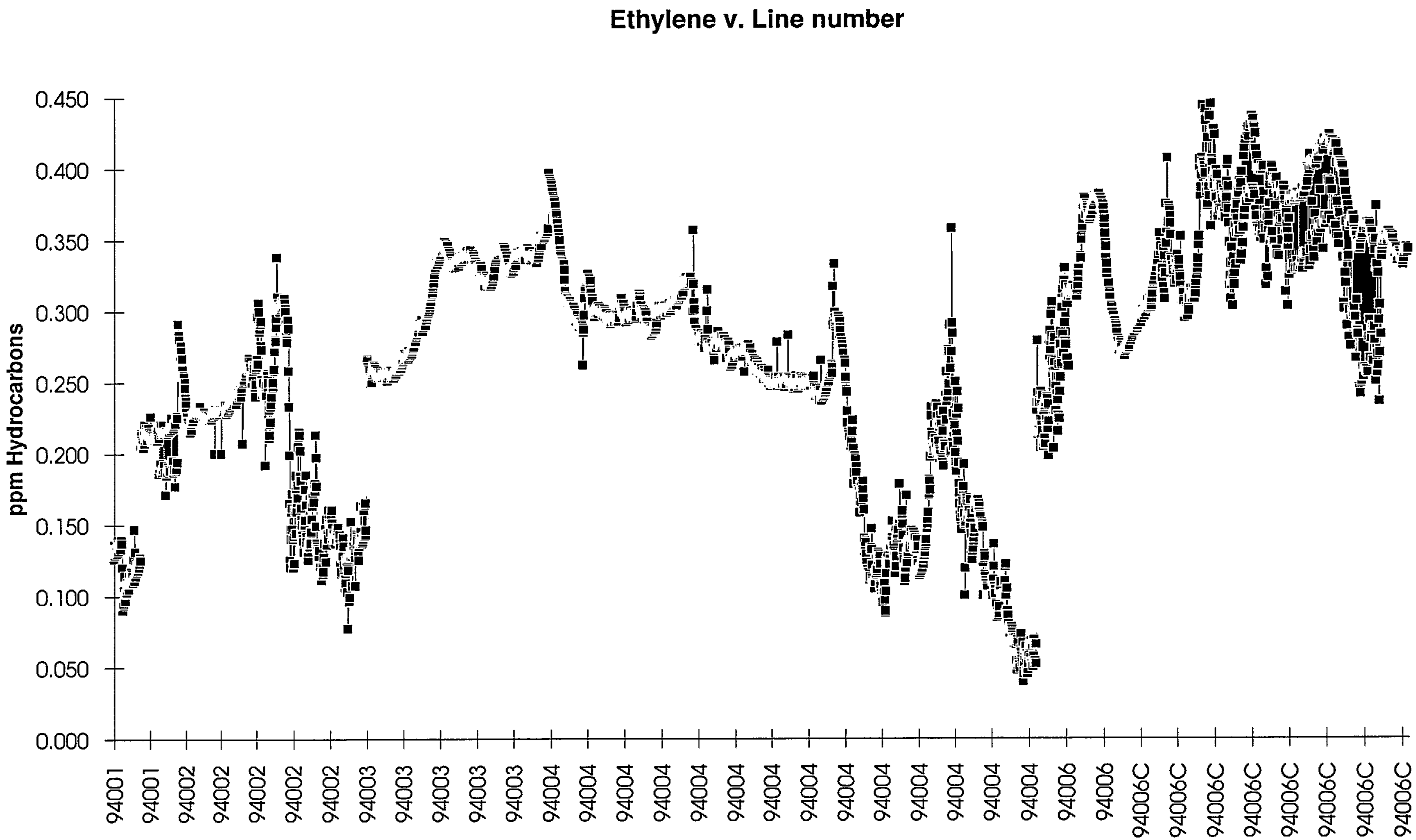


Figure 6. Ethylene versus line number (survey lines 1-6).

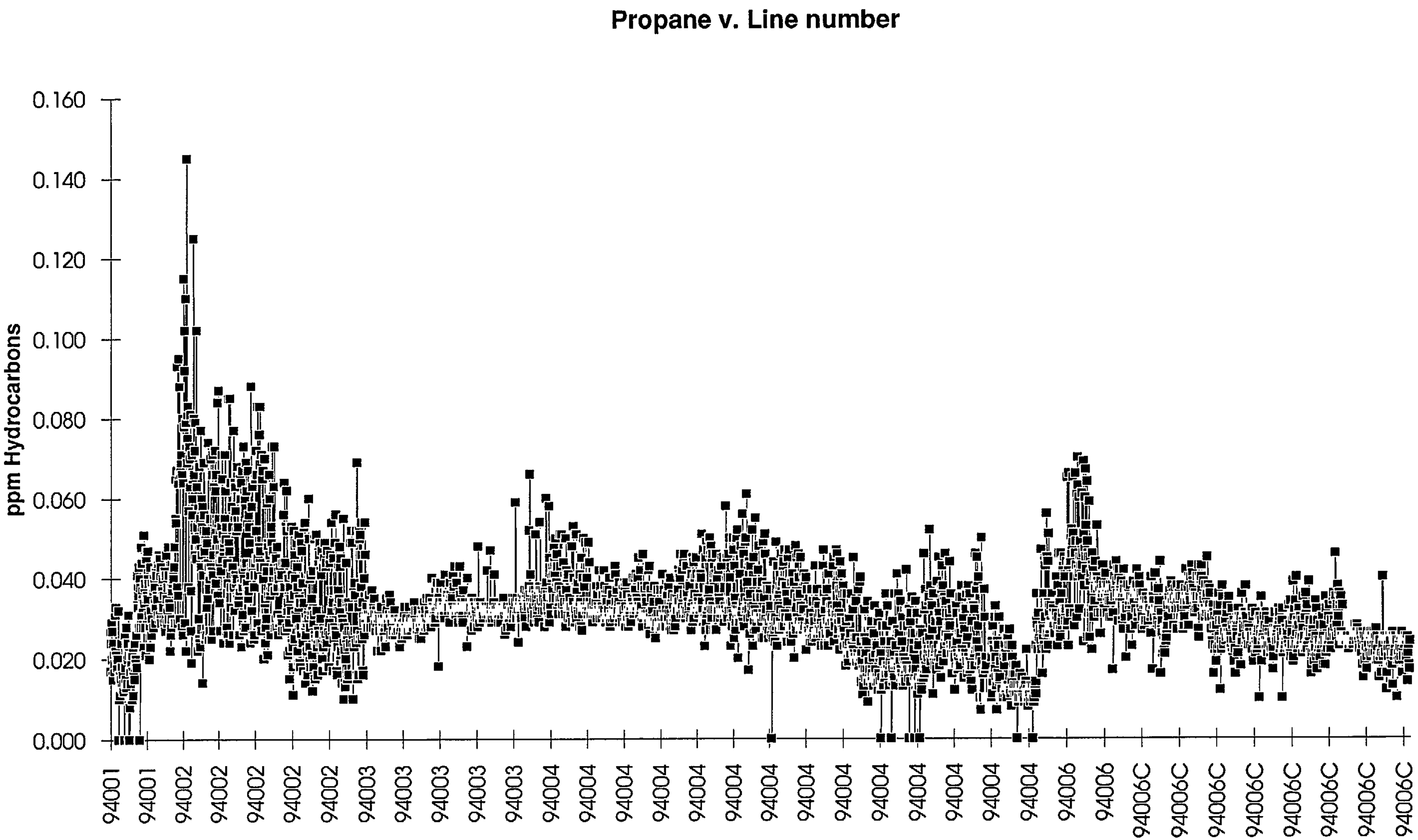


Figure 7. Propane versus line number (survey lines 1-6).

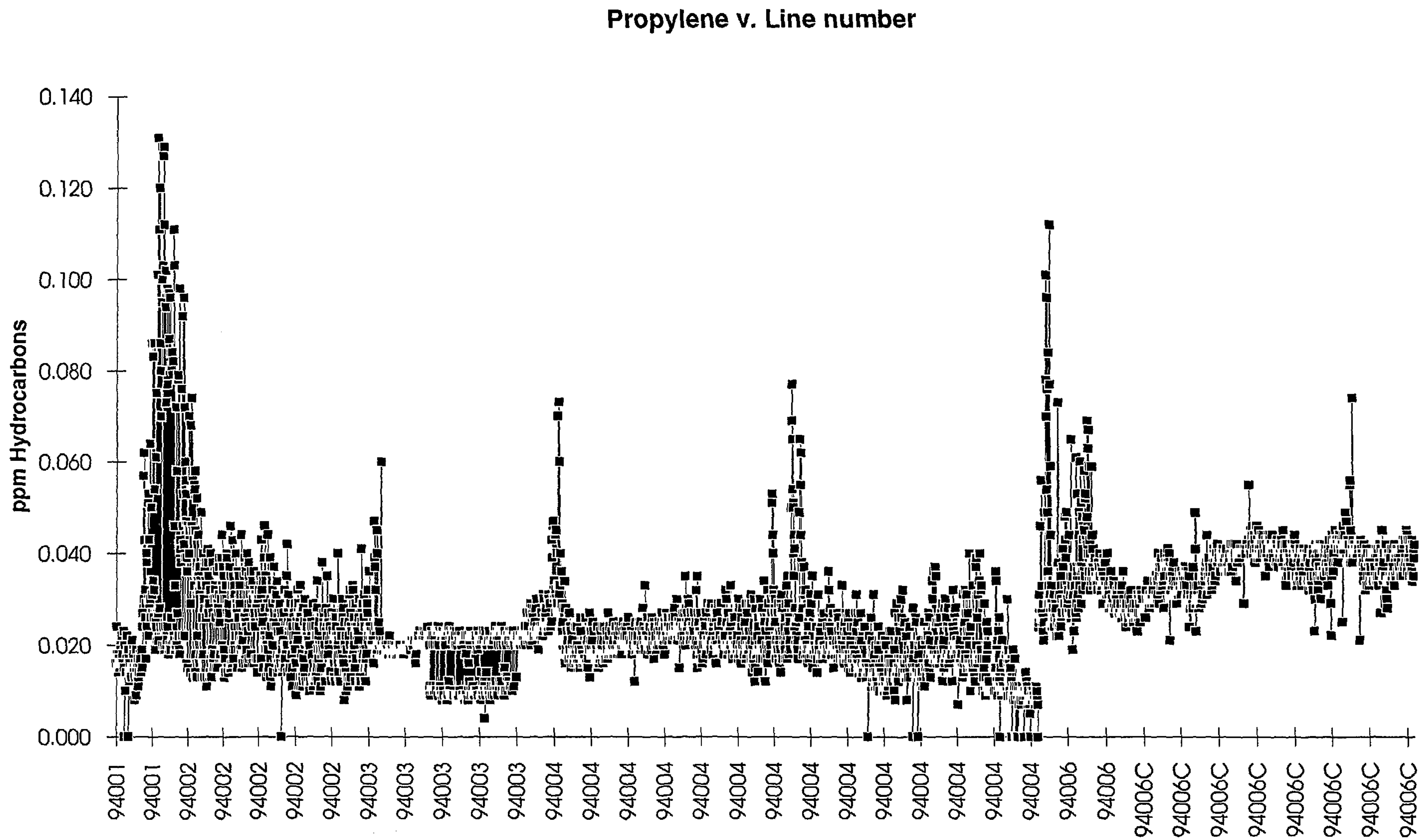


Figure 8. Propylene versus line number (survey lines 1-6).

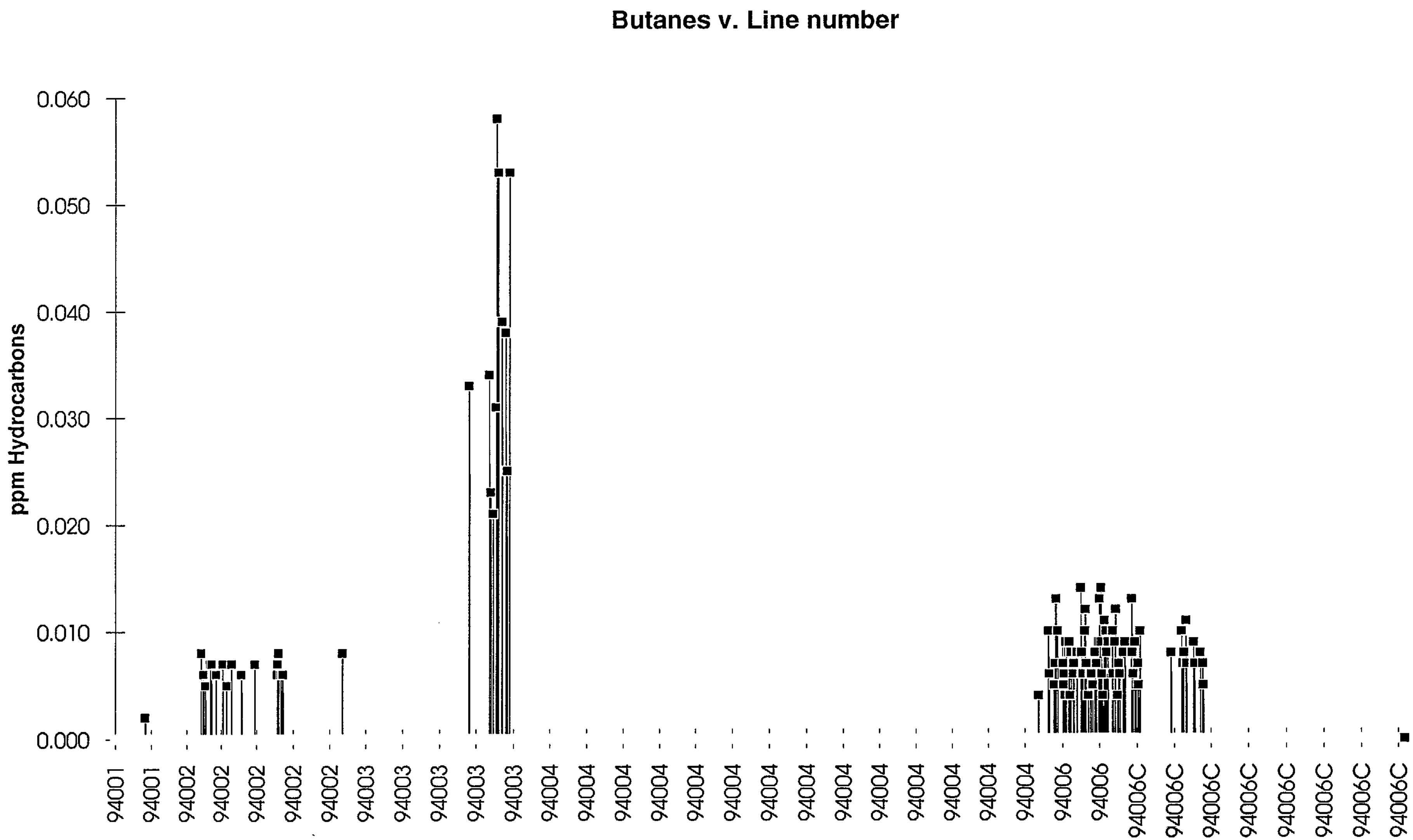


Figure 9. Butane versus line number (survey lines 1-6).

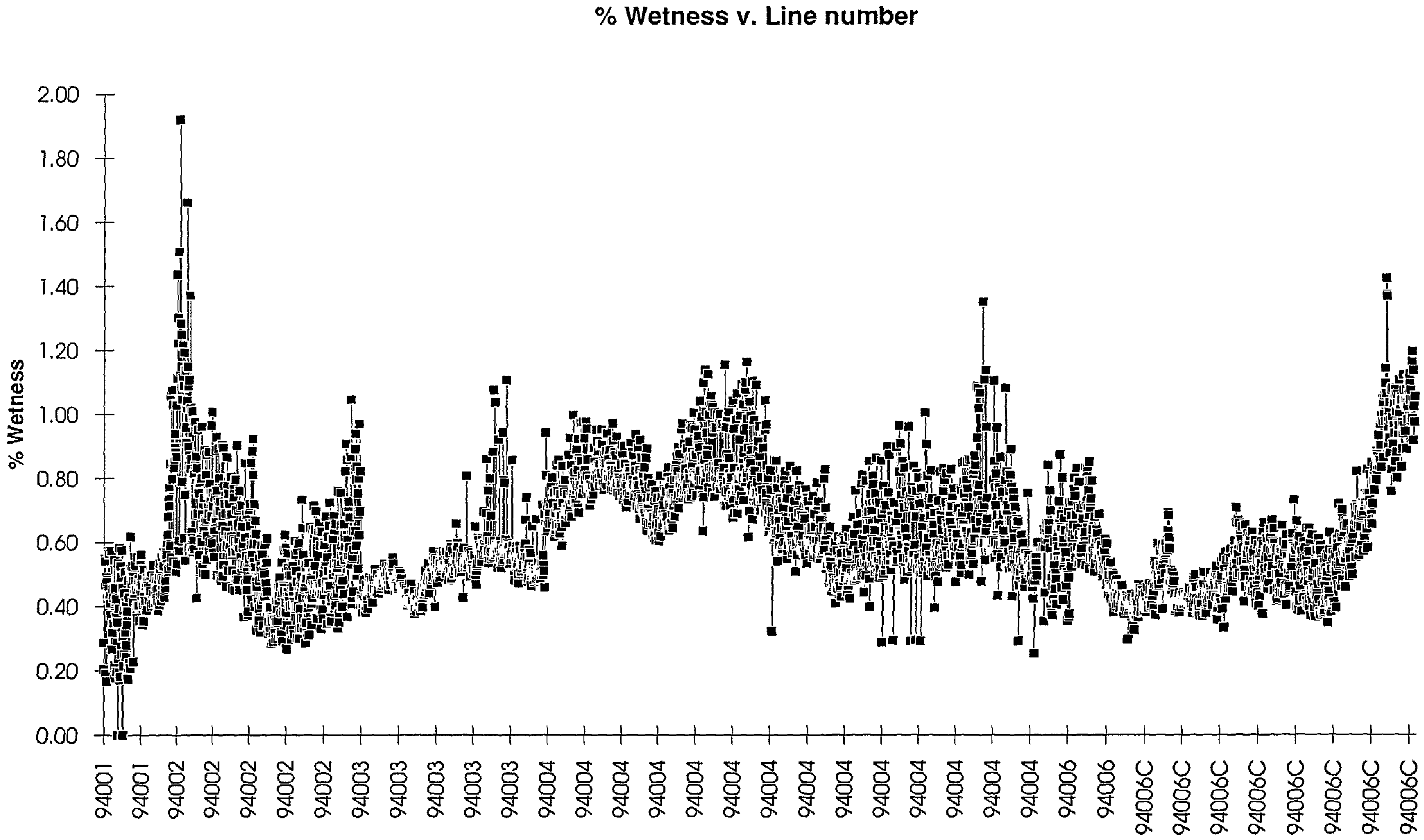


Figure 10. Percent hydrocarbon wetness versus line number (survey lines 1-6).

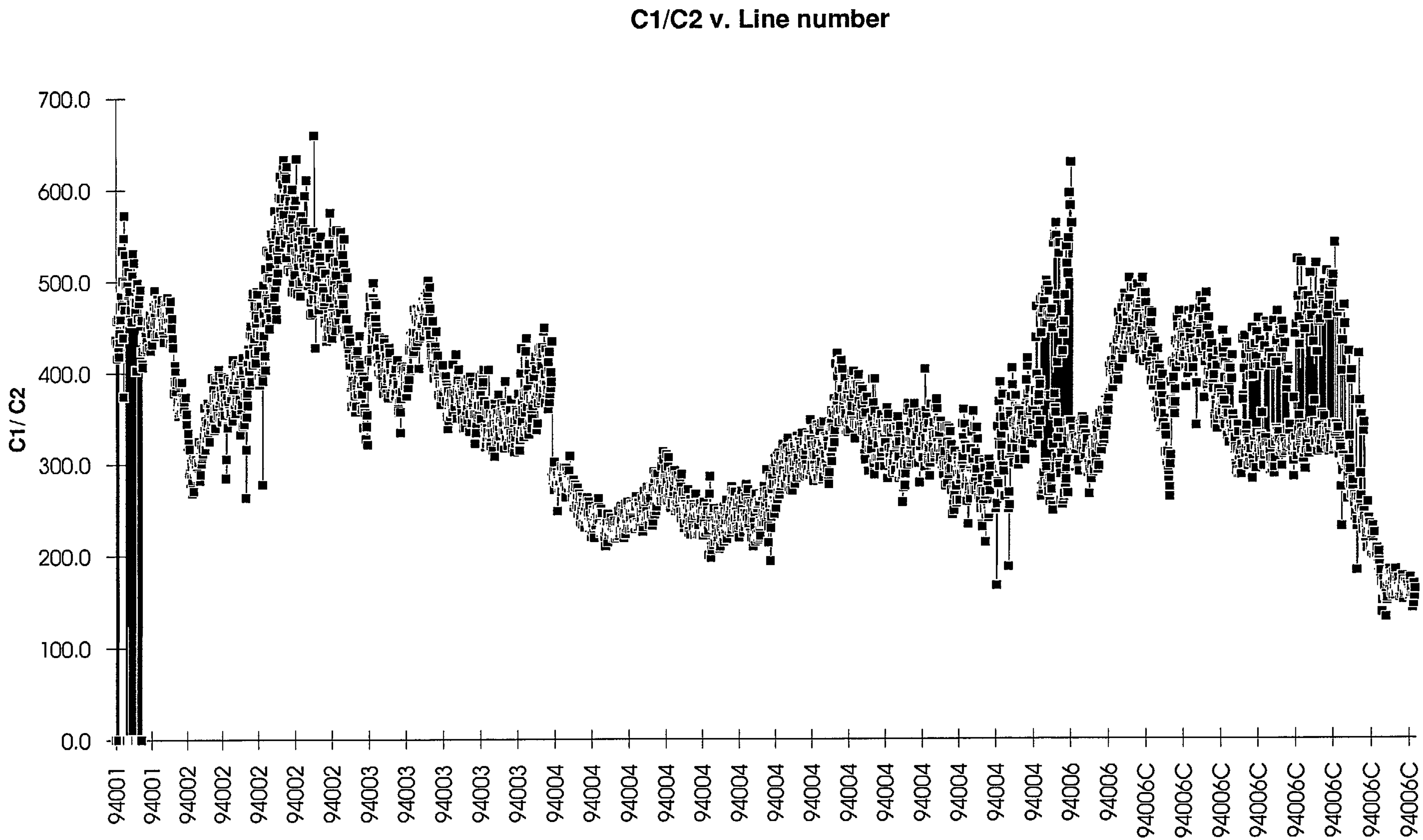


Figure 11. Ratio of C1/C2 versus line number (survey lines 1-6).

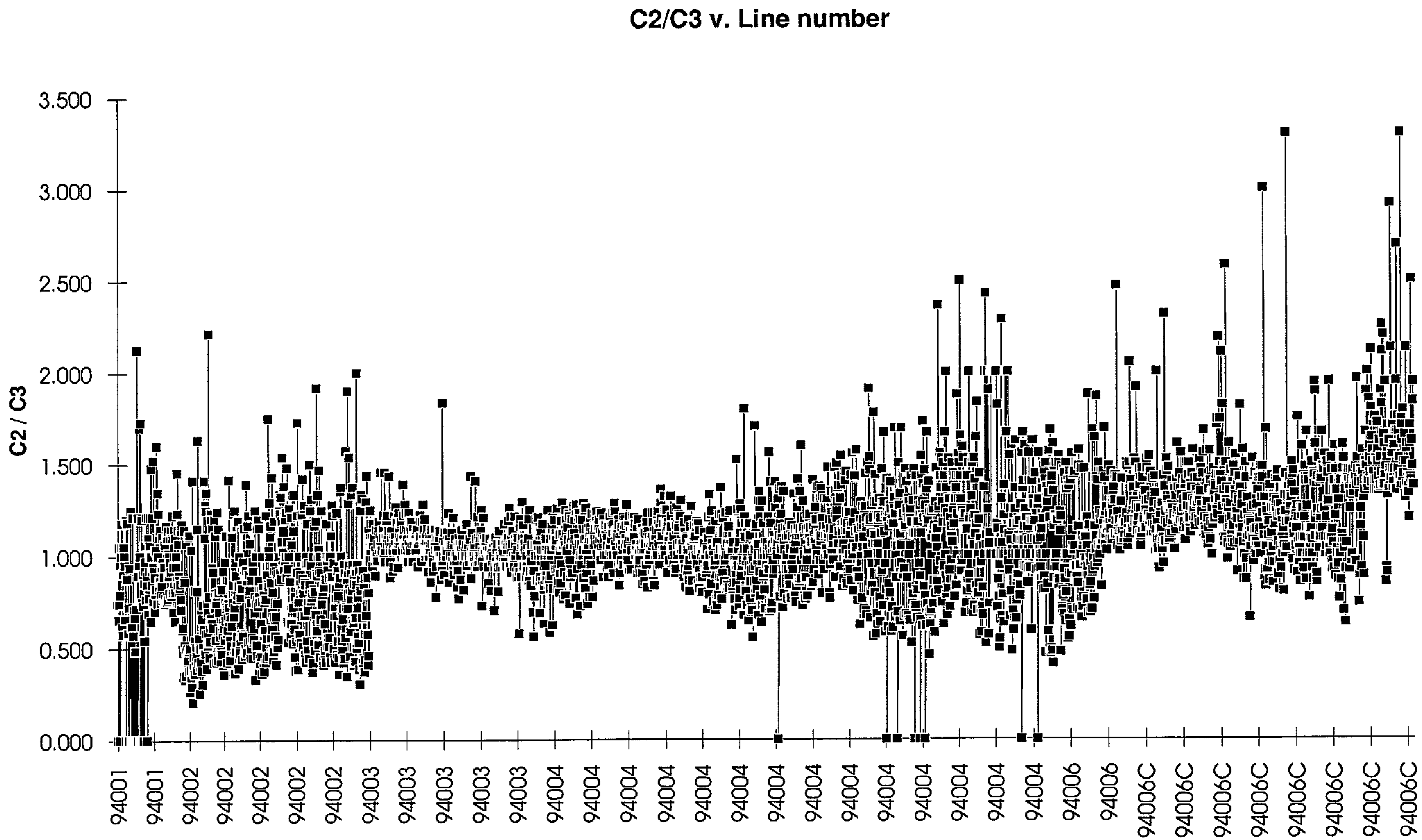


Figure 12. Ratio of C2/C3 versus line number (survey lines 1-6).

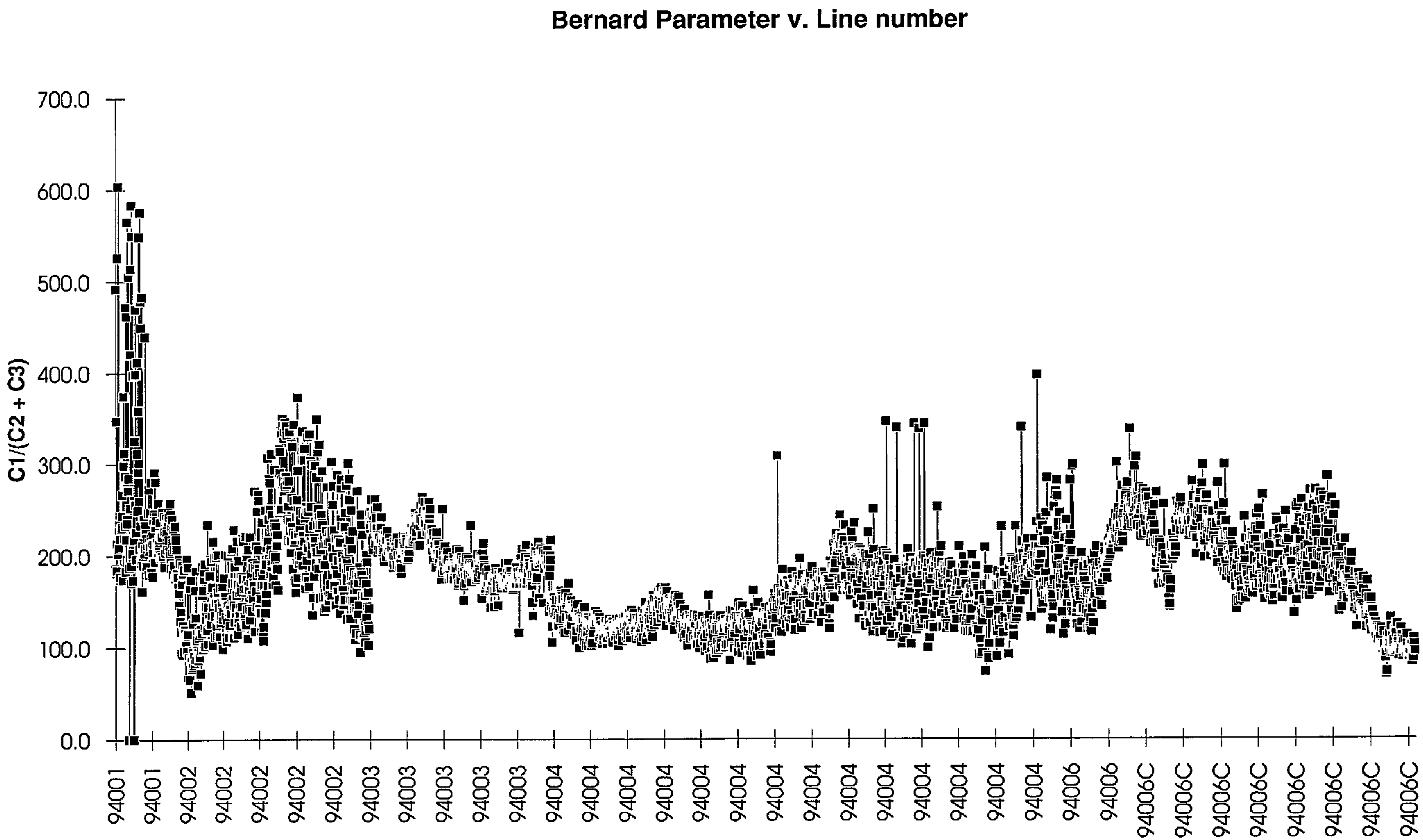


Figure 13. Bernard Parameter versus line number (survey lines 1-6).

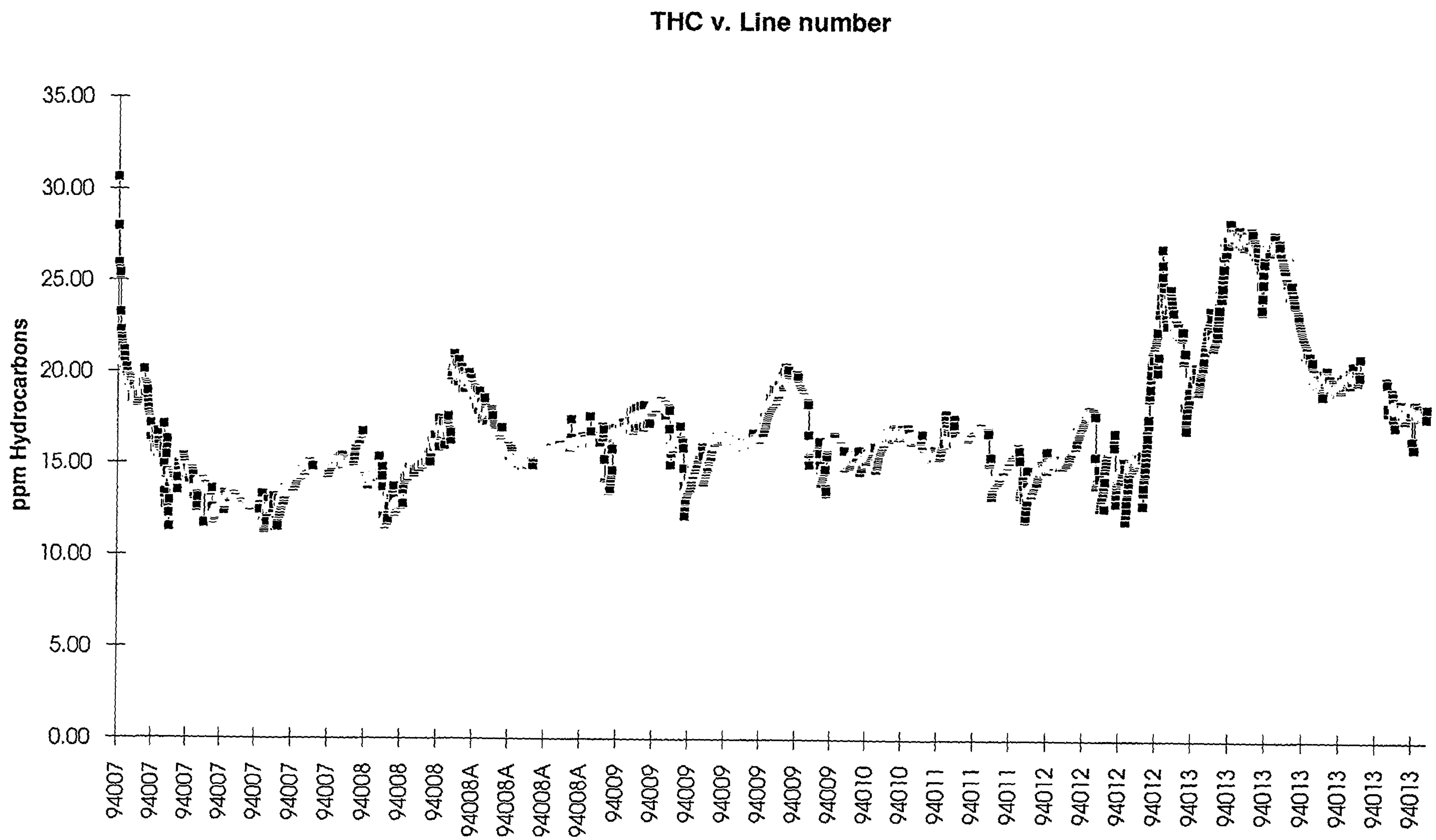


Figure 14. THC versus line number (survey lines 7-13).

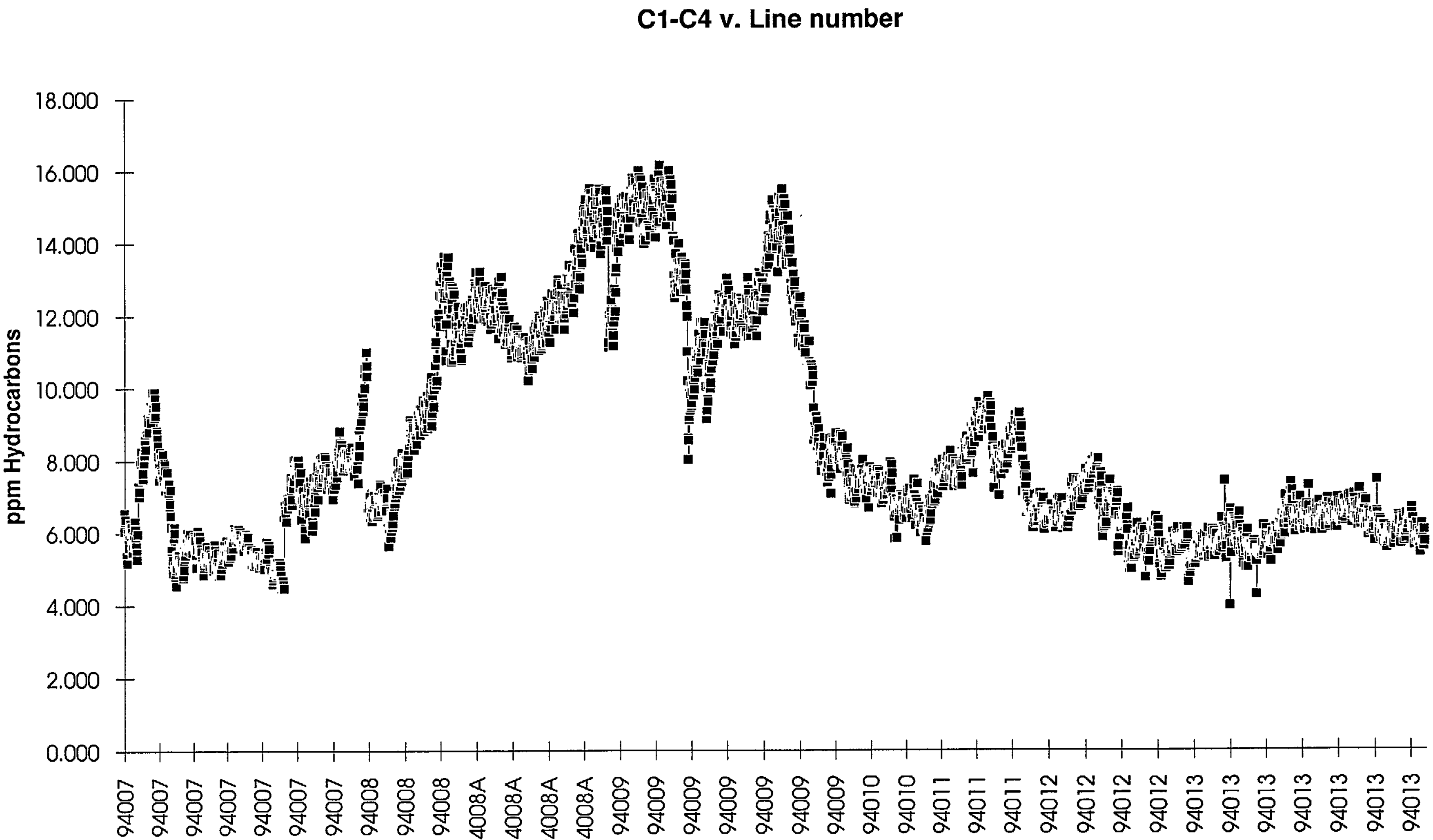


Figure 15. Sum of C1-C4 hydrocarbons versus line number (survey lines 7-13).

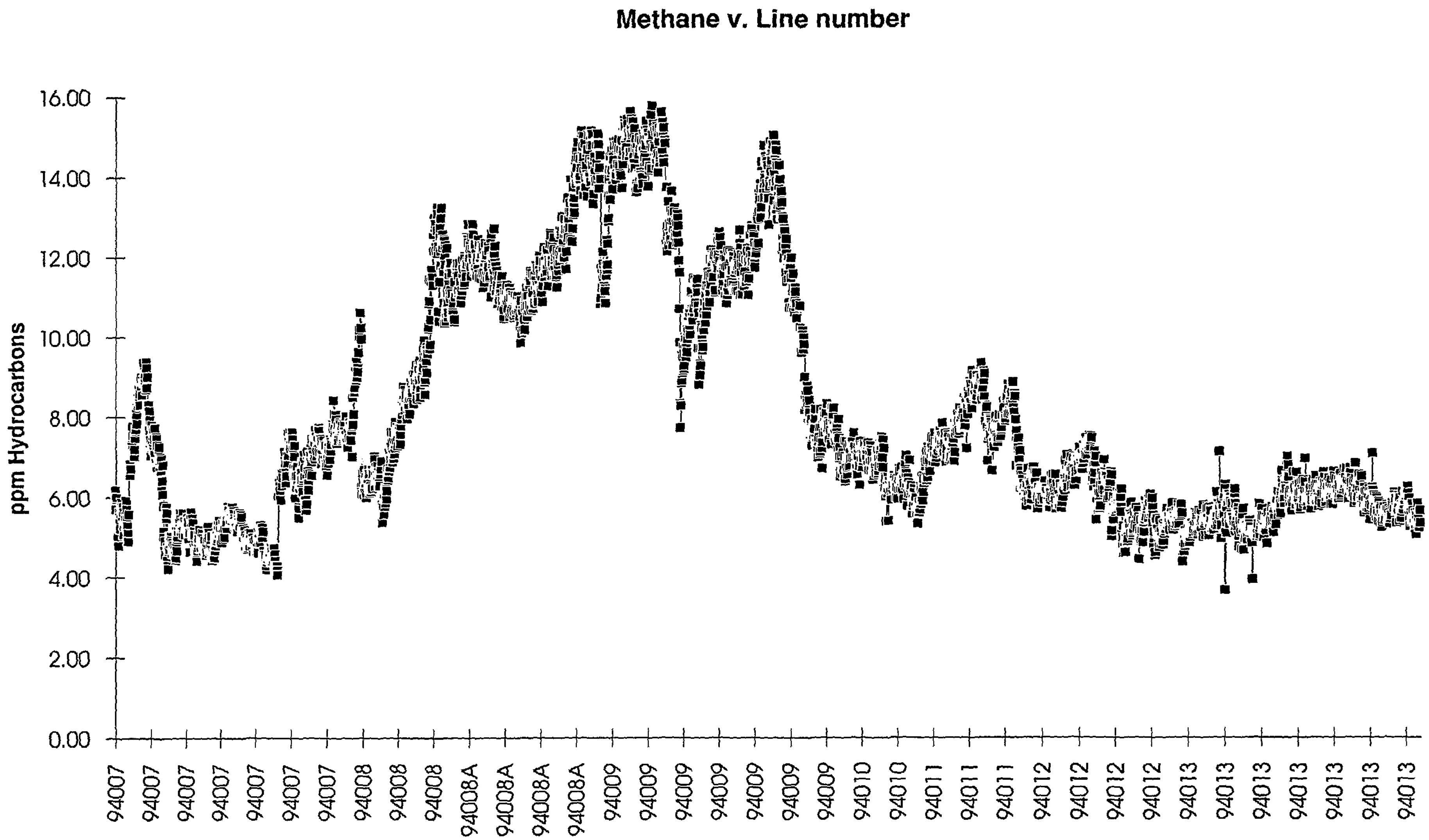


Figure 16. Methane versus line number (survey lines 7-13).

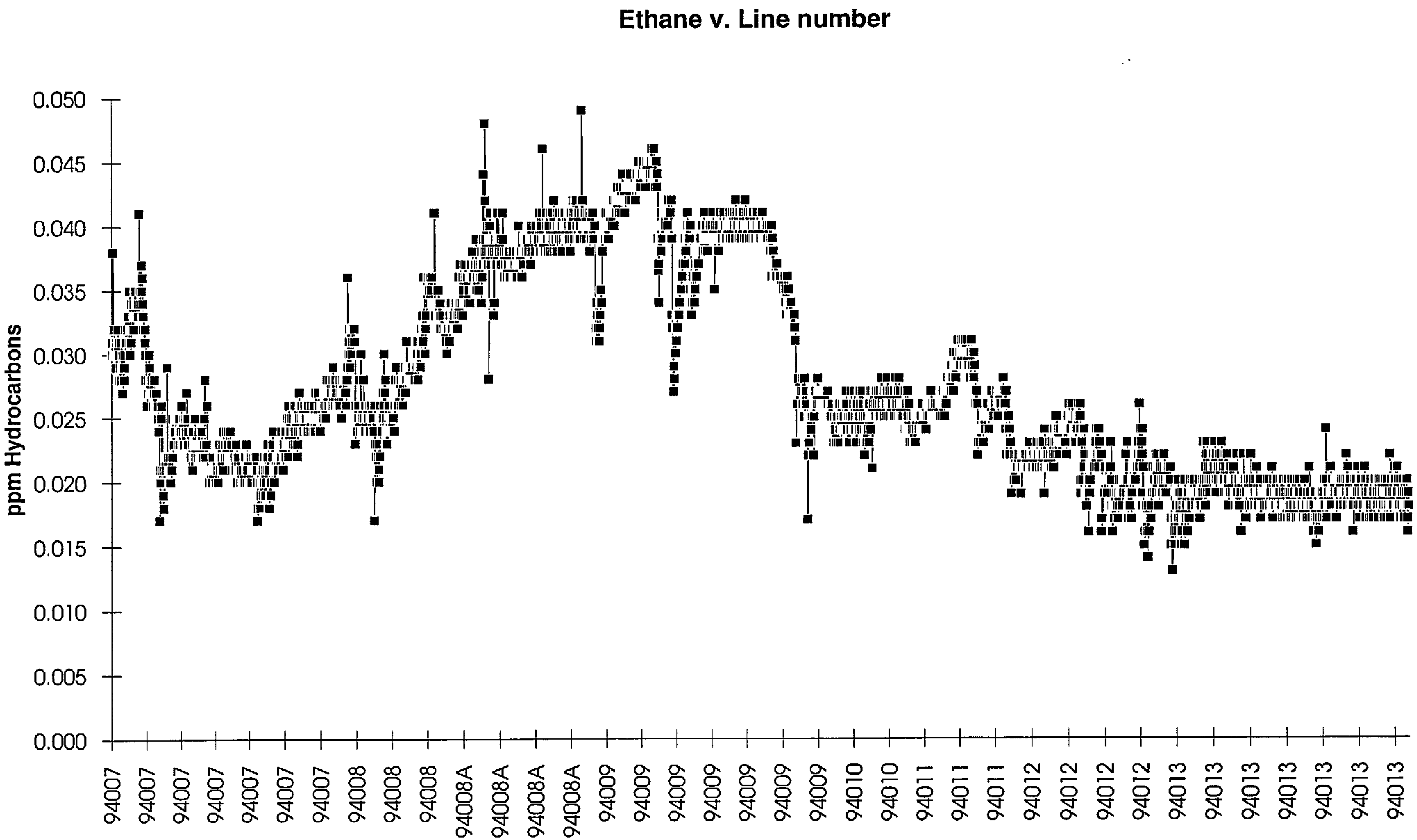


Figure 17. Ethane versus line number (survey lines 7-13).

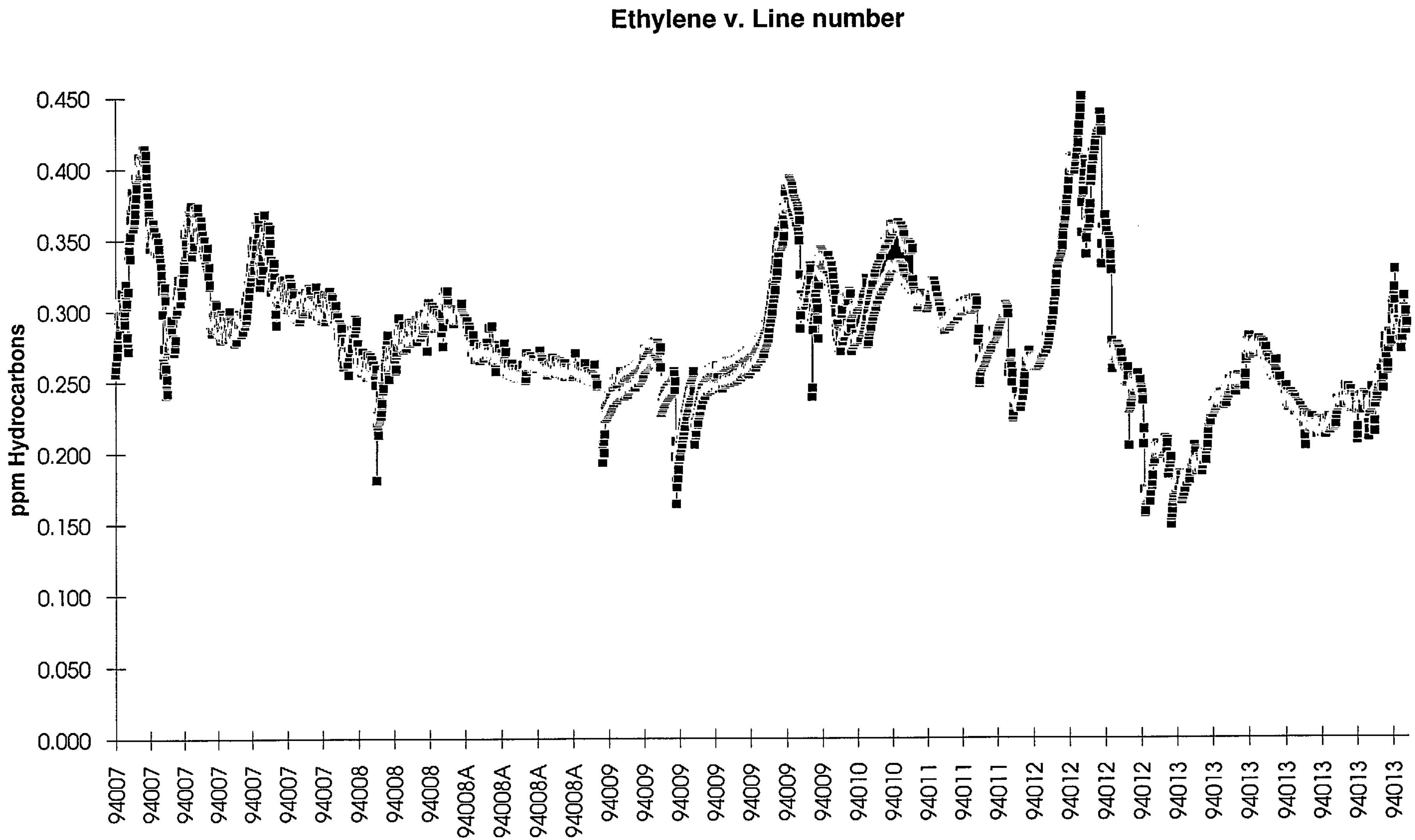


Figure 18. Ethylene versus line number (survey lines 7-13).

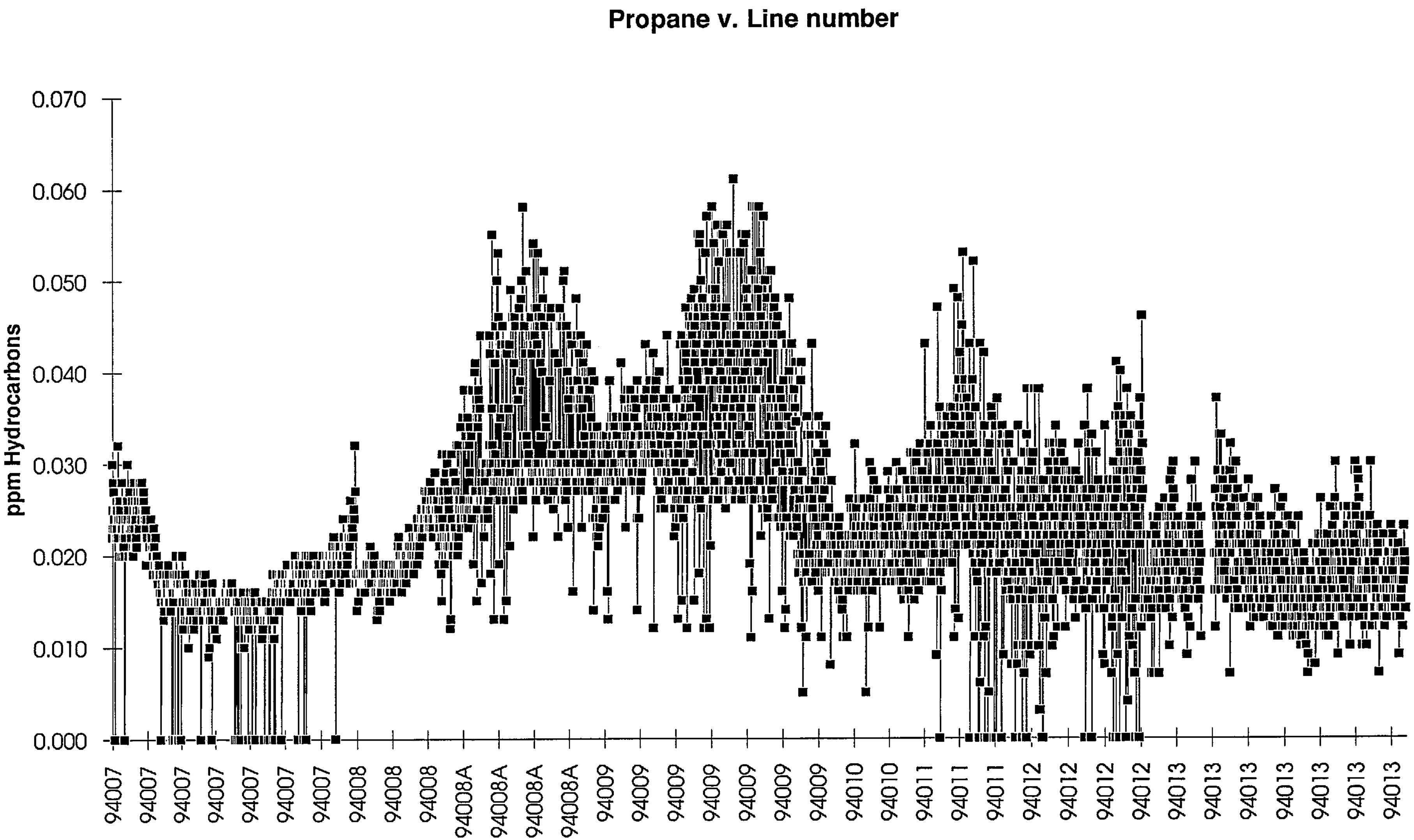


Figure 19. Propane versus line number (survey lines 7-13).

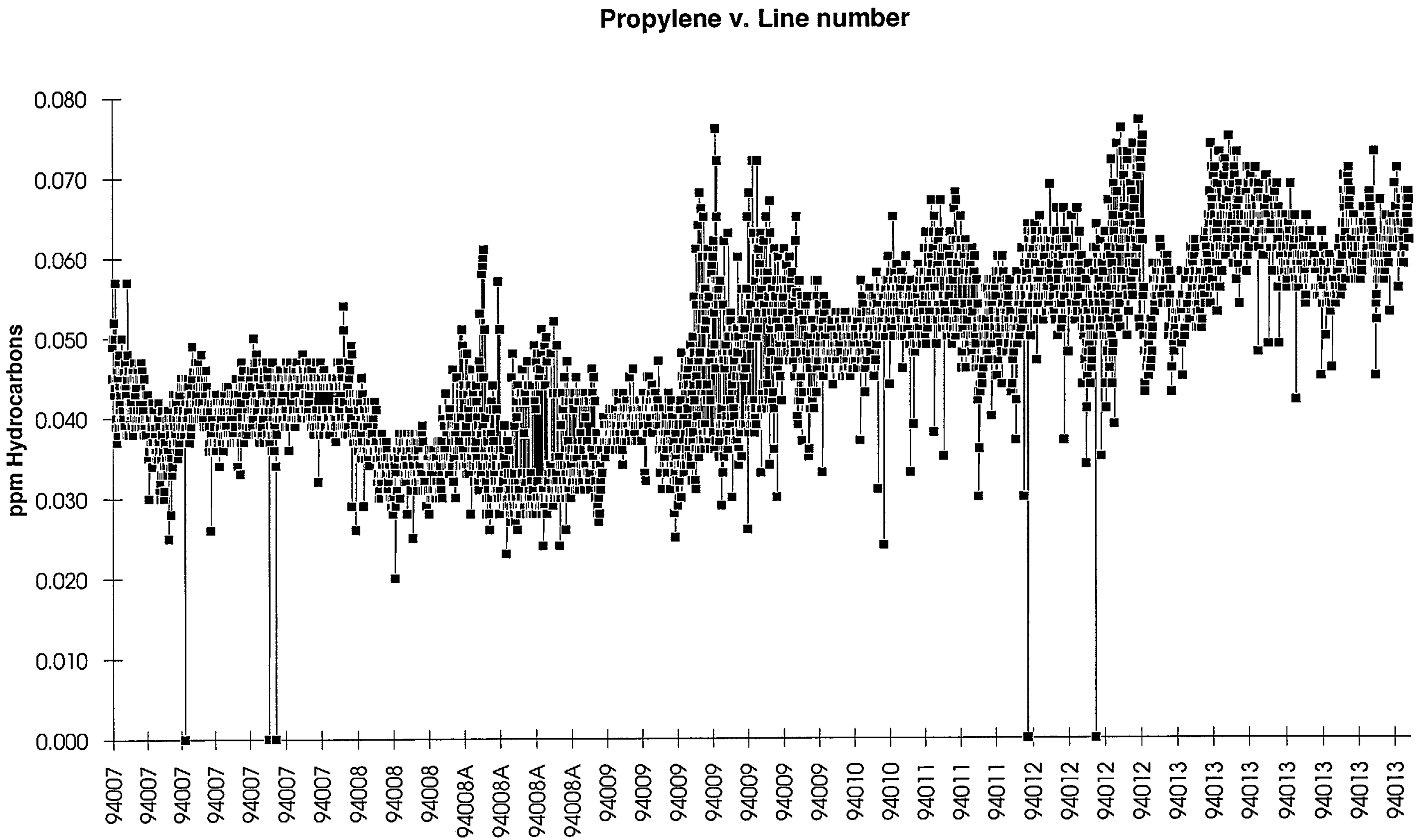


Figure 20. Propylene versus line number (survey lines 7-13).

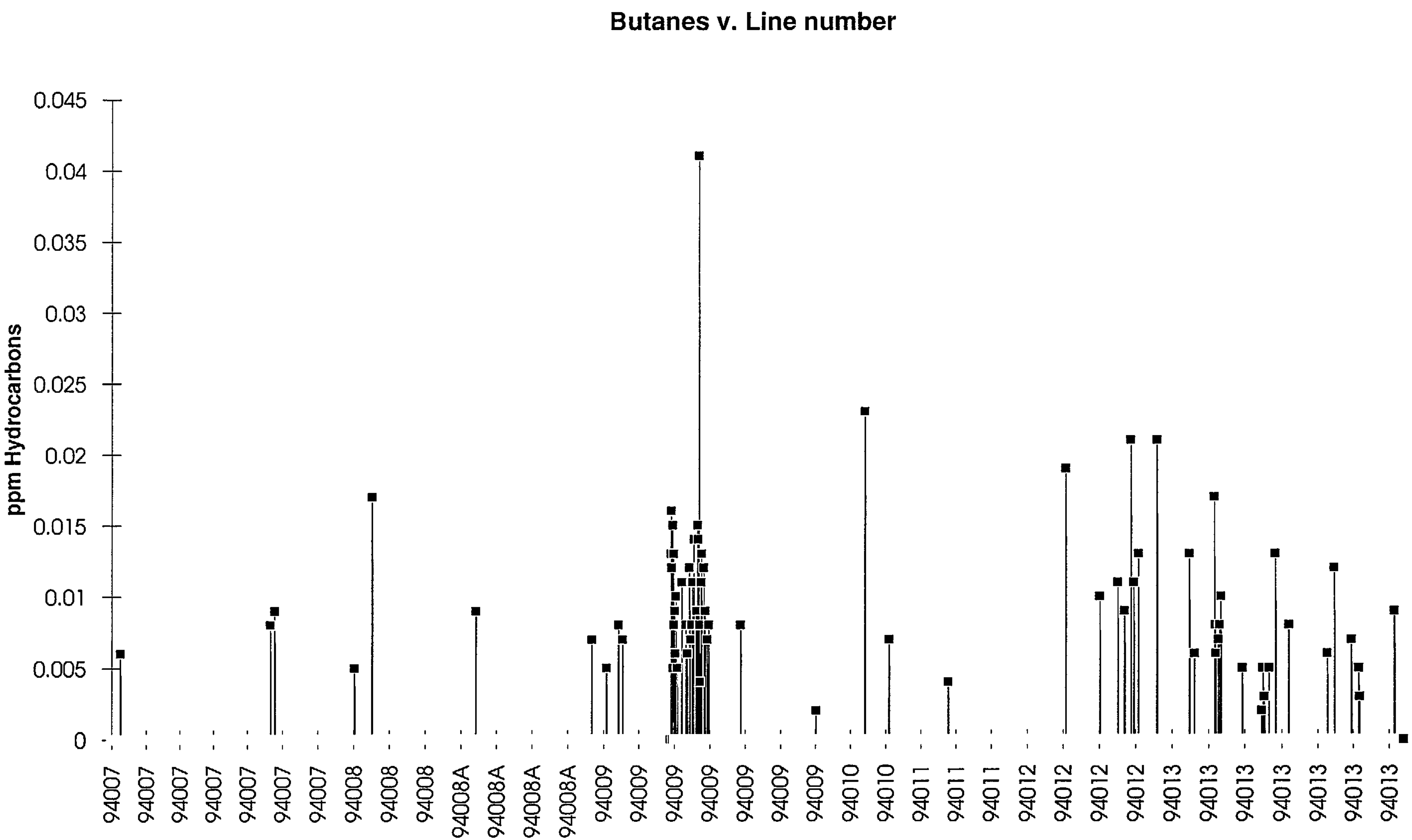


Figure 21. Butanes versus line number (survey lines 7-13).

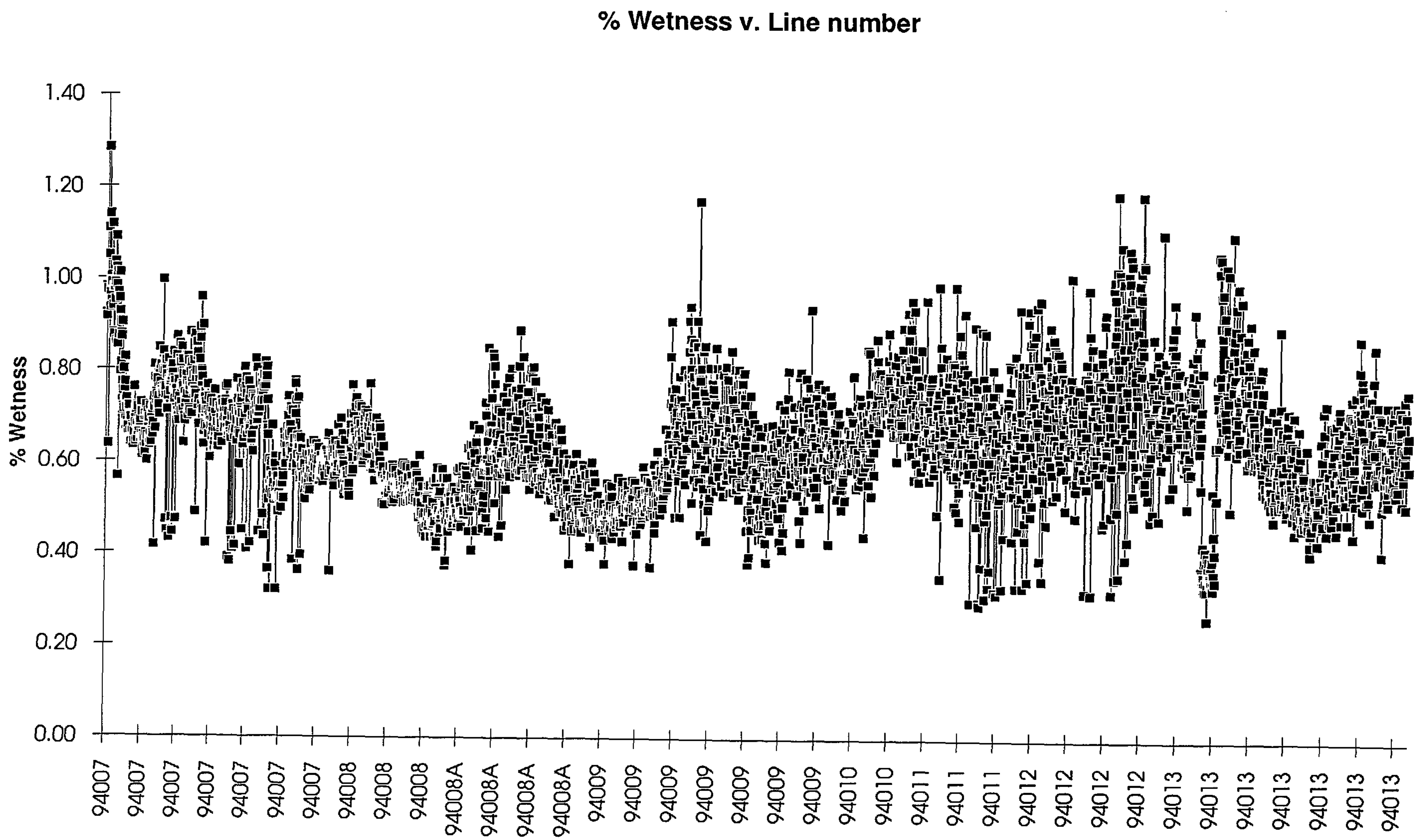


Figure 22. Percent hydrocarbon wetness versus line number (survey lines 7-13).

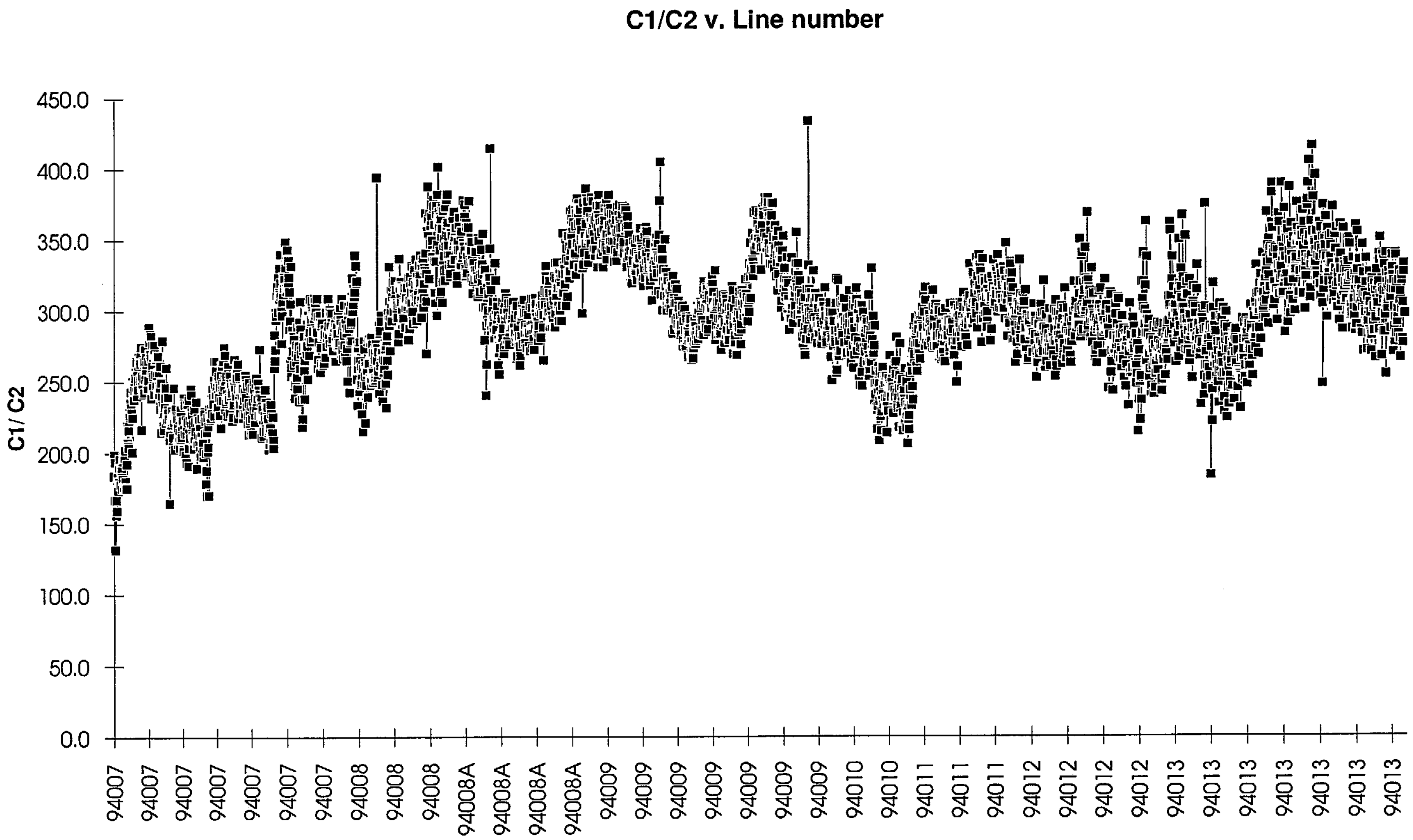


Figure 23. Ratio of C1/C2 versus line number (survey lines 7-13).

C2/C3 v. Line number

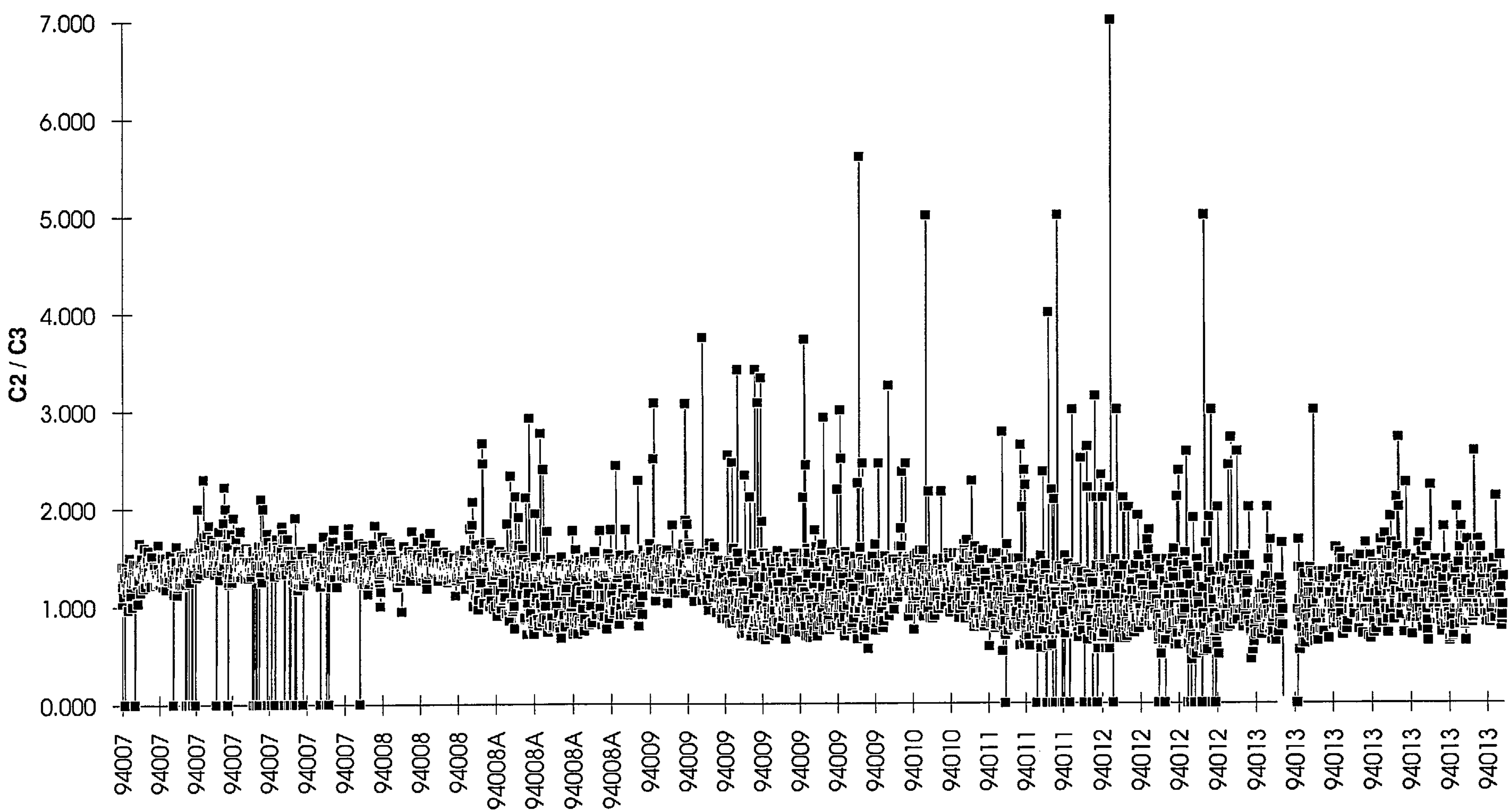


Figure 24. Ratio of C2/C3 versus line number (survey lines 7-13).

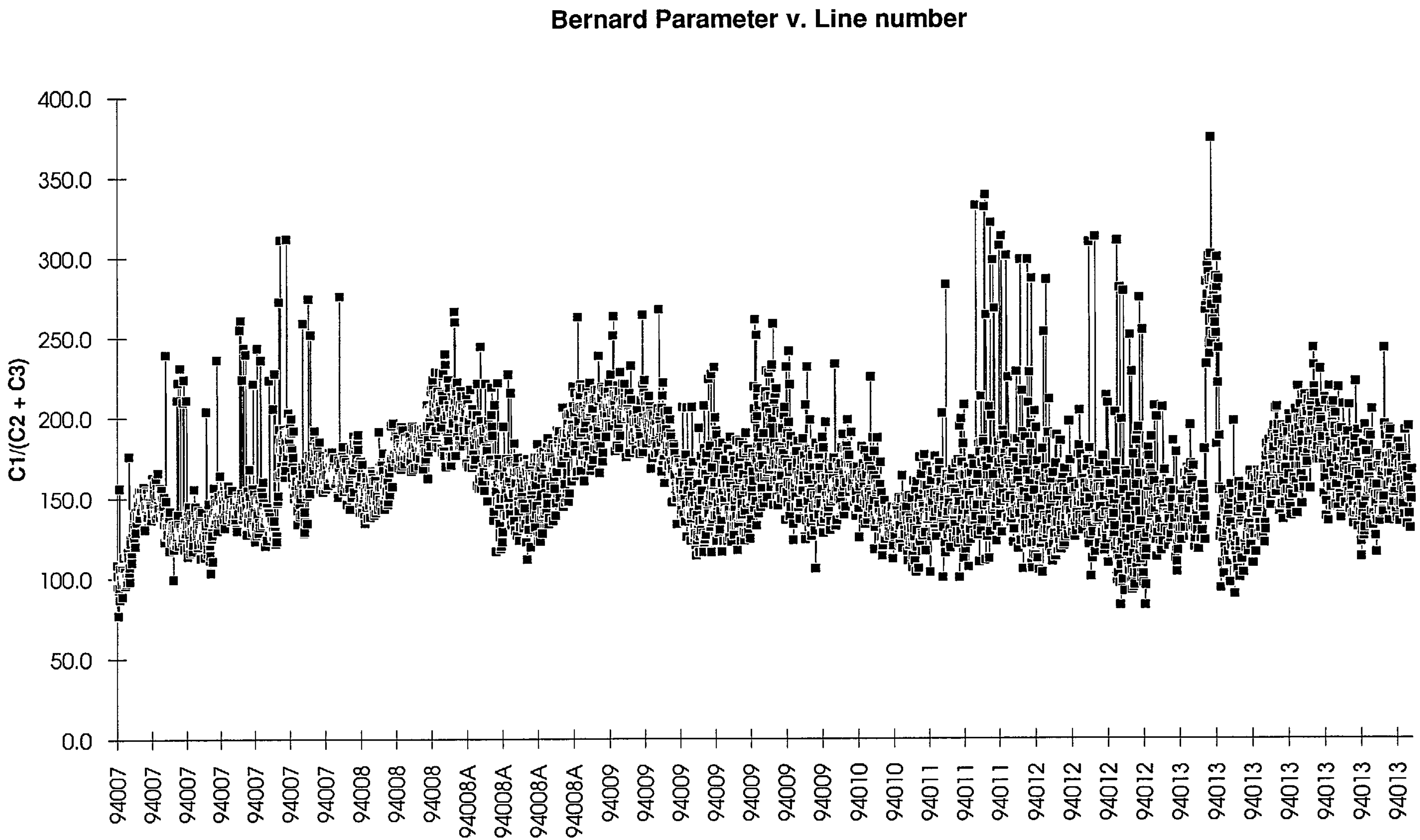


Figure 25. Bernard Parameter versus line number (survey lines 7-13).

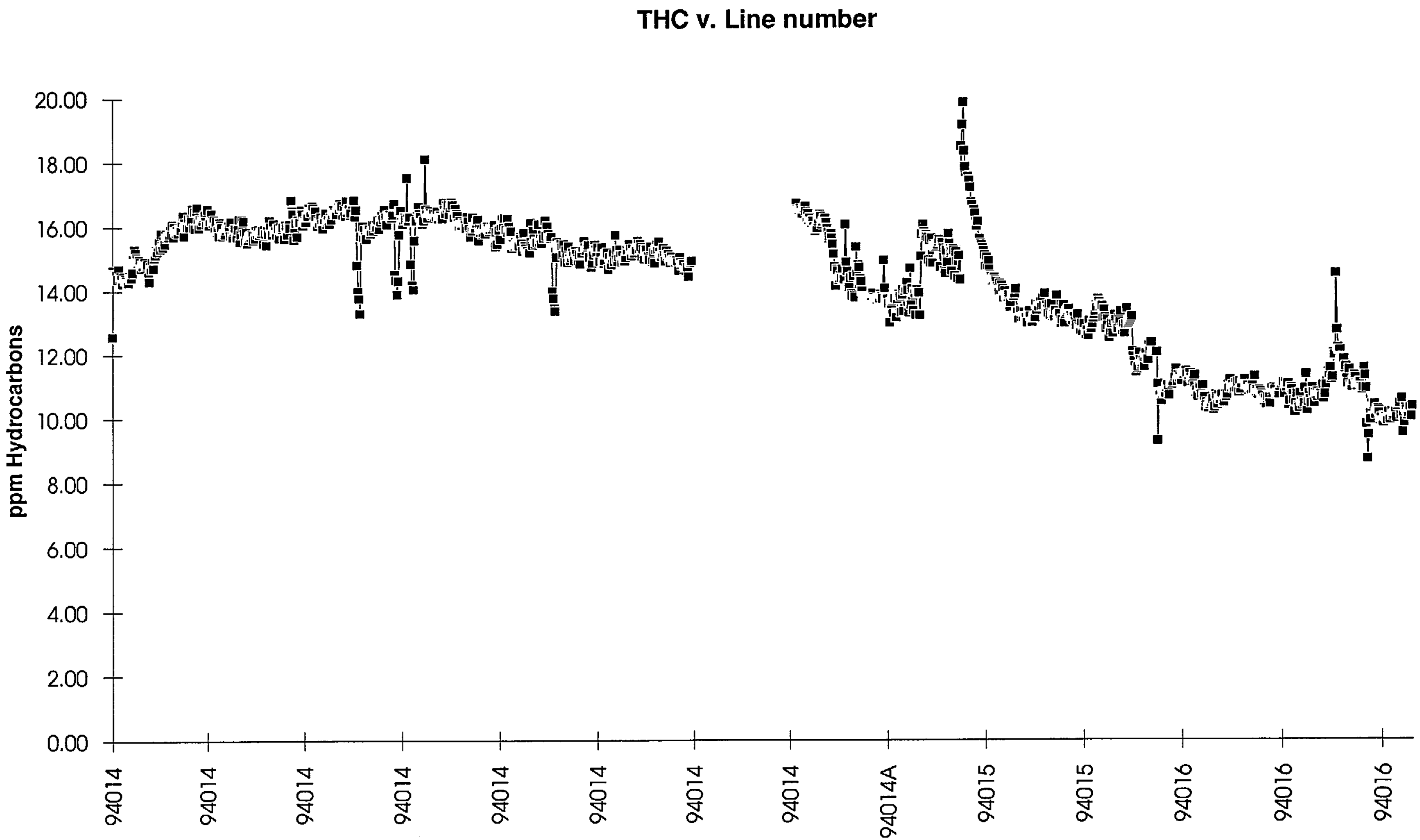


Figure 26. THC versus line number (survey lines 14-16).

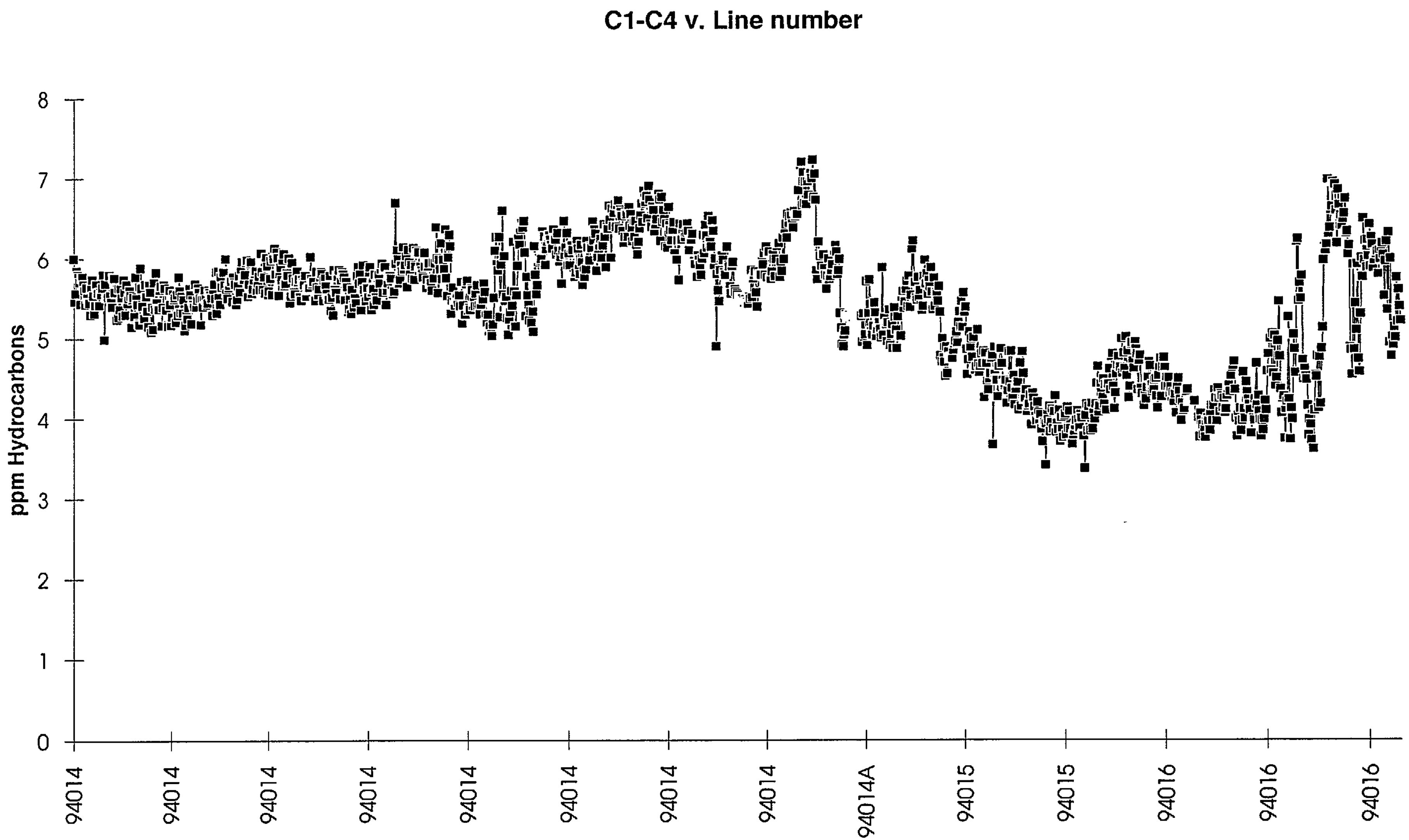


Figure 27. Sum C1-C4 versus line number (survey lines 14-16).

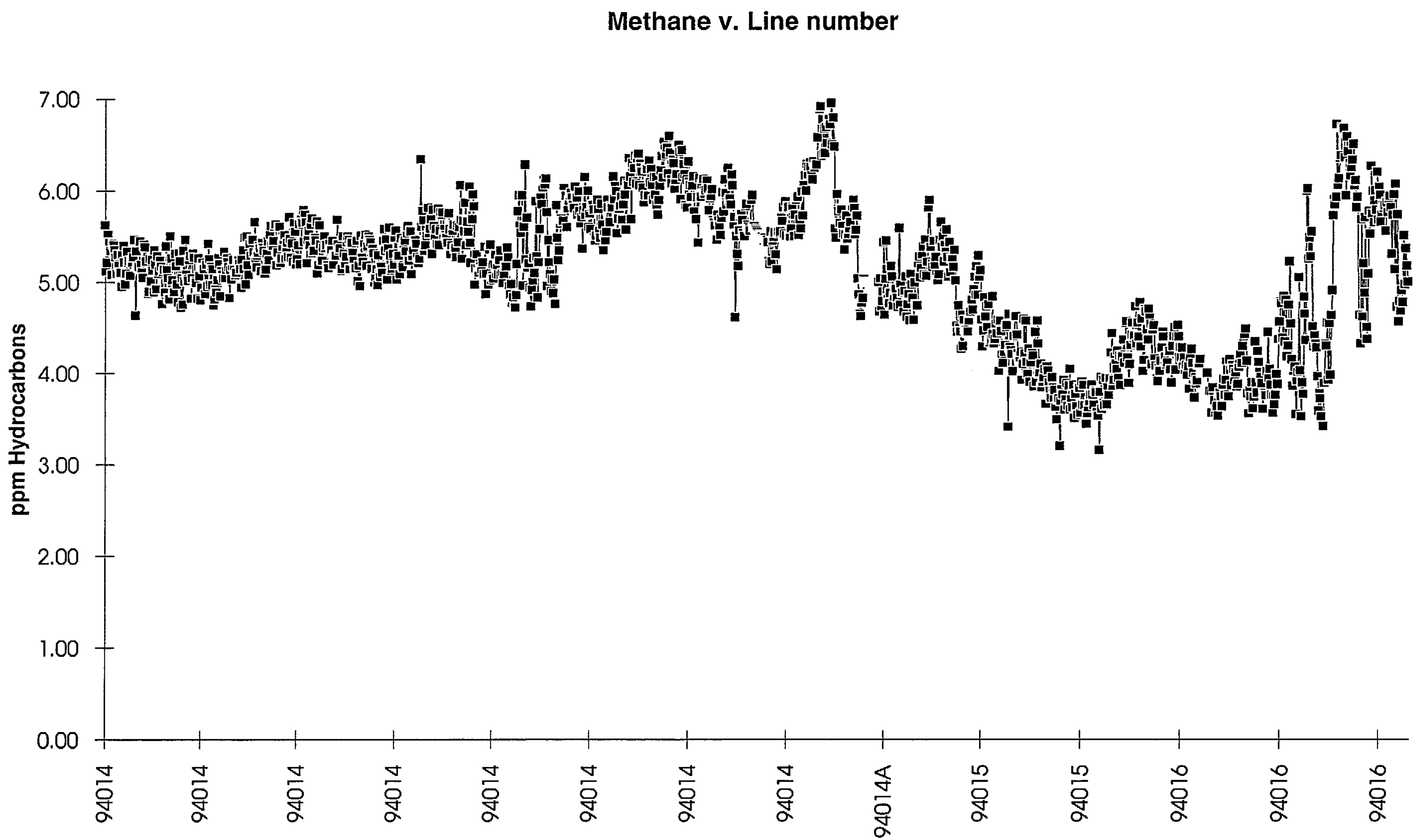


Figure 28. Methane versus line number (survey lines 14-16).

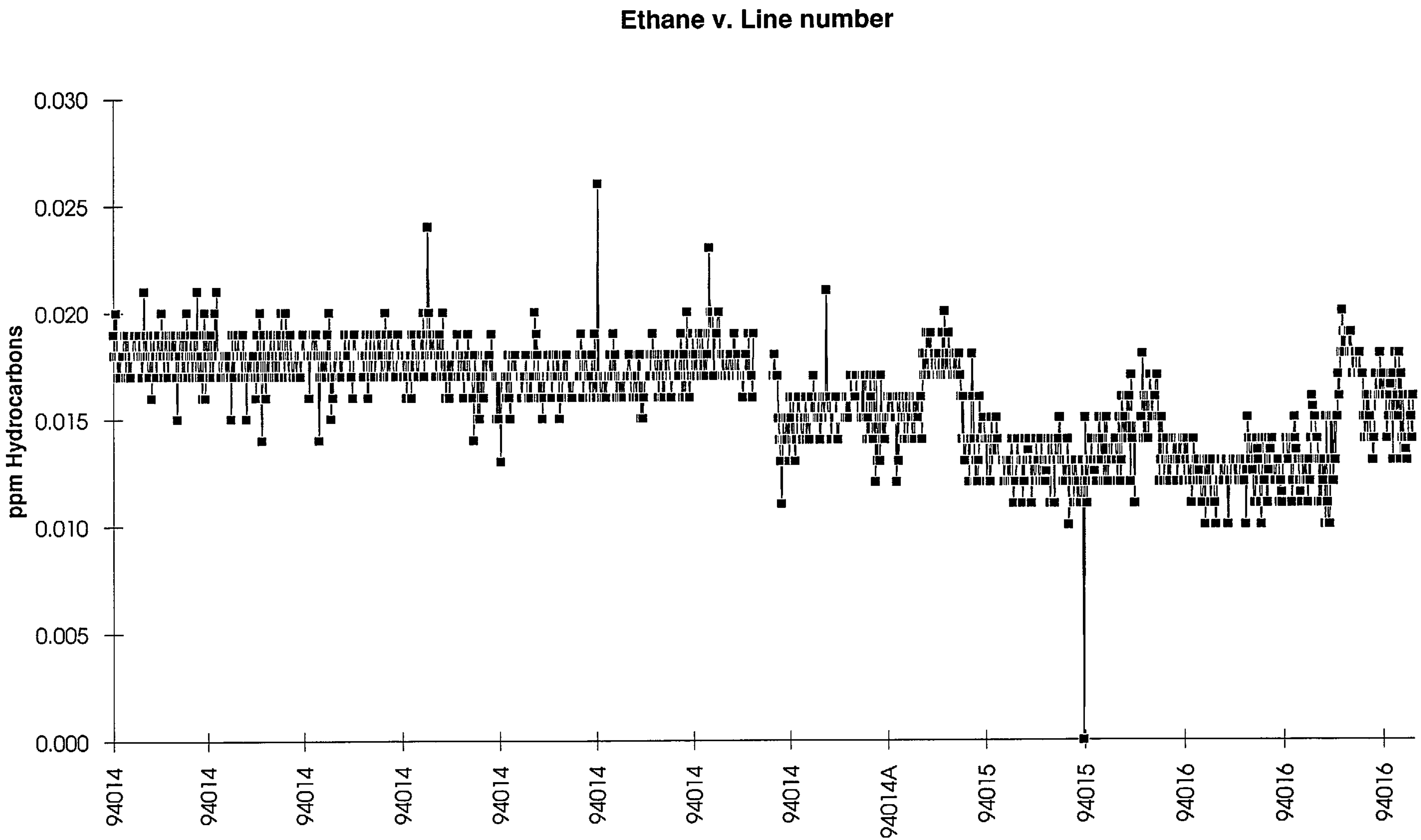


Figure 29. Ethane versus line number (survey lines 14-16).

Figure 30. Ethylene versus line number (survey lines 14-16).

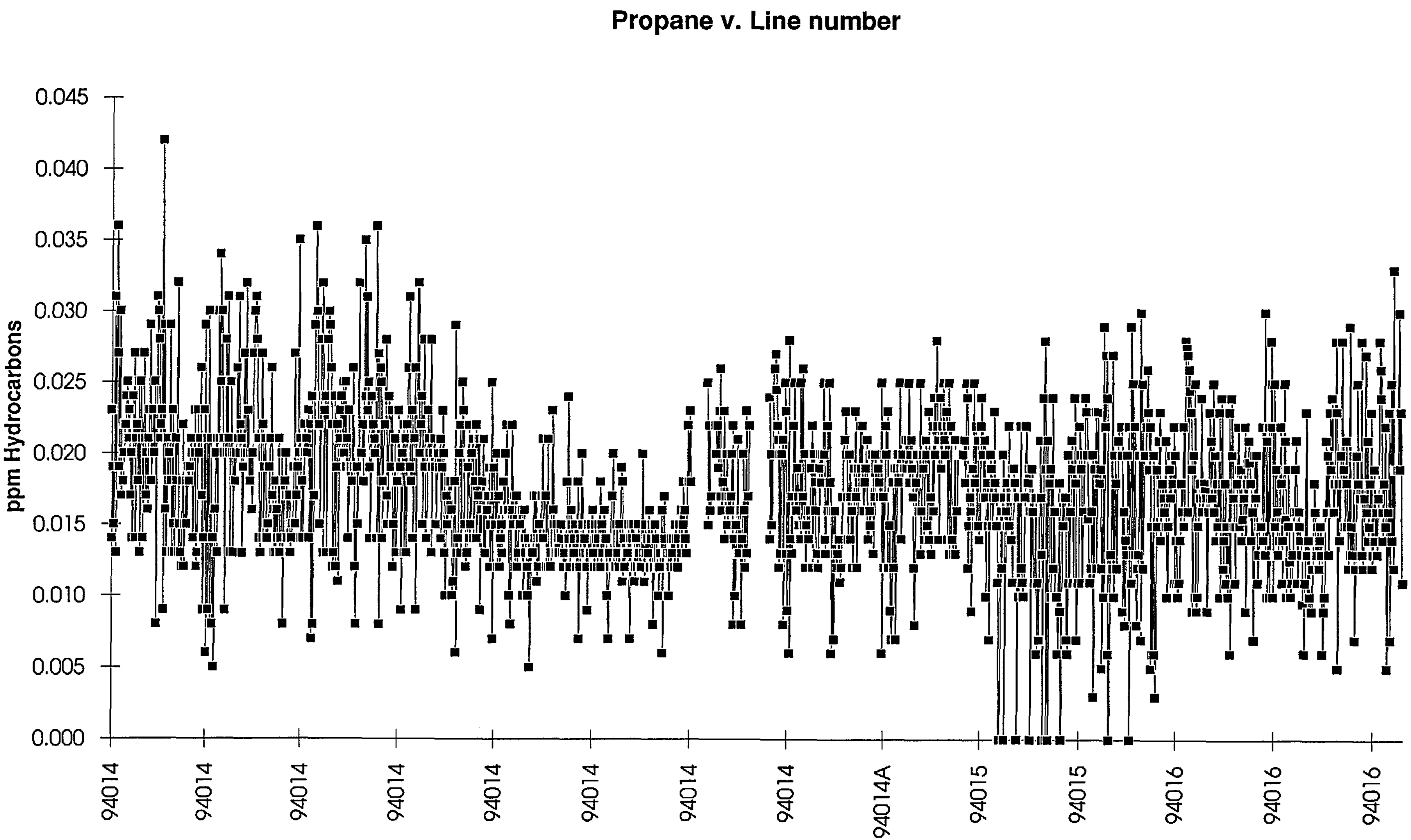


Figure 31. Propane versus line number (survey lines 14-16).

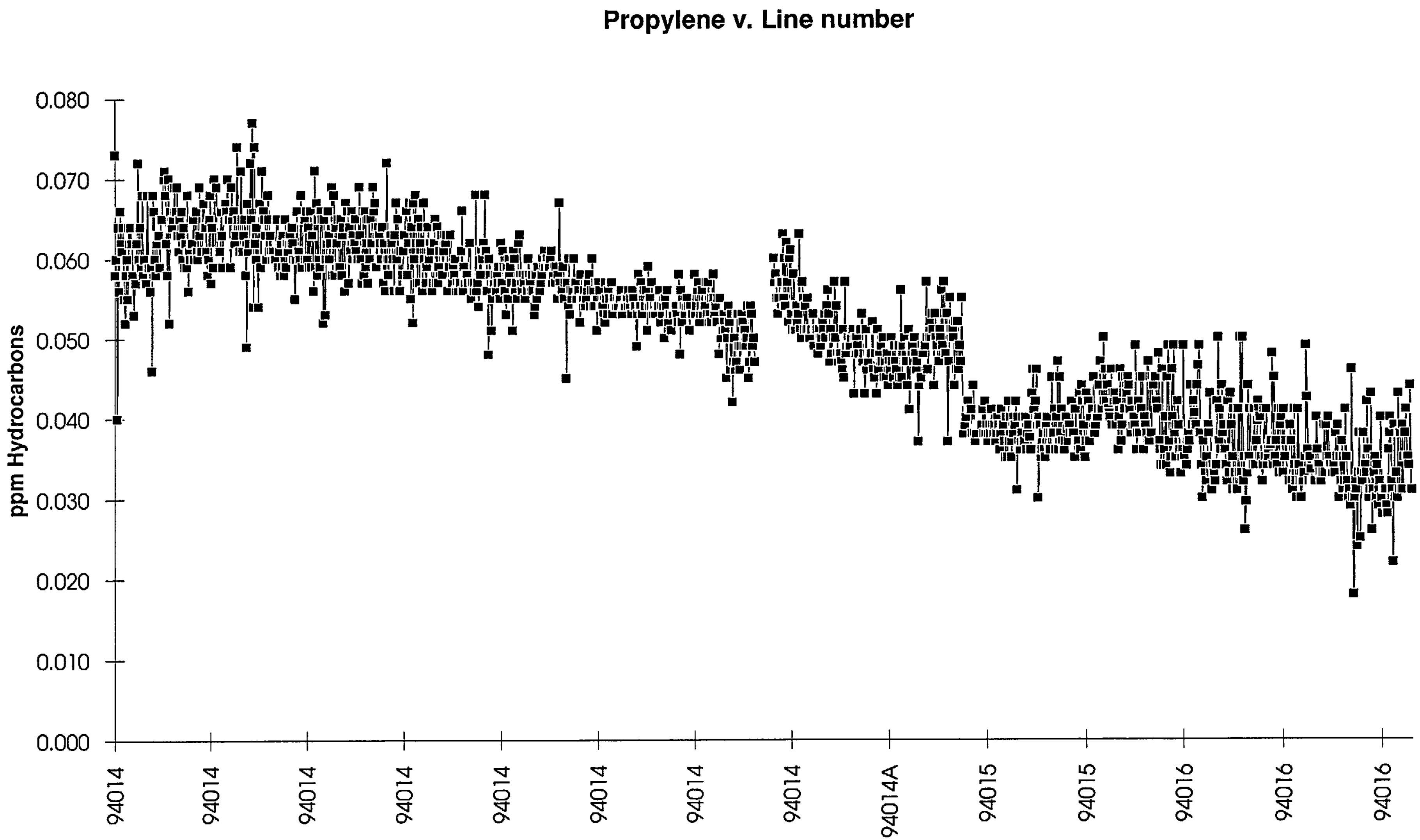


Figure 32. Propylene versus line number (survey lines 14-16).

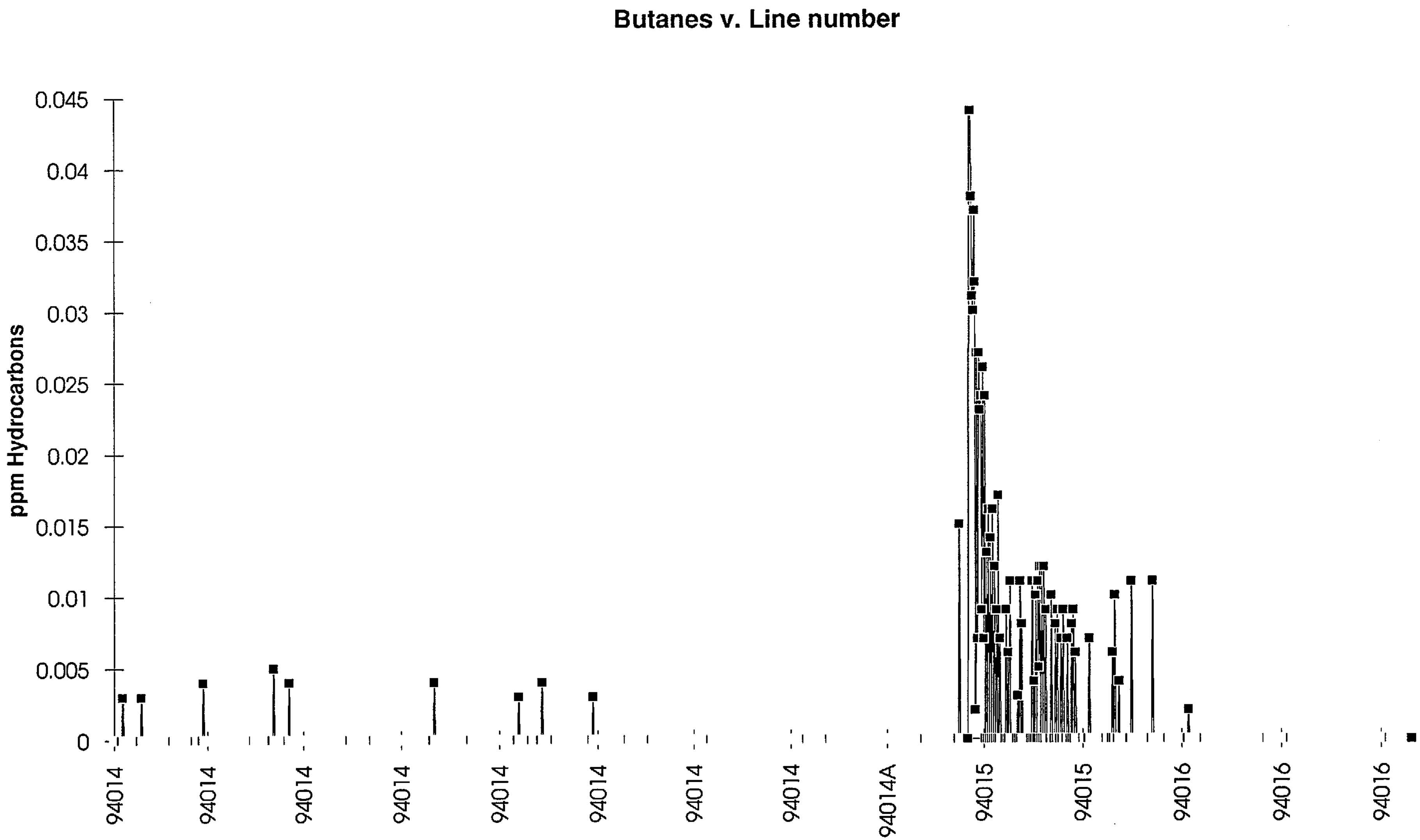


Figure 33. Butanes versus line number (survey lines 14-16).

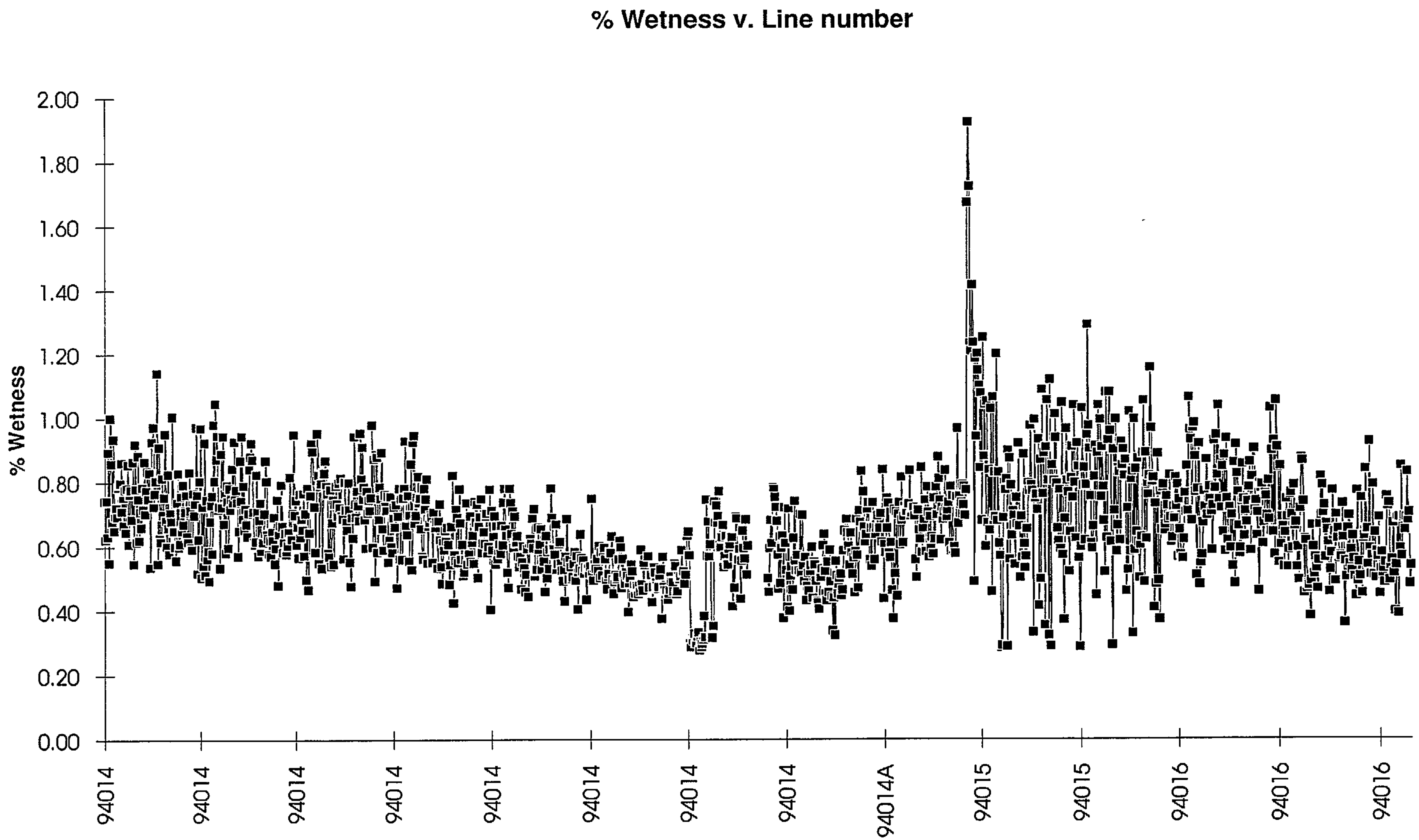


Figure 34. Percent hydrocarbon wetness versus line number (survey lines 14-16).

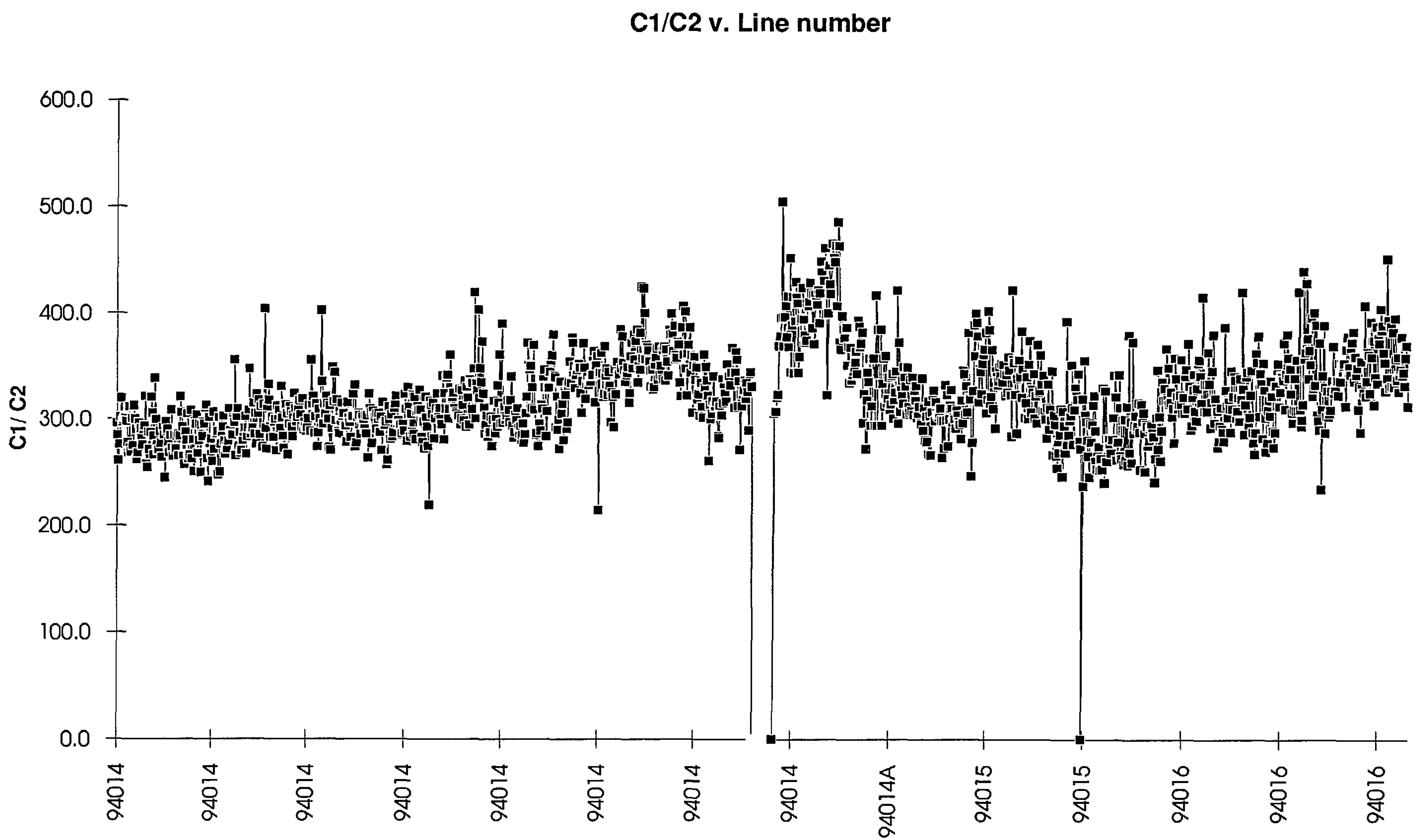


Figure 35. Ratio of C1/C2 versus line number (survey lines 14-16).

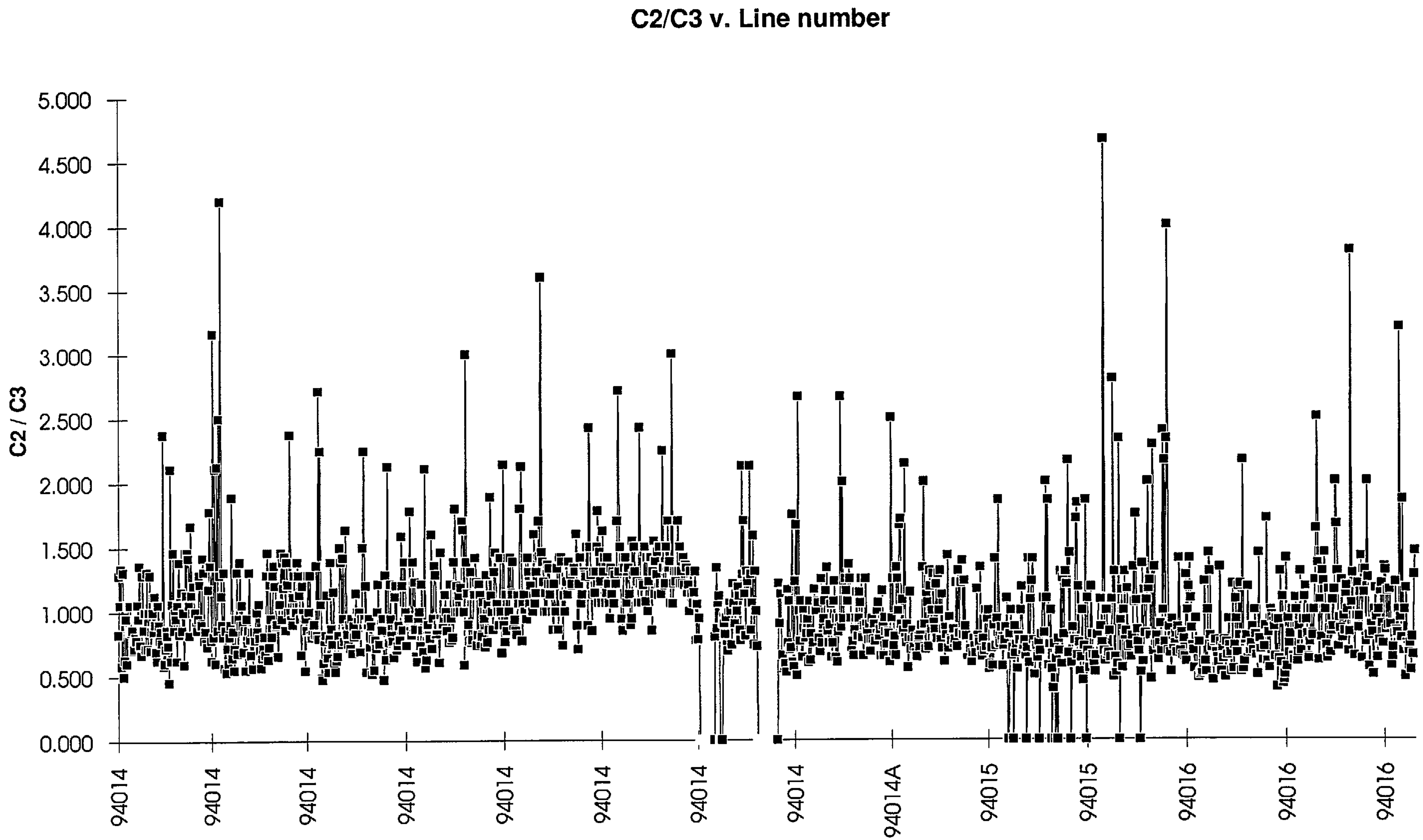


Figure 36. Ratio of C2/C3 versus line number (survey lines 14-16).

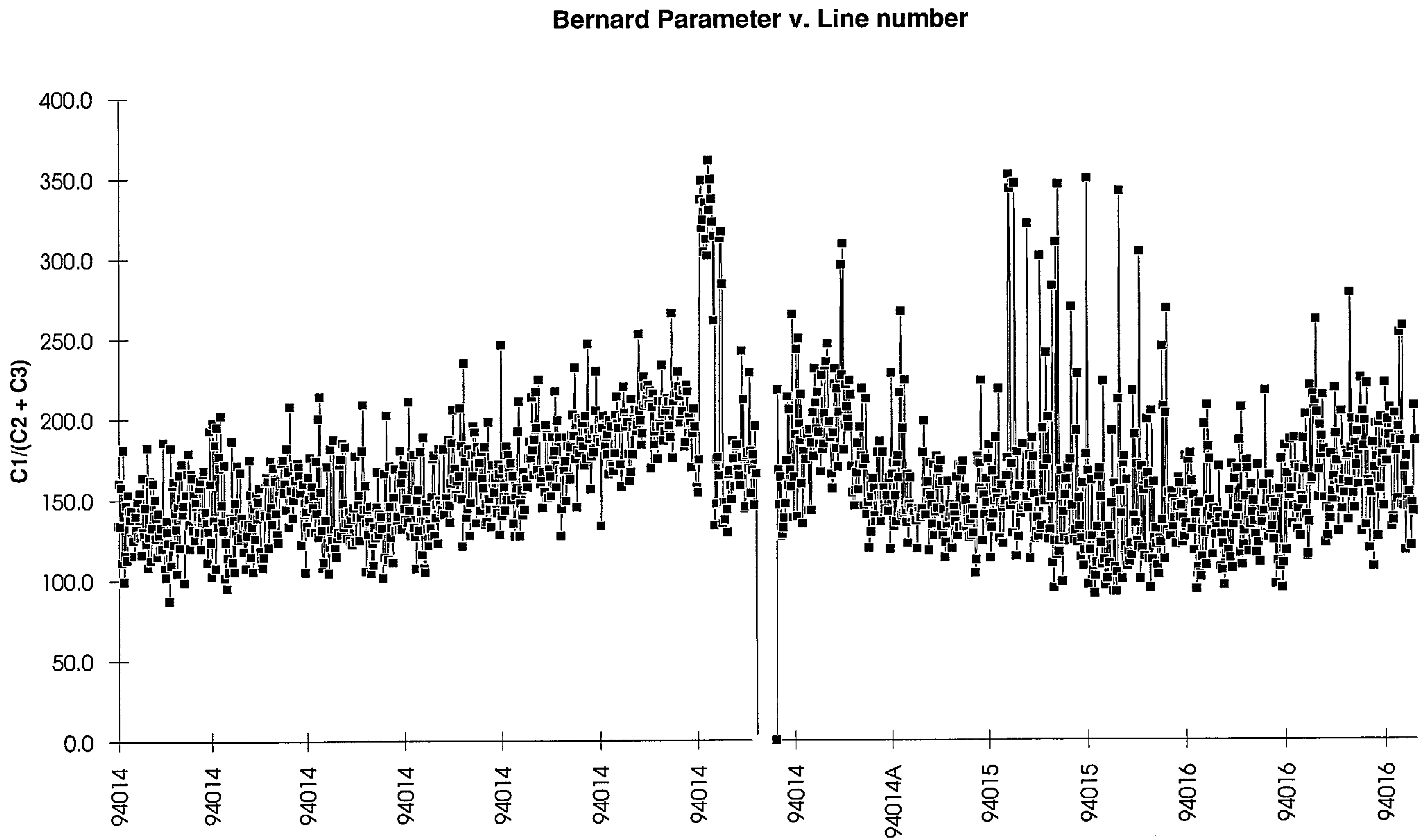


Figure 37. Bernard Parameter versus line number (survey lines 14-16).

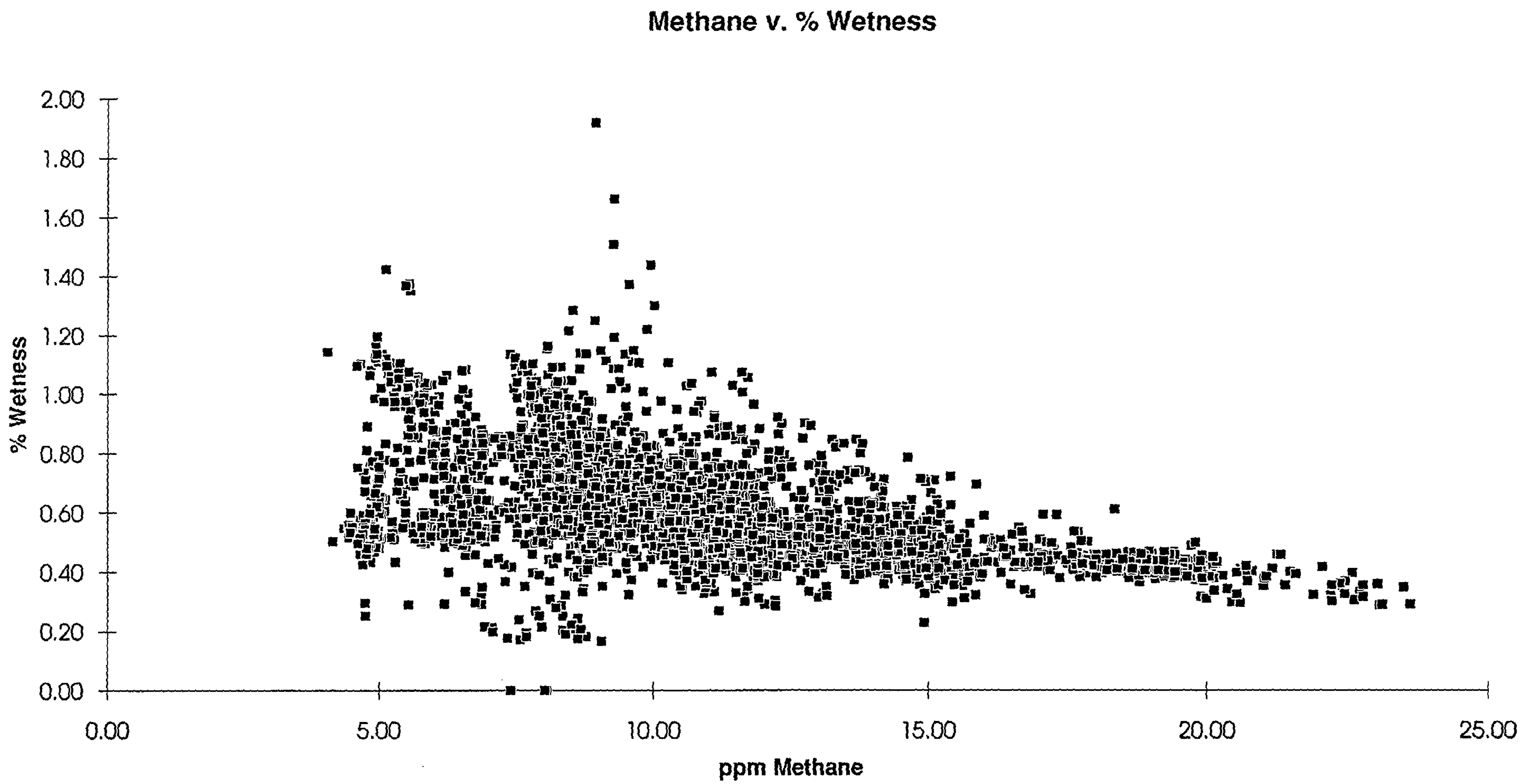


Figure 38. Methane versus percent wetness (survey lines 1-6).

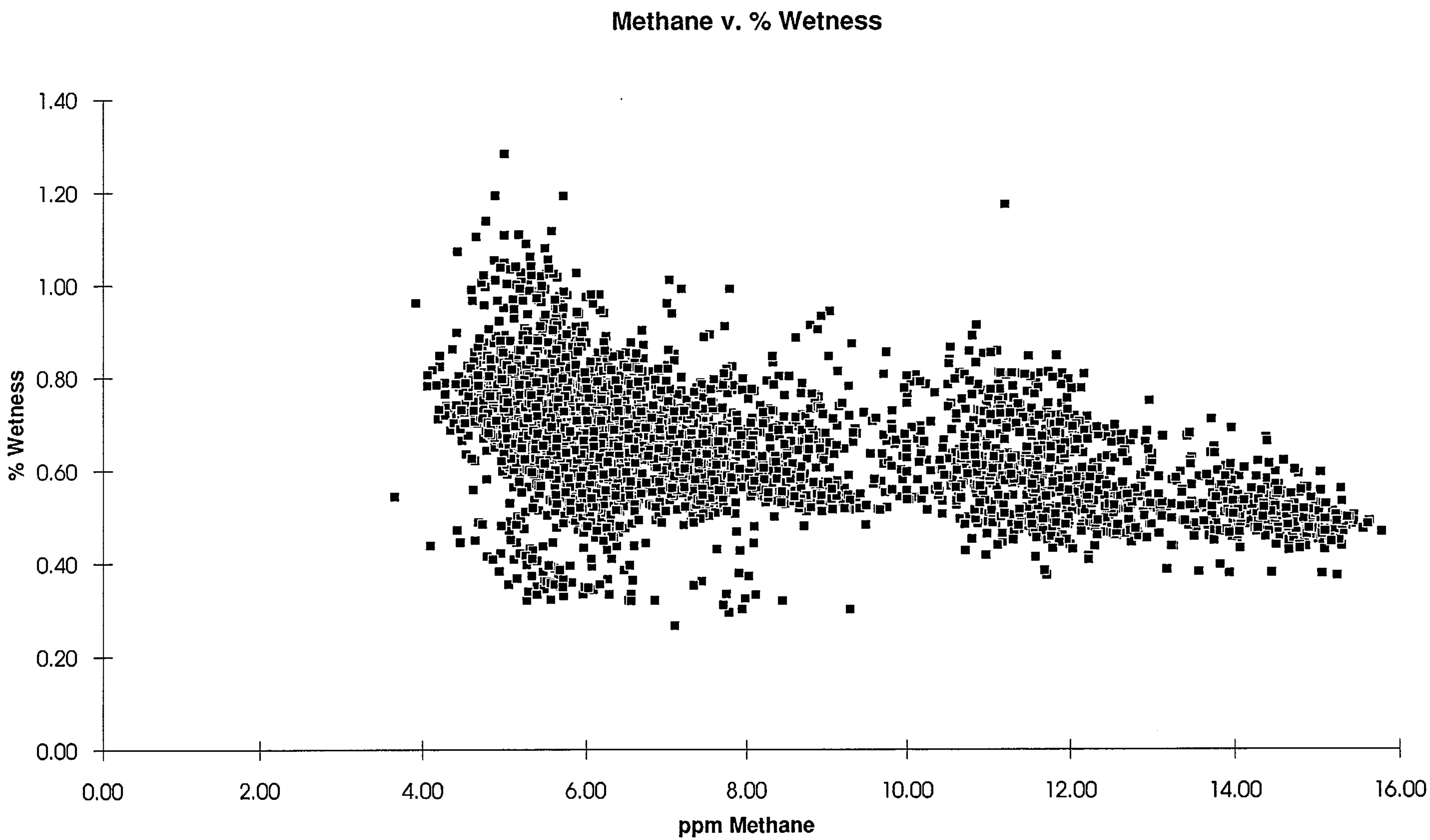


Figure 39. Methane versus percent wetness (survey lines 7-13).

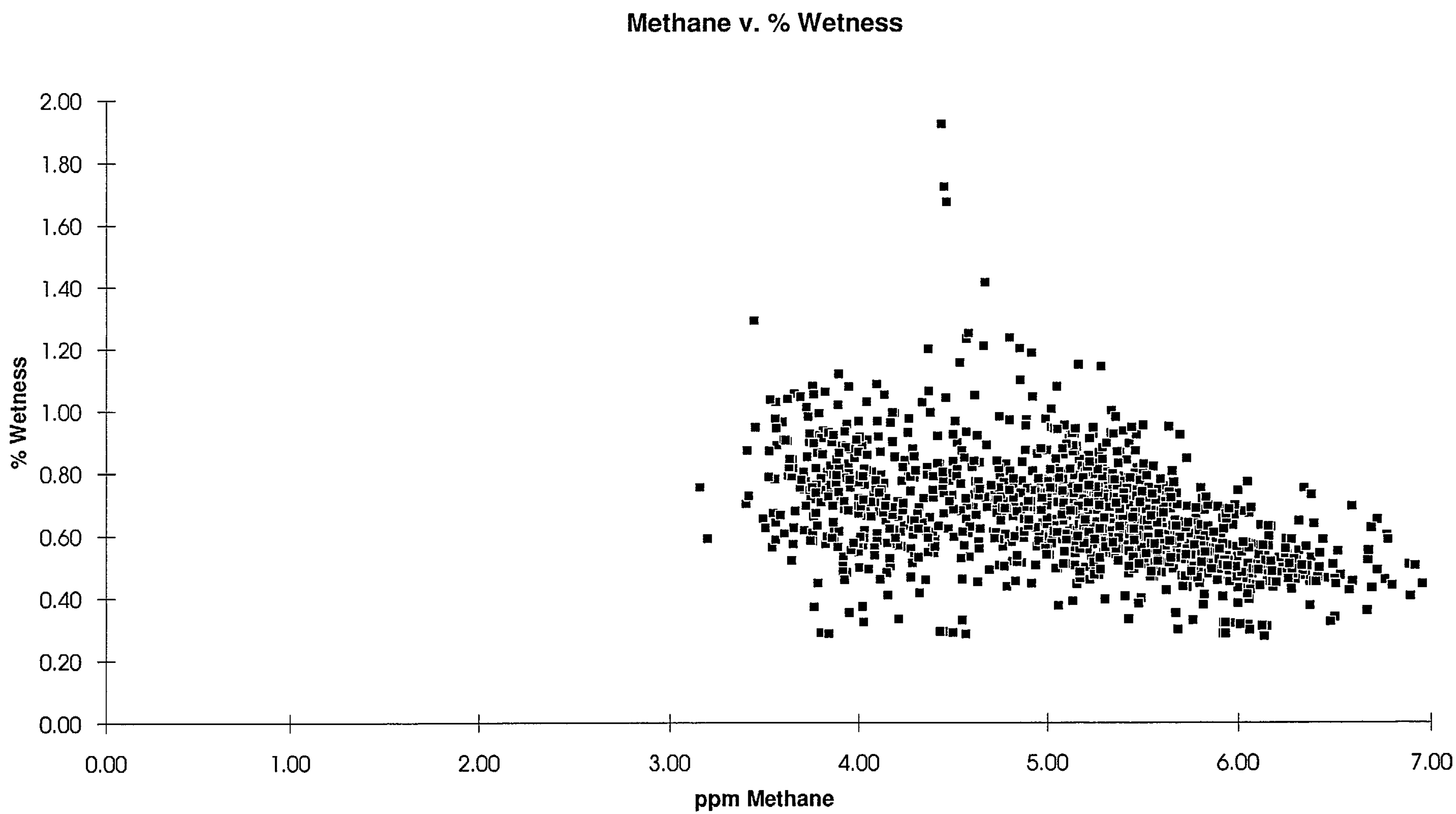


Figure 40. Methane versus percent wetness (survey lines 14-16).

APPENDIX I

GRAPHS OF HYDROCARBON CONCENTRATIONS VS SHOTPOINT

DATA SUMMARY SHEETS

Line Summary

Line Number	94001
No. of Shotpoints	177

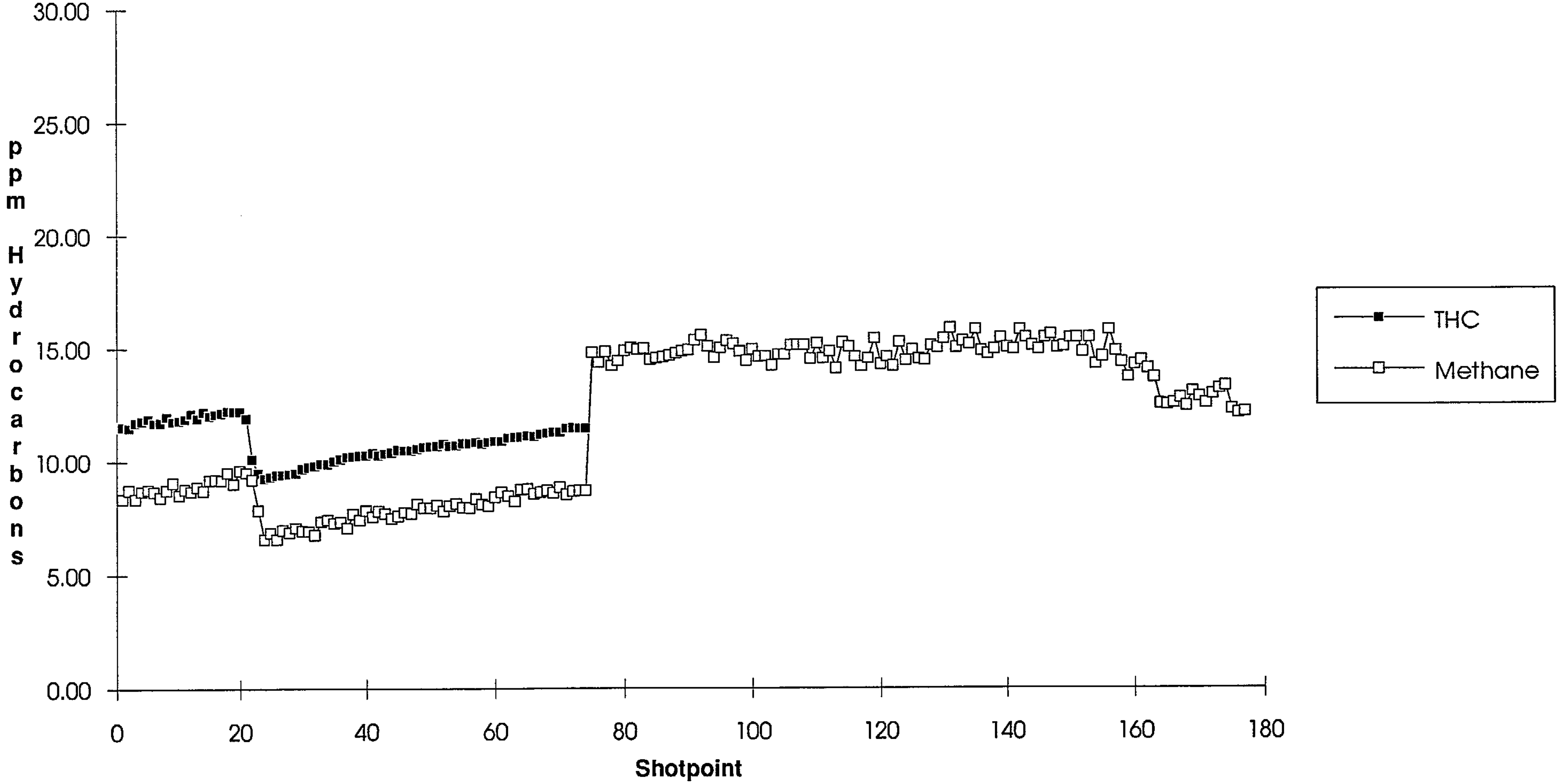
	Shotpoint	Date	Time	Latitude		Longitude	
Start	2	27-Feb-90	19:17:30	9	55.679	132	27.548
End	420	28-Feb-90	16:50:15	10	16.600	132	40.303

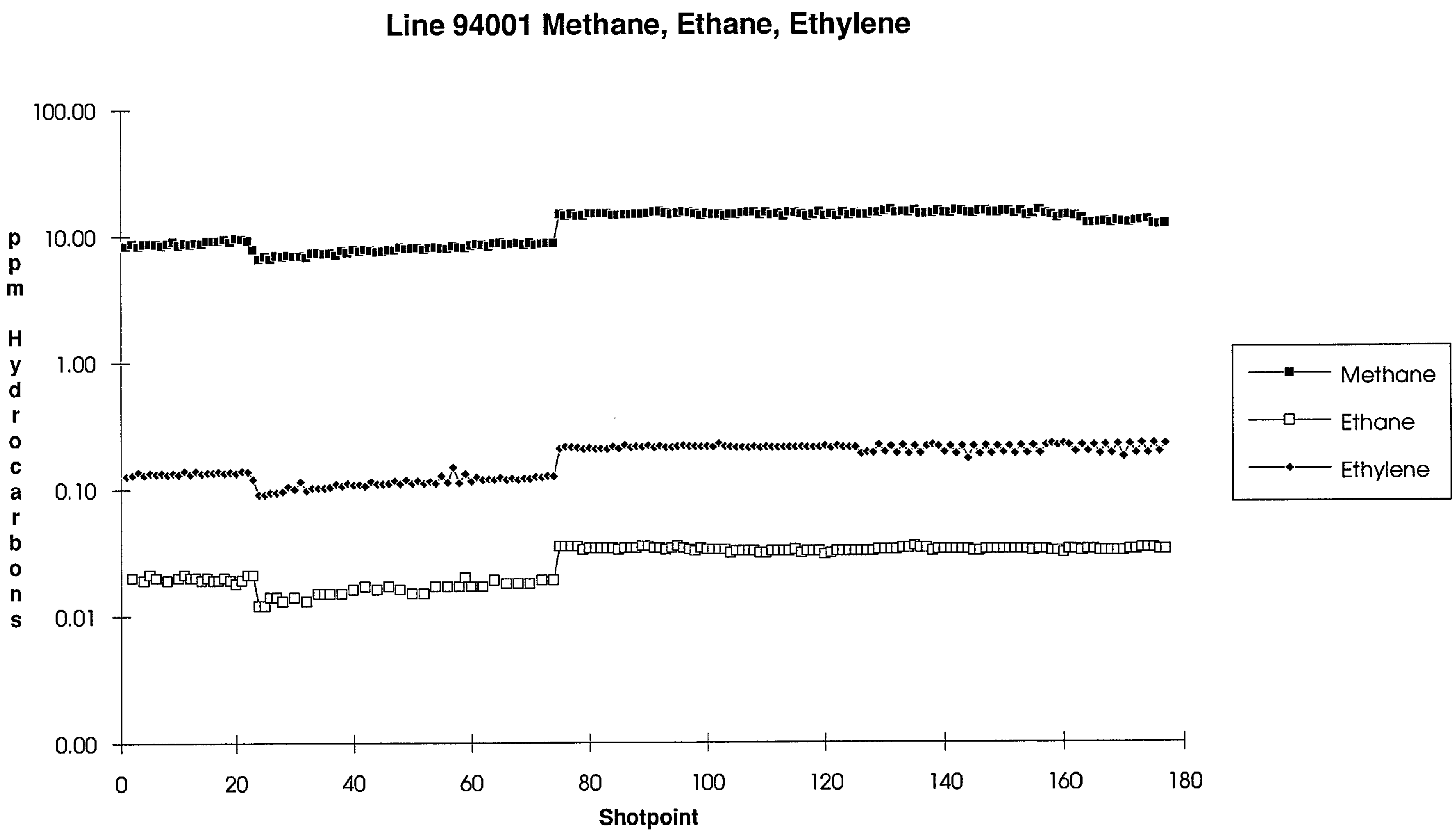
	THC	Methane	Ethane	Ethylene	Propane	Propylene	i-Butane	n-Butane	i-Pentane	n-Pentane	i-Hexane	n-Hexane	%Wetness
Mean	10.885	11.883	0.024	0.171	0.028	0.037	0.000	0.000	0.000	0.000	0.000	0.000	0.424
Std. Dev.	0.849	3.271	0.012	0.046	0.011	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.119
Minimum	9.251	6.571	0.000	0.090	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	12.229	15.842	0.035	0.226	0.051	0.131	0.002	0.000	0.000	0.000	0.000	0.000	0.624

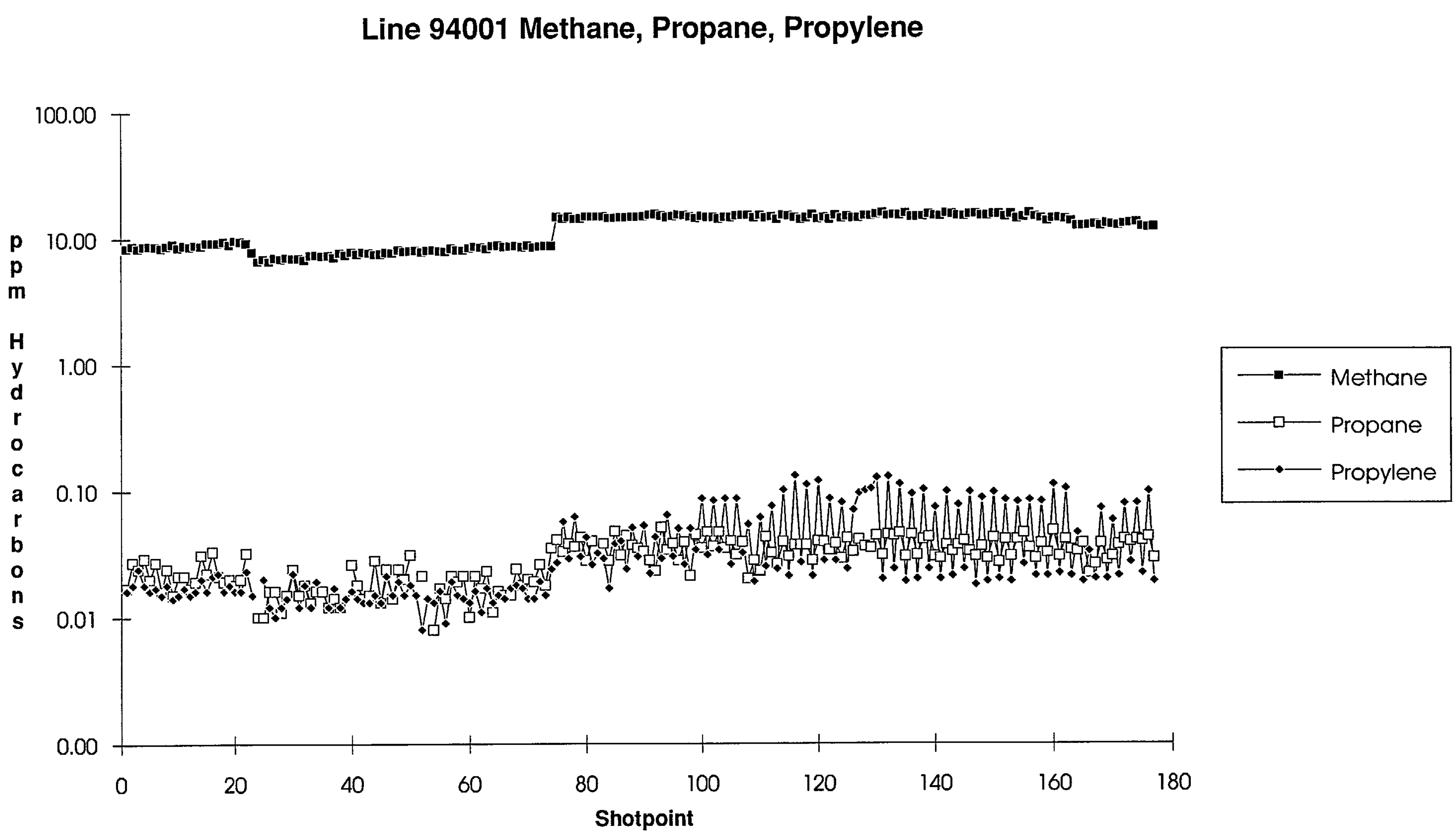
	Cond.	Temp.	F. Depth	W.Depth	Altitude
Mean	55.349	24.864	60.345	74.215	13.870
Std. Dev.	0.532	0.383	6.287	5.004	2.440
Minimum	54.620	24.160	40.000	53.000	10.000
Maximum	56.410	25.760	68.000	79.000	18.000

Notes
THC was not analysed after SP 75 due to contamination caused by the insertion of a new sub-pump hose
Shift in values at SP75 caused by a break in acquisition due to DHD and seismic system problems
Variations in ethane,ethylene,propane and propylene towards and of line due to differences in integration of the two gas chromatographs
Fish altitude has been calculated thus Altitude=water depth-fish depth
Navigation added to file at post processing stage

Line 94001 THC, Methane

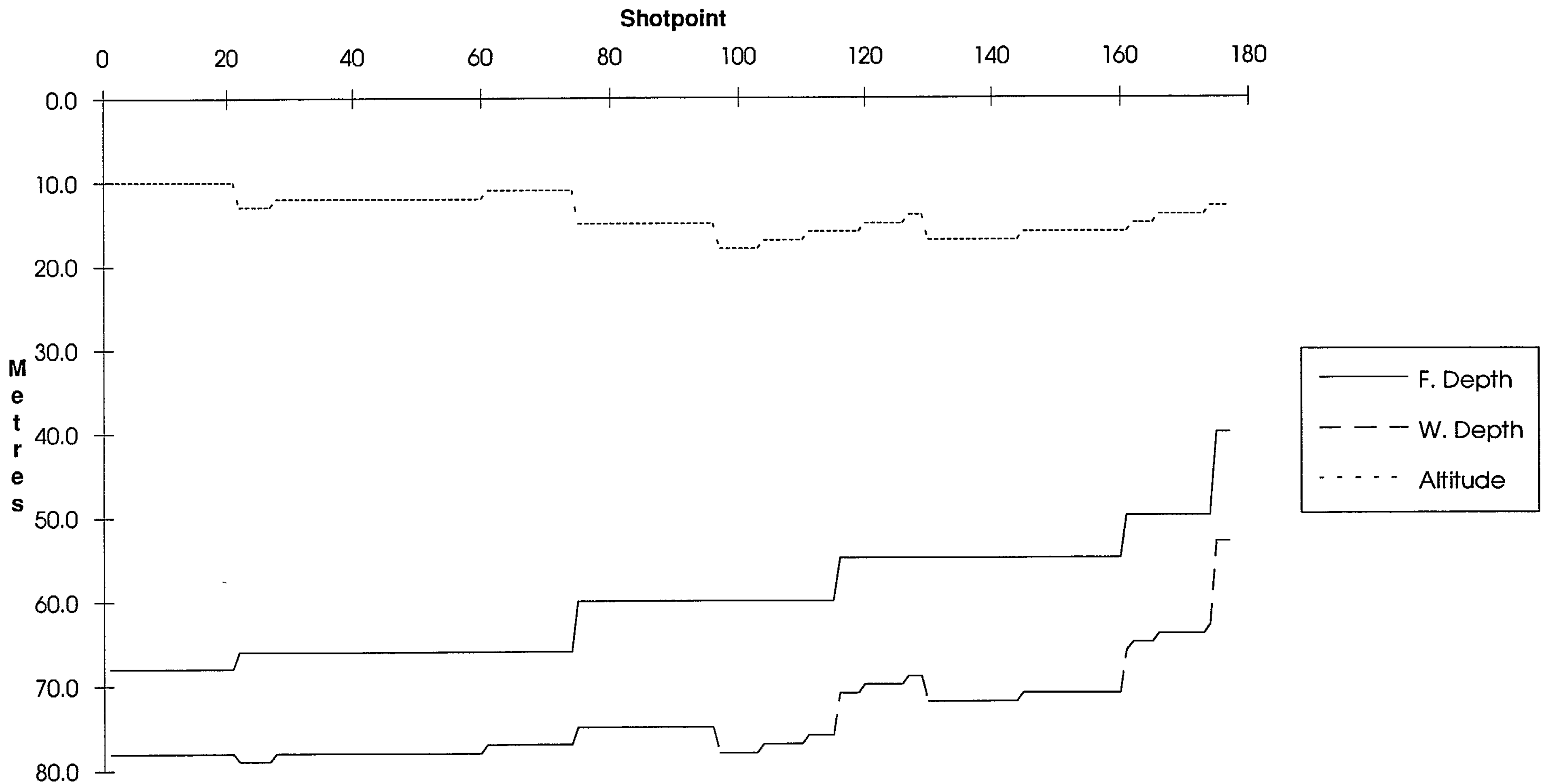



Line 94001 Methane, Ethane, Ethylene
100.00
10.00
1.00
0.10
0.01
0.00
ppm Hydrocarbons
0
20
40
60
80
100
120
140
160
180
Shotpoint
Methane
Ethane
Ethylene



Line 94001 Methane, Propane, Propylene
ppm Hydrocarbons
100.00
10.00
1.00
0.10
0.01
0.00
0
20
40
60
80
100
120
140
160
180
Shotpoint
Methane
Propane
Propylene

Line 94001 Depths, Altitude



Line Summary

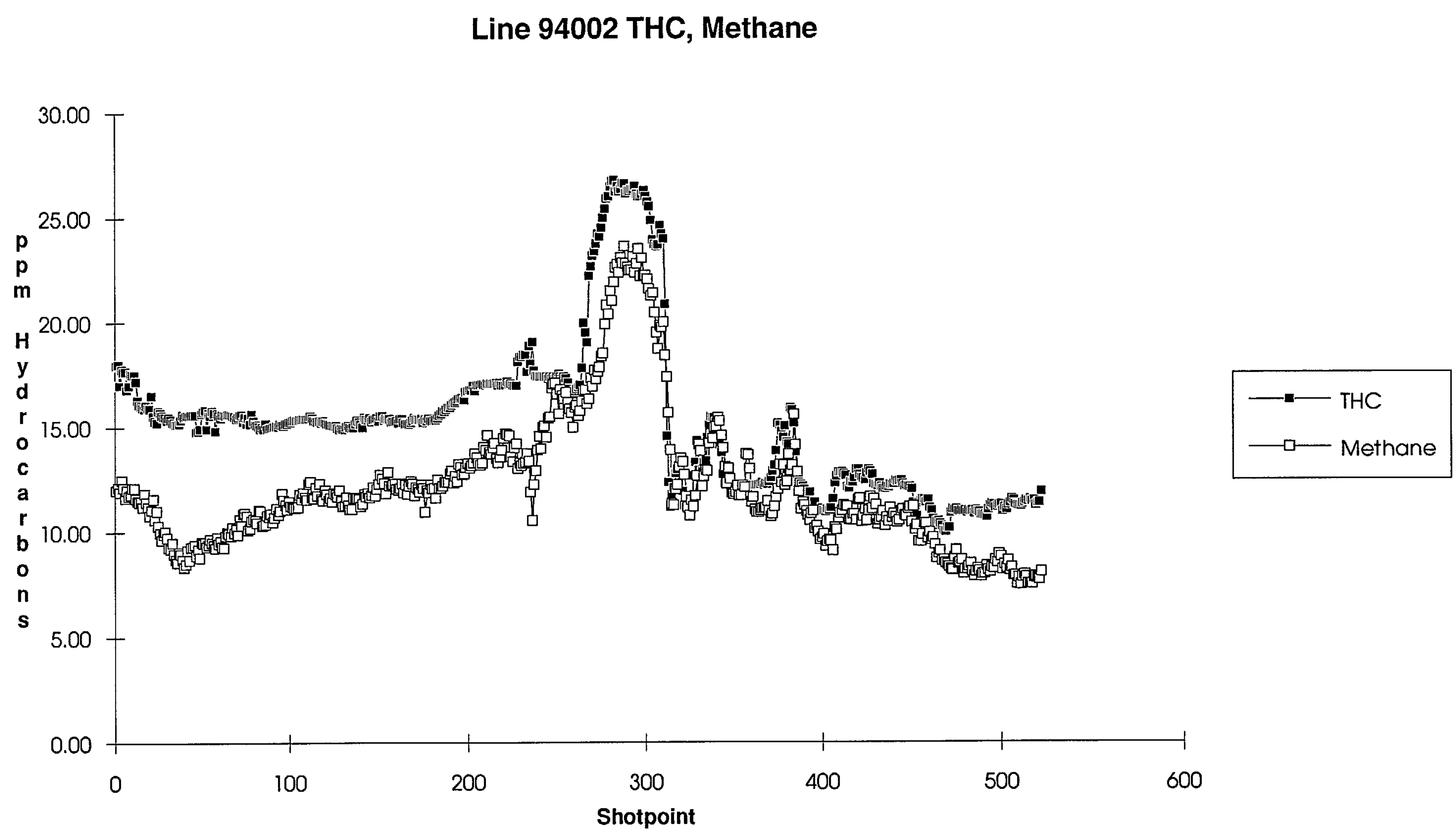
Line Number	94002
No. of Shotpoints	522

	Shotpoint	Date	Time	Latitude		Longitude	
Start	21	1-Mar-90	09:32:16	10	25.864	133	05.490
End	563	2-Mar-90	04:15:38	9	01.278	133	27.528

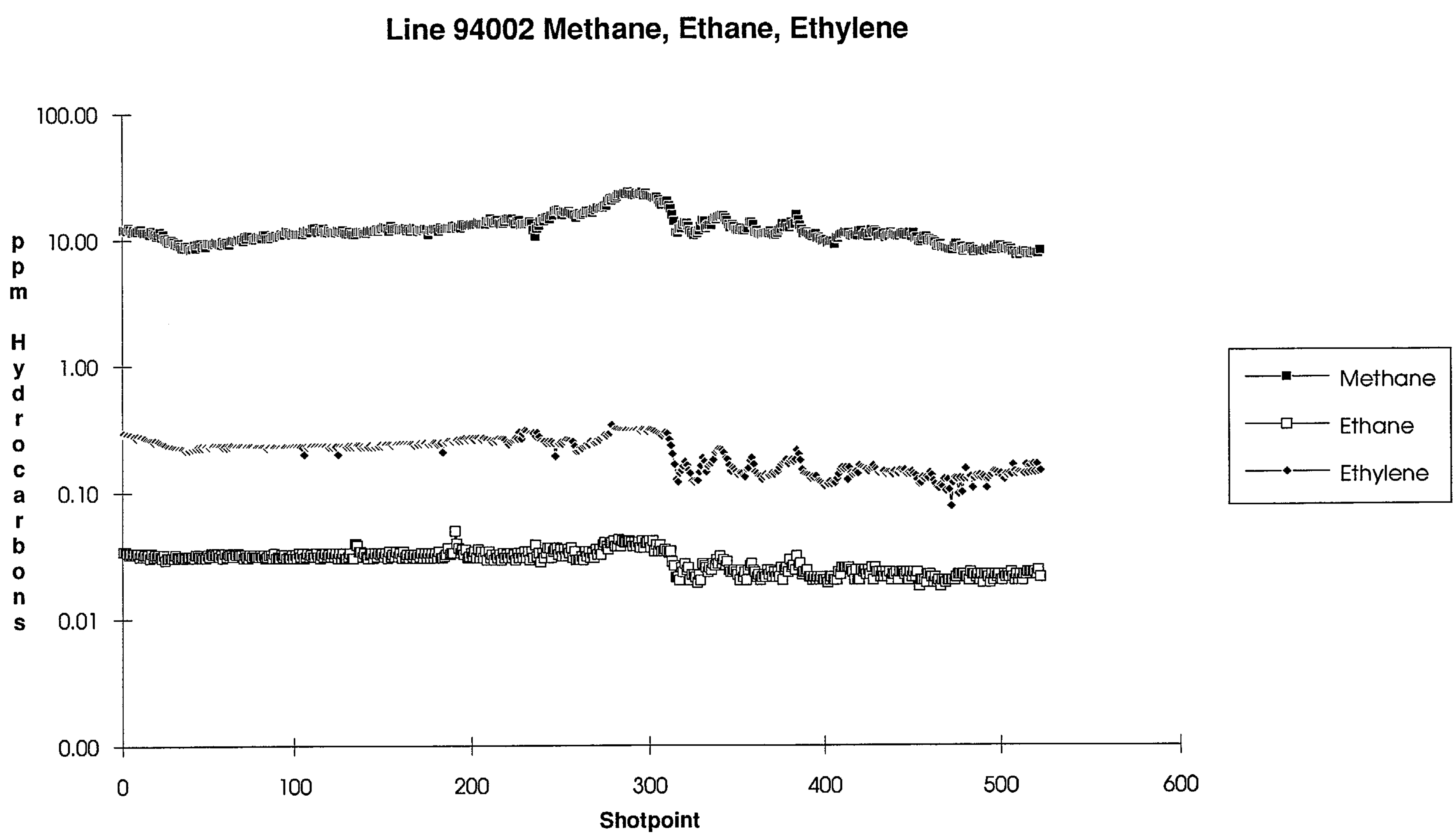
	THC	Methane	Ethane	Ethylene	Propane	Propylene	i-Butane	n-Butane	i-Pentane	n-Pentane	i-Hexane	n-Hexane	%Wetness
Mean	15.187	12.188	0.028	0.206	0.043	0.026	0.000	0.000	0.000	0.000	0.000	0.000	0.609
Std. Dev.	3.734	3.332	0.006	0.057	0.019	0.012	0.001	0.000	0.000	0.000	0.000	0.000	0.224
Minimum	9.979	7.472	0.018	0.077	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.267
Maximum	26.740	23.633	0.049	0.338	0.145	0.096	0.008	0.000	0.000	0.000	0.000	0.000	1.919

	Cond.	Temp.	F. Depth	W.Depth	Altitude
Mean	55.416	24.736	81.020	107.643	26.623
Std. Dev.	1.021	1.050	23.591	40.661	22.582
Minimum	53.340	22.710	47.000	63.000	5.000
Maximum	57.040	26.630	122.500	208.000	102.000

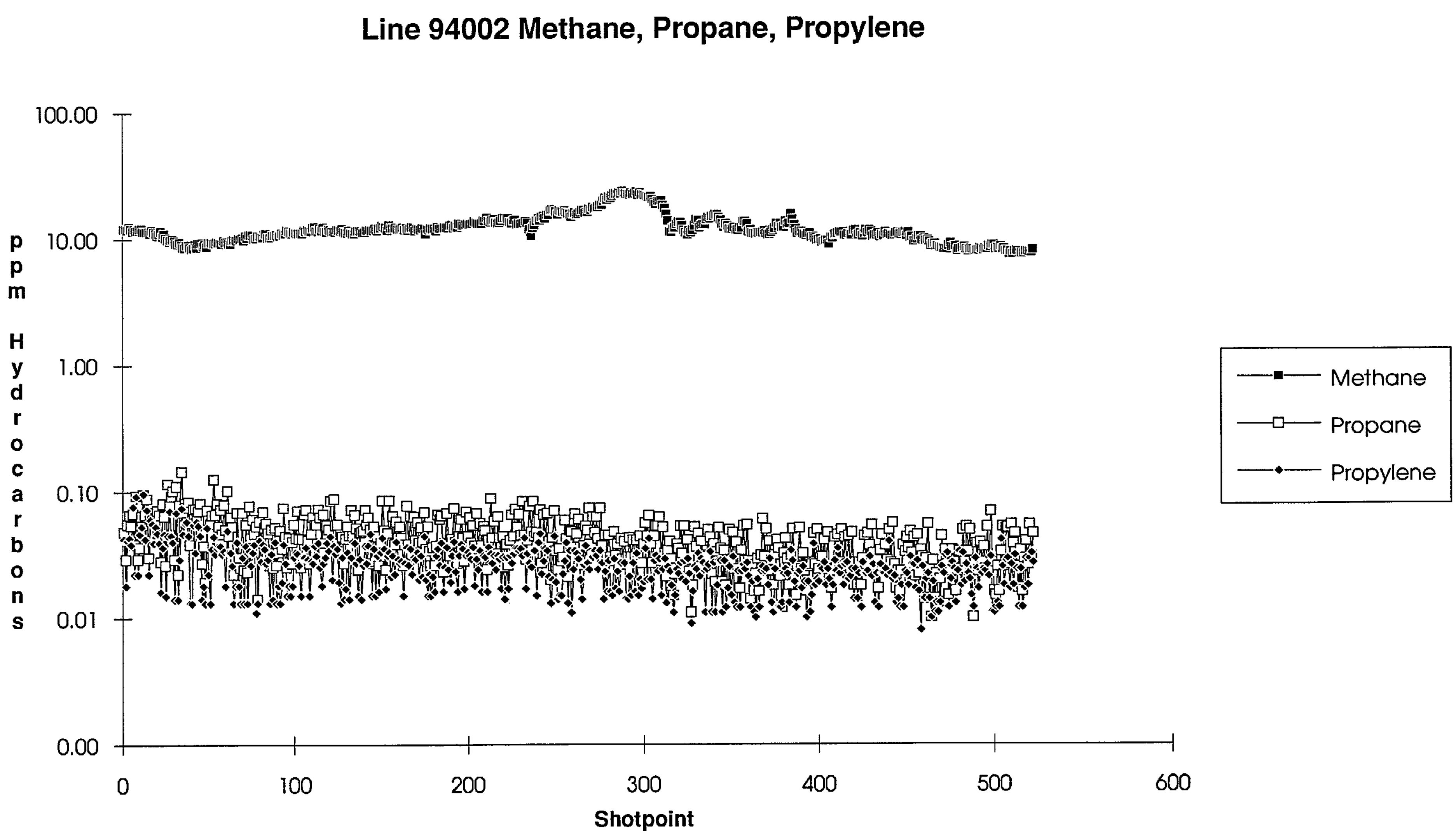
Notes
THC and methane anomaly, probably biogenic
Fish altitude has been calculated thus Altitude=water depth-fish depth
Navigation added to file at post processing stage
EOL at SP563 due to problems in fish



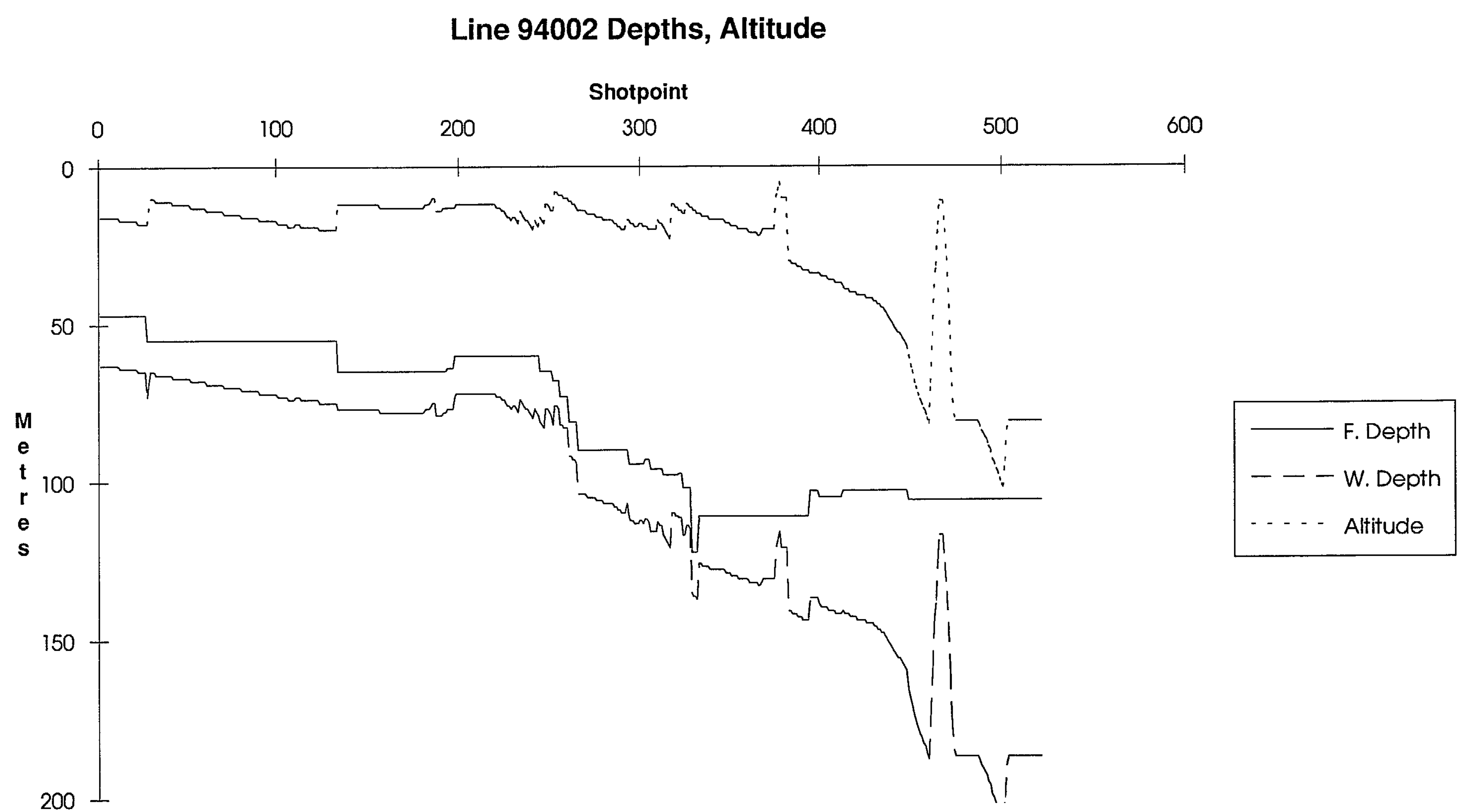
Line 94002 THC, Methane
ppm Hydrocarbons
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
100
200
300
400
500
600
Shotpoint
THC
Methane



Line 94002 Methane, Ethane, Ethylene
ppm Hydrocarbons
100.00
10.00
1.00
0.10
0.01
0.00
0
100
200
300
400
500
600
Shotpoint
Methane
Ethane
Ethylene



Line 94002 Methane, Propane, Propylene
ppm Hydrocarbons
100.00
10.00
1.00
0.10
0.01
0.00
0
100
200
300
400
500
600
Shotpoint
Methane
Propane
Propylene



Line 94002 Depths, Altitude
Shotpoint
0
100
200
300
400
500
600
0
50
100
150
200
Metres
F. Depth
W. Depth
Altitude

Line Summary

Line Number	94003
No. of Shotpoints	495

	Shotpoint	Date	Time	Latitude		Longitude	
Start	20	3-Mar-90	14:01:45	10	04.470	133	29.245
End	523	4-Mar-90	07:30:44	10	54.374	133	16.872

	THC	Methane	Ethane	Ethylene	Propane	Propylene	i-Butane	n-Butane	i-Pentane	n-Pentane	i-Hexane	n-Hexane	%Wetness
Mean	15.786	12.669	0.033	0.312	0.032	0.019	0.001	0.000	0.000	0.000	0.000	0.000	0.520
Std. Dev.	1.630	1.161	0.002	0.035	0.004	0.006	0.006	0.000	0.000	0.000	0.000	0.000	0.087
Minimum	14.030	10.274	0.028	0.250	0.018	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.378
Maximum	22.921	15.936	0.038	0.358	0.066	0.060	0.058	0.000	0.000	0.000	0.000	0.000	1.107

	Cond.	Temp.	F. Depth	W.Depth	Altitude
Mean	57.563	26.727	41.434	56.163	14.729
Std. Dev.	1.151	1.081	3.397	2.769	2.203
Minimum	55.320	24.720	34.000	50.000	9.000
Maximum	59.650	28.610	47.000	65.000	21.000

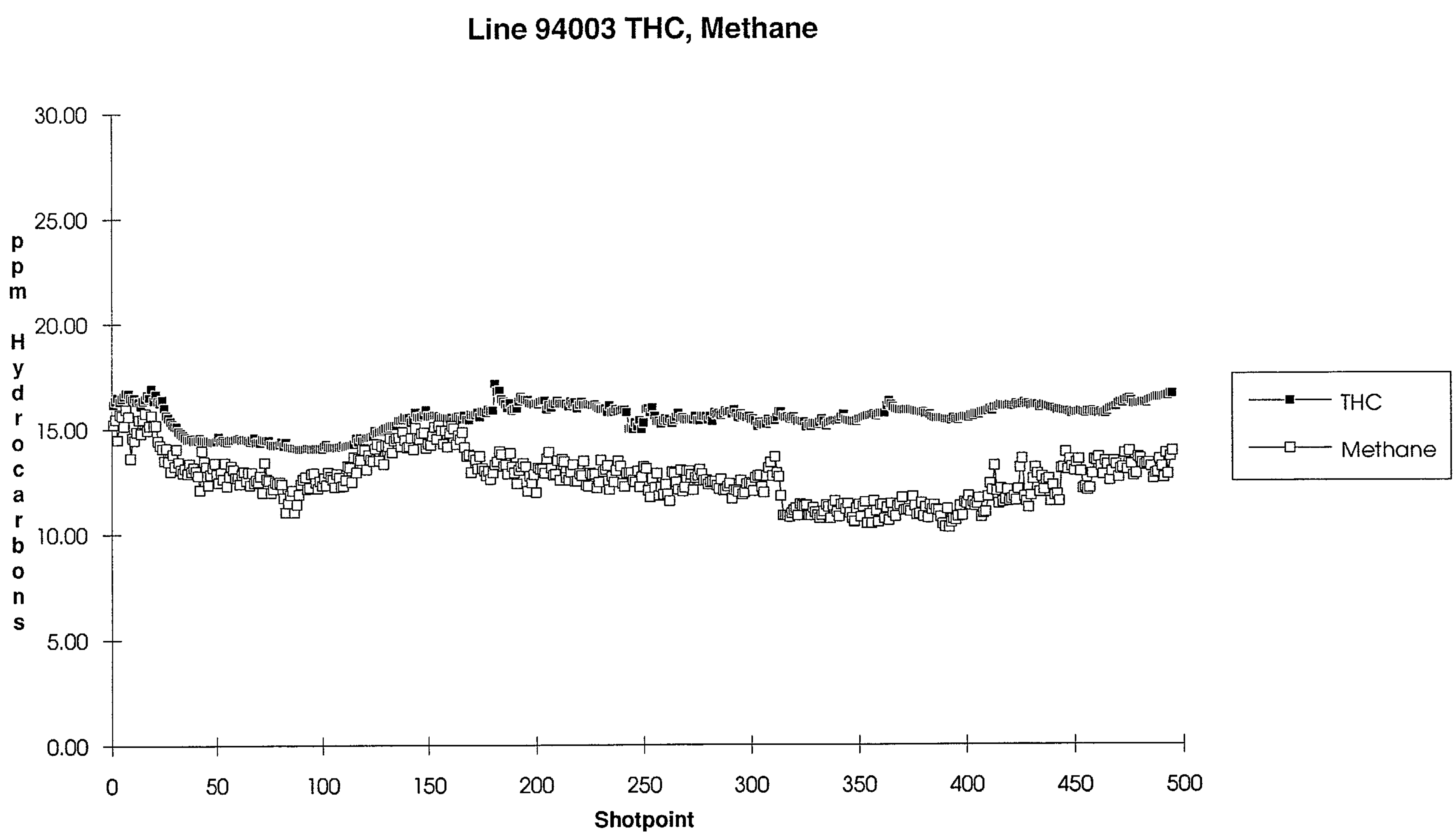
Notes

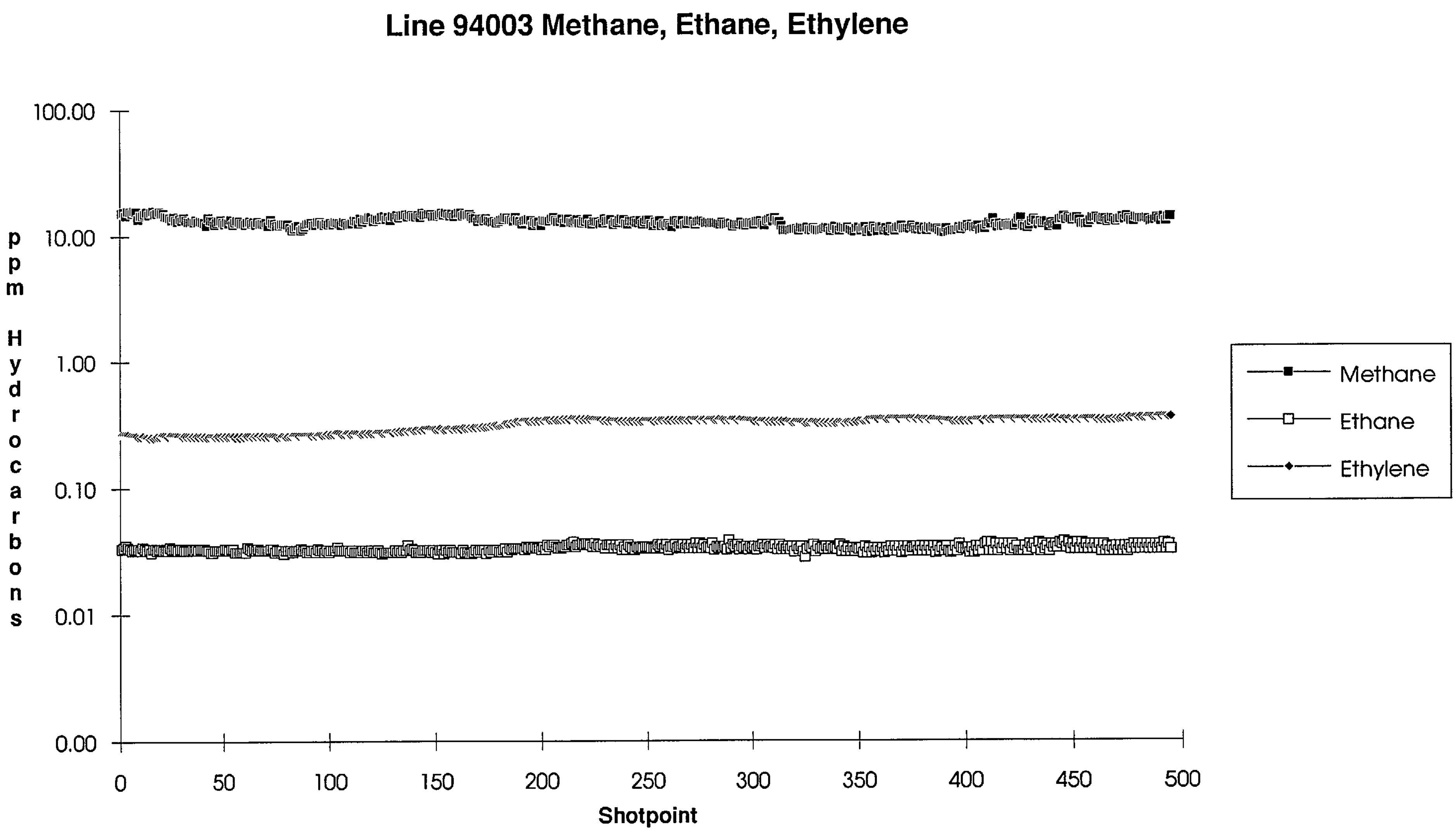
DHD data was not collected on the northern end of this seismic line

No conductivity and temperature data until SP 114

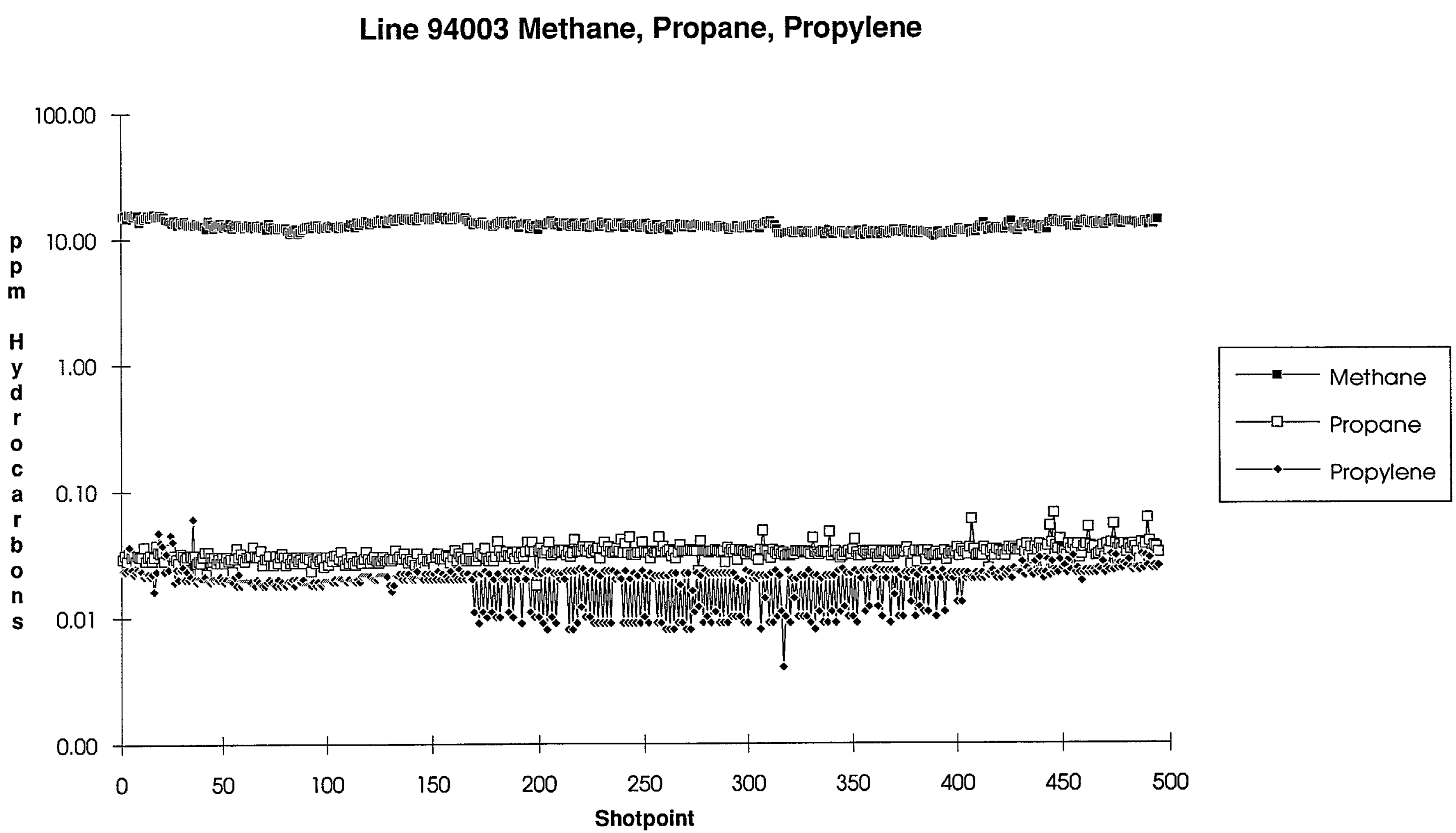
Fish altitude has been calculated thus: Altitude=water depth-fish depth

Navigation added to file at post processing stage

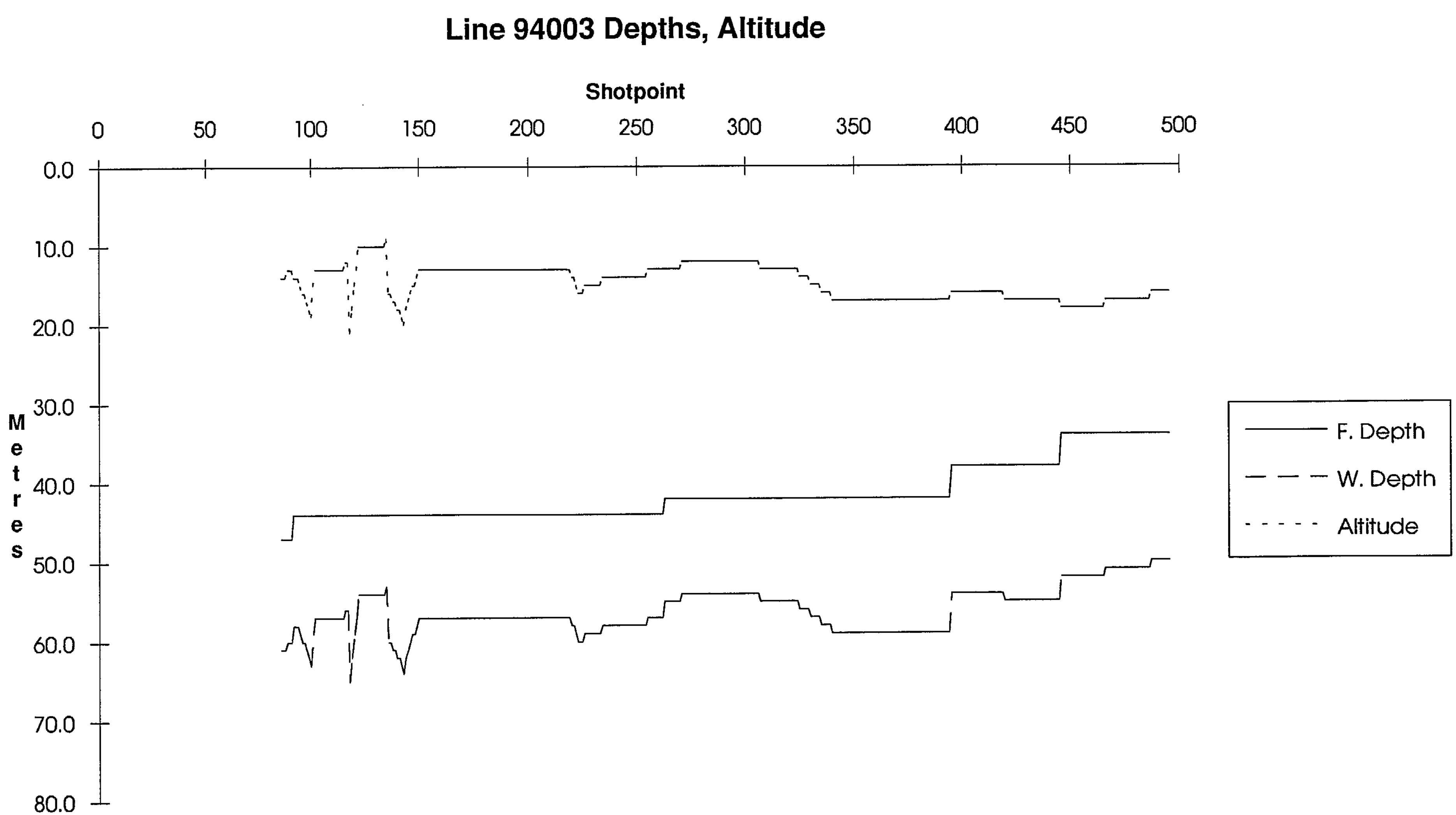

Line 94003 THC, Methane
30.00
25.00
20.00
15.00
10.00
5.00
0.00
ppm Hydrocarbons
0
50
100
150
200
250
300
350
400
450
500
Shotpoint
THC
Methane



Line 94003 Methane, Ethane, Ethylene
ppm Hydrocarbons
100.00
10.00
1.00
0.10
0.01
0.00
0
50
100
150
200
250
300
350
400
450
500
Shotpoint
Methane
Ethane
Ethylene



Line 94003 Methane, Propane, Propylene
ppm Hydrocarbons
100.00
10.00
1.00
0.10
0.01
0.00
0
50
100
150
200
250
300
350
400
450
500
Shotpoint
Methane
Propane
Propylene



Line 94003 Depths, Altitude
Shotpoint
0
50
100
150
200
250
300
350
400
450
500
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Metres
F. Depth
W. Depth
Altitude

Line Summary

Line Number	94004
No. of Shotpoints	1327

	Shotpoint	Date	Time	Latitude		Longitude	
Start	33	6-Mar-90	13:31:32	10	47.018	132	33.315
End	1364	8-Mar-90	10:11:43	8	57.234	133	02.280

	THC	Methane	Ethane	Ethylene	Propane	Propylene	i-Butane	n-Butane	i-Pentane	n-Pentane	i-Hexane	n-Hexane	%Wetness
Mean	13.072	8.273	0.030	0.228	0.028	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.697
Std. Dev.	3.533	1.917	0.008	0.082	0.010	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.145
Minimum	5.760	4.164	0.010	0.040	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.252
Maximum	24.481	15.193	0.044	0.397	0.061	0.077	0.000	0.000	0.000	0.000	0.000	0.000	1.350

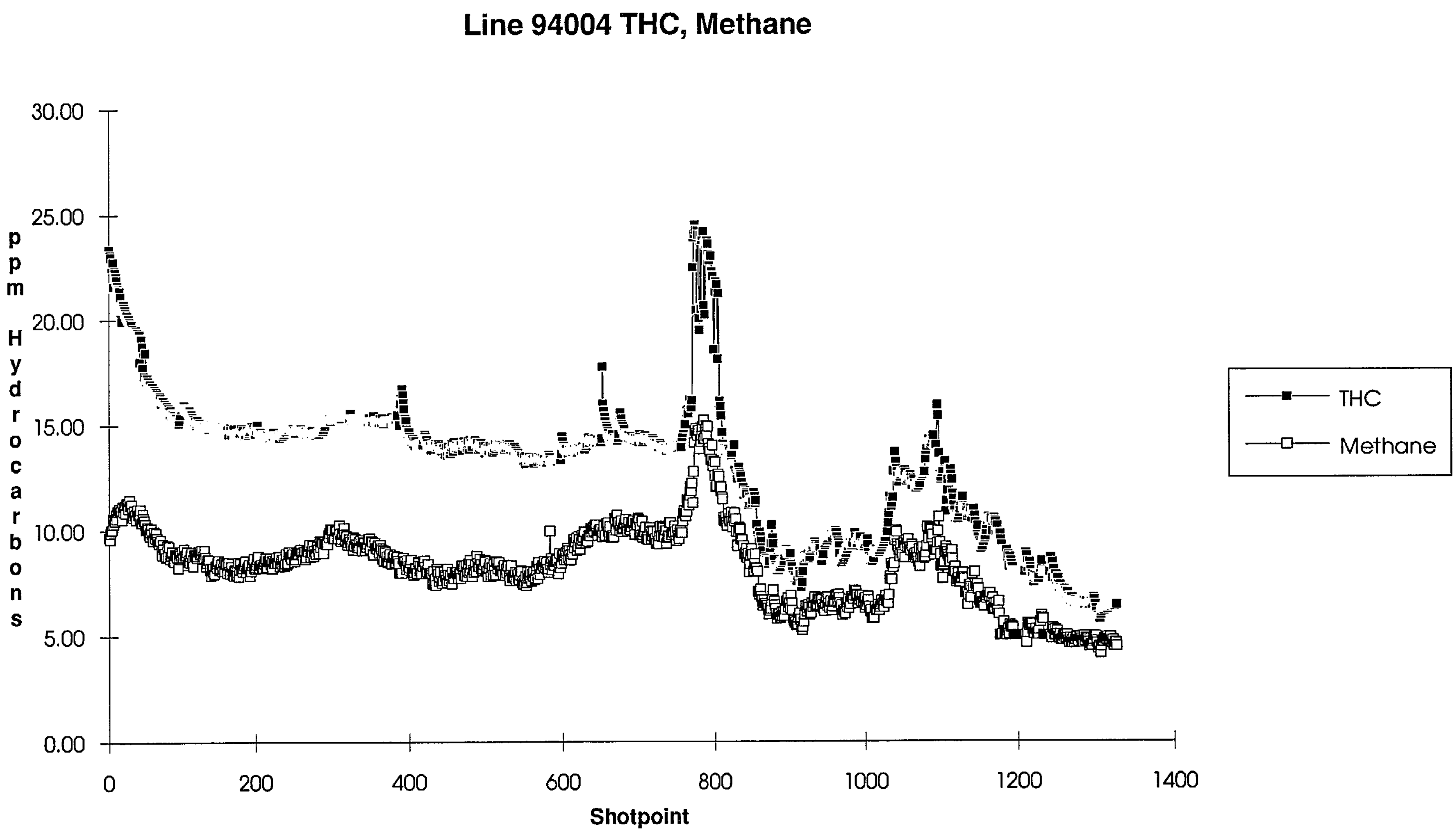
	Cond.	Temp.	F. Depth	W.Depth	Altitude
Mean	55.396	24.628	81.115	97.004	15.889
Std. Dev.	1.426	1.383	35.393	41.192	8.242
Minimum	51.070	20.410	37.000	49.000	9.000
Maximum	58.550	27.600	157.000	220.000	63.000

Notes

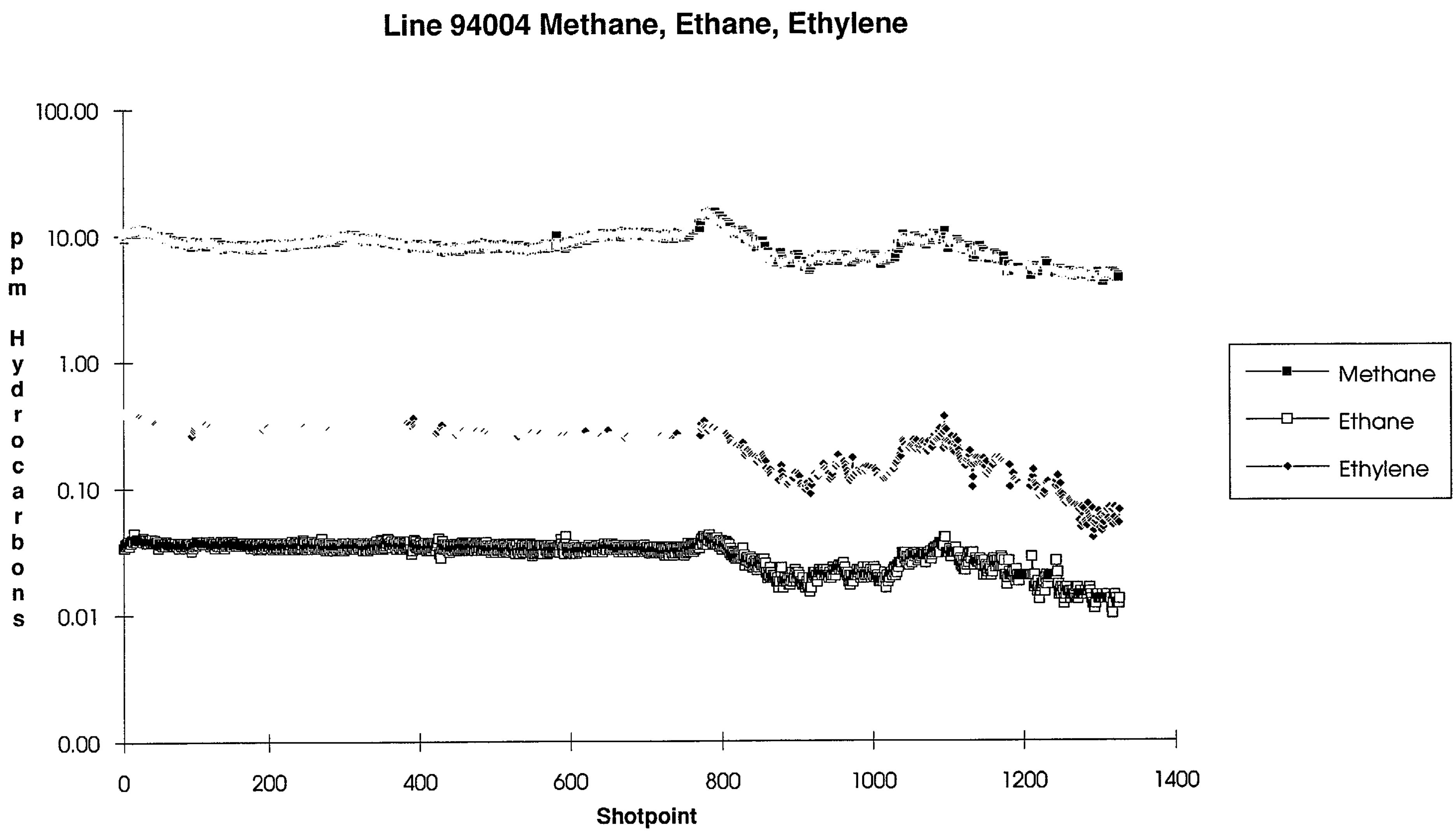
Weak THC, methane anomalies at start of line SP40, SP818, and SP1089: probably biogenic

Fish altitude has been calculated thus: Altitude=water depth-fish depth

Navigation added to file at post processing stage

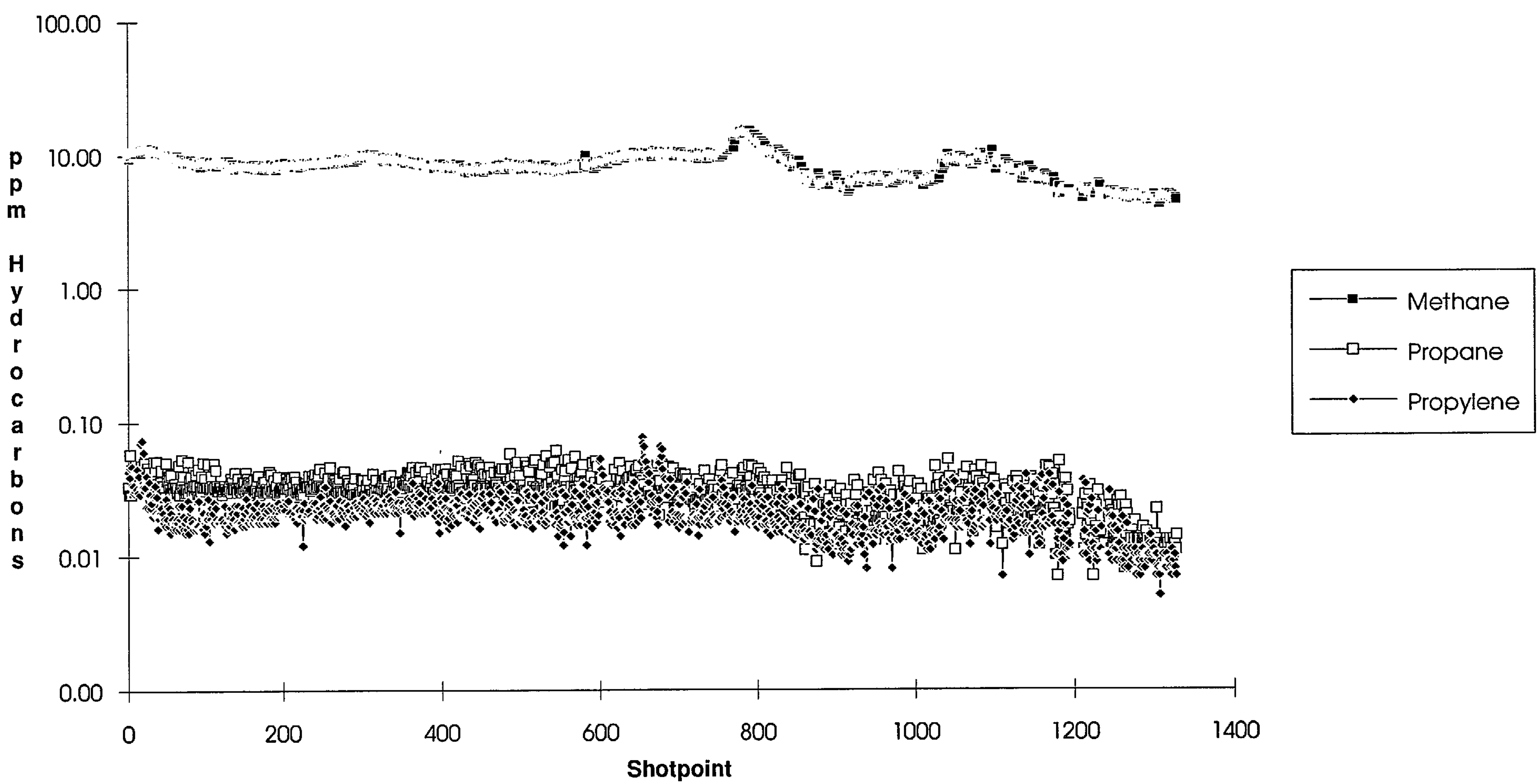


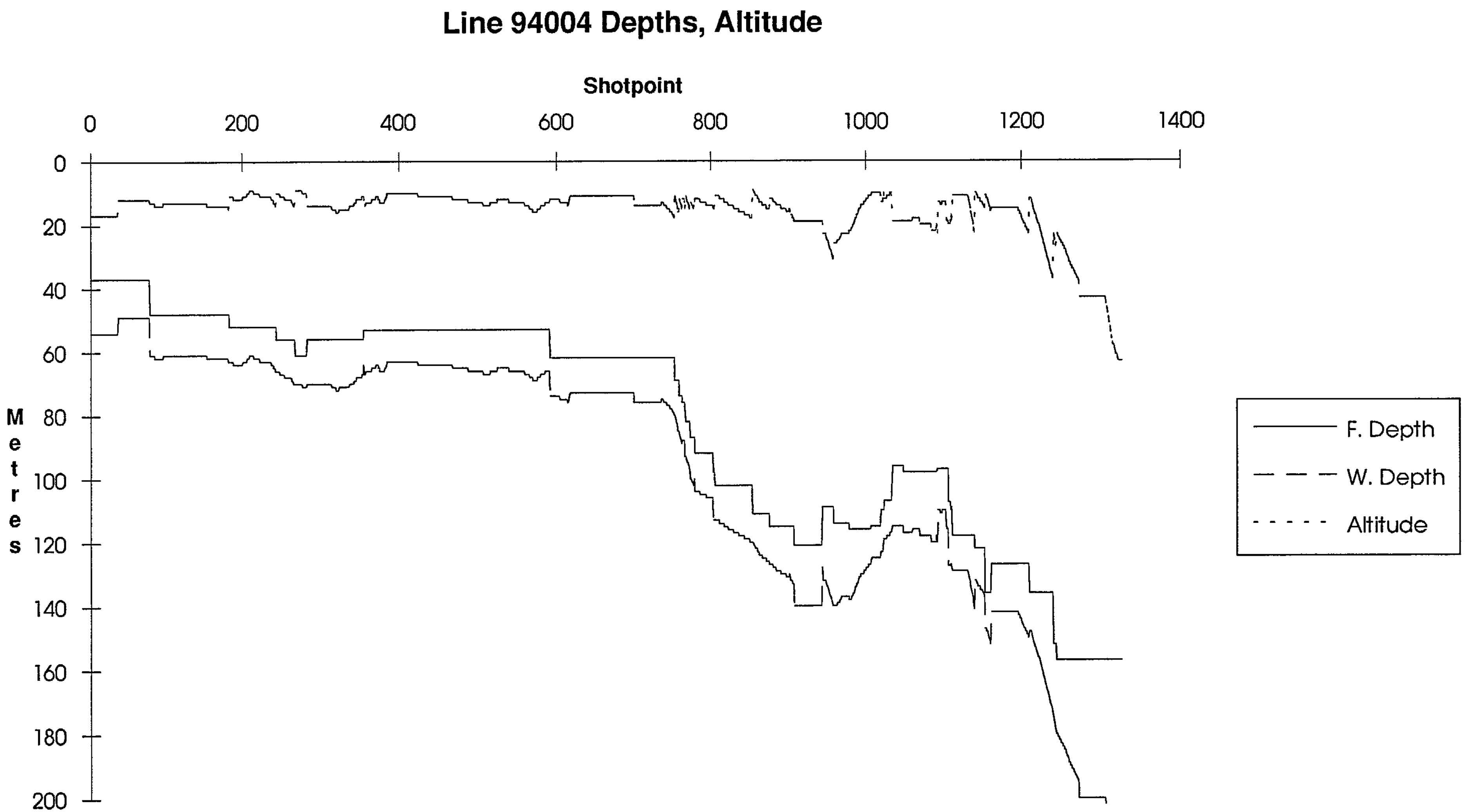
Line 94004 THC, Methane
30.00
25.00
20.00
15.00
10.00
5.00
0.00
ppm Hydrocarbons
0
200
400
600
800
1000
1200
1400
Shotpoint
THC
Methane



Line 94004 Methane, Ethane, Ethylene
ppm Hydrocarbons
100.00
10.00
1.00
0.10
0.01
0.00
0
200
400
600
800
1000
1200
1400
Shotpoint
Methane
Ethane
Ethylene

Line 94004 Methane, Propane, Propylene





Line 94004 Depths, Altitude
Shotpoint
0
200
400
600
800
1000
1200
1400
0
20
40
60
80
100
120
140
160
180
200
Metres
F. Depth
W. Depth
Altitude

Line Summary

Line Number	94006
No. of Shotpoints	998

	Shotpoint	Date	Time	Latitude		Longitude	
Start	18	12-Mar-90	12:11:00	9	15.499	134	15.895
End	759	13-Mar-90	22:36:40	11	15.560	133	51.300

	THC	Methane	Ethane	Ethylene	Propane	Propylene	i-Butane	n-Butane	i-Pentane	n-Pentane	i-Hexane	n-Hexane	%Wetness
Mean	19.129	12.505	0.036	0.339	0.030	0.037	0.001	0.000	0.000	0.000	0.000	0.000	0.573
Std. Dev.	2.173	4.177	0.007	0.048	0.008	0.008	0.002	0.000	0.000	0.000	0.000	0.000	0.180
Minimum	14.581	4.068	0.019	0.198	0.010	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.295
Maximum	24.207	21.311	0.058	0.445	0.070	0.112	0.014	0.000	0.000	0.000	0.000	0.000	1.423

	Cond.	Temp.	F. Depth	W.Depth	Altitude
Mean	56.767	25.324	54.029	69.406	15.377
Std. Dev.	0.955	0.744	14.625	16.367	4.715
Minimum	54.480	23.580	31.000	43.000	6.000
Maximum	58.700	26.810	96.000	127.000	53.000

Notes

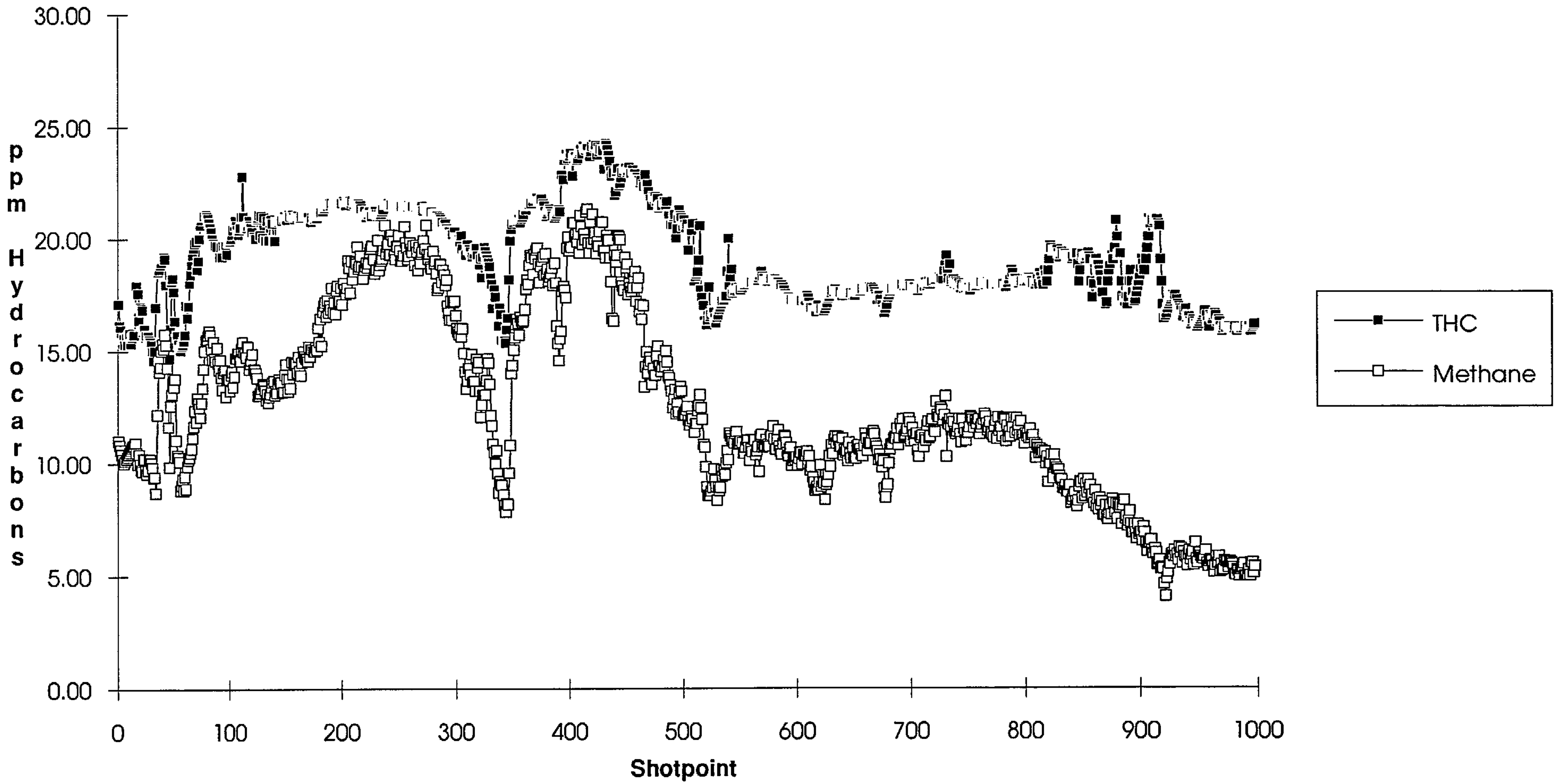
Weak THC and methane anomalies at SP 250 and SP400, probably biogenic

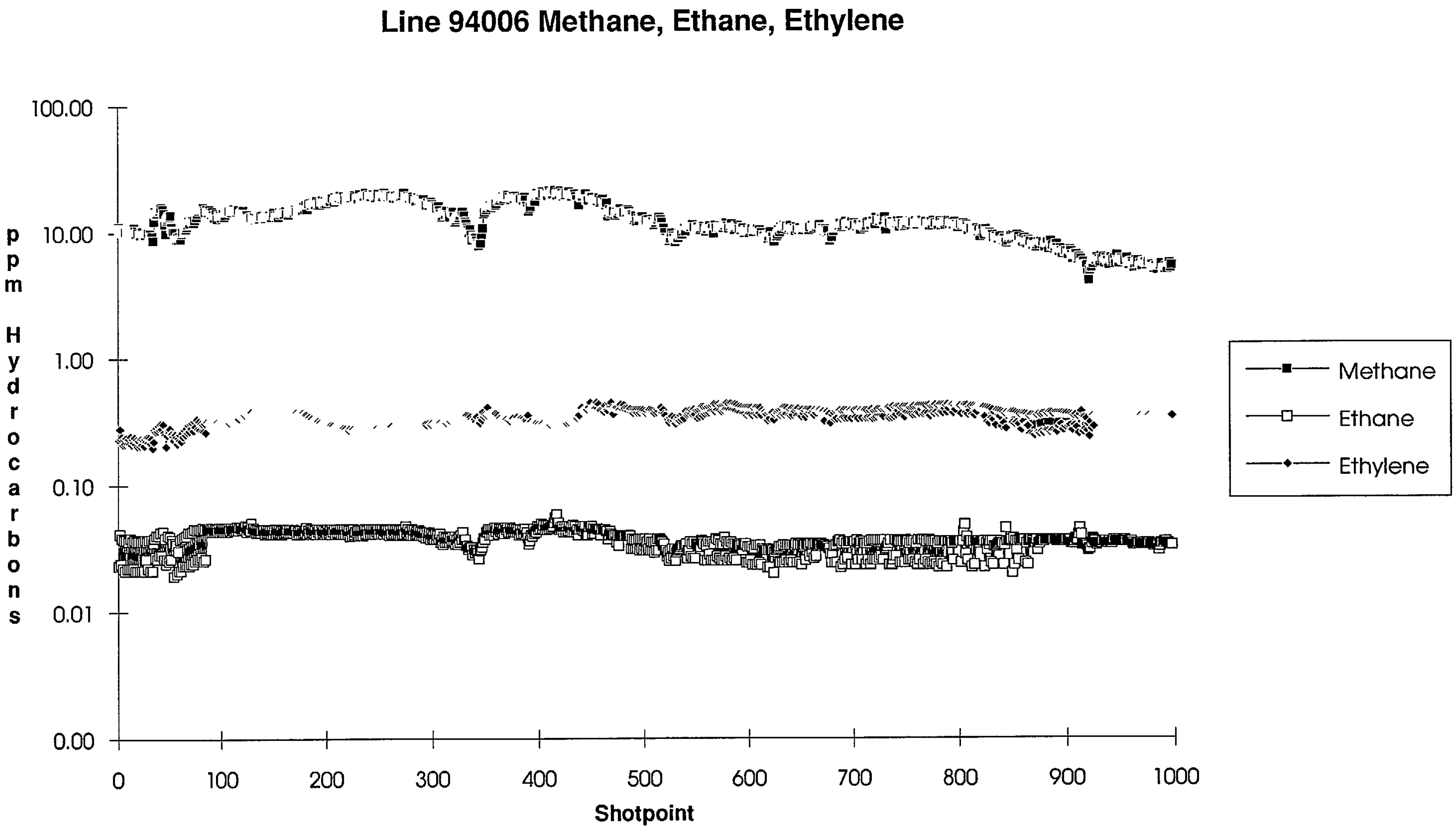
Factor of two decrease in methane between start and end of line. Slight decrease in ethane and propane to end of line

Fish altitude has been calculated thus: Altitude=water depth-fish depth

Navigation added to file at post processing stage

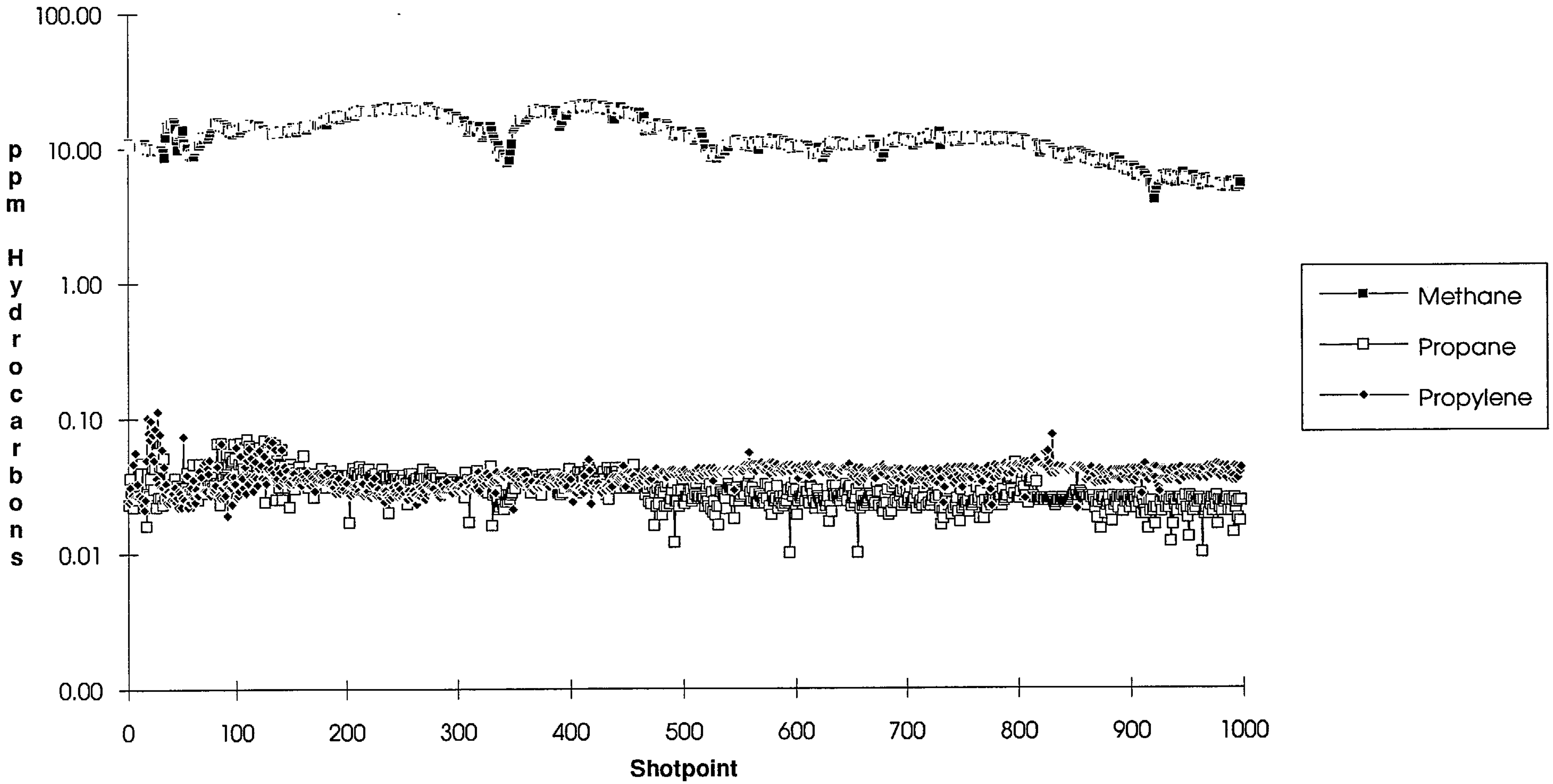
Line 94006 THC, Methane

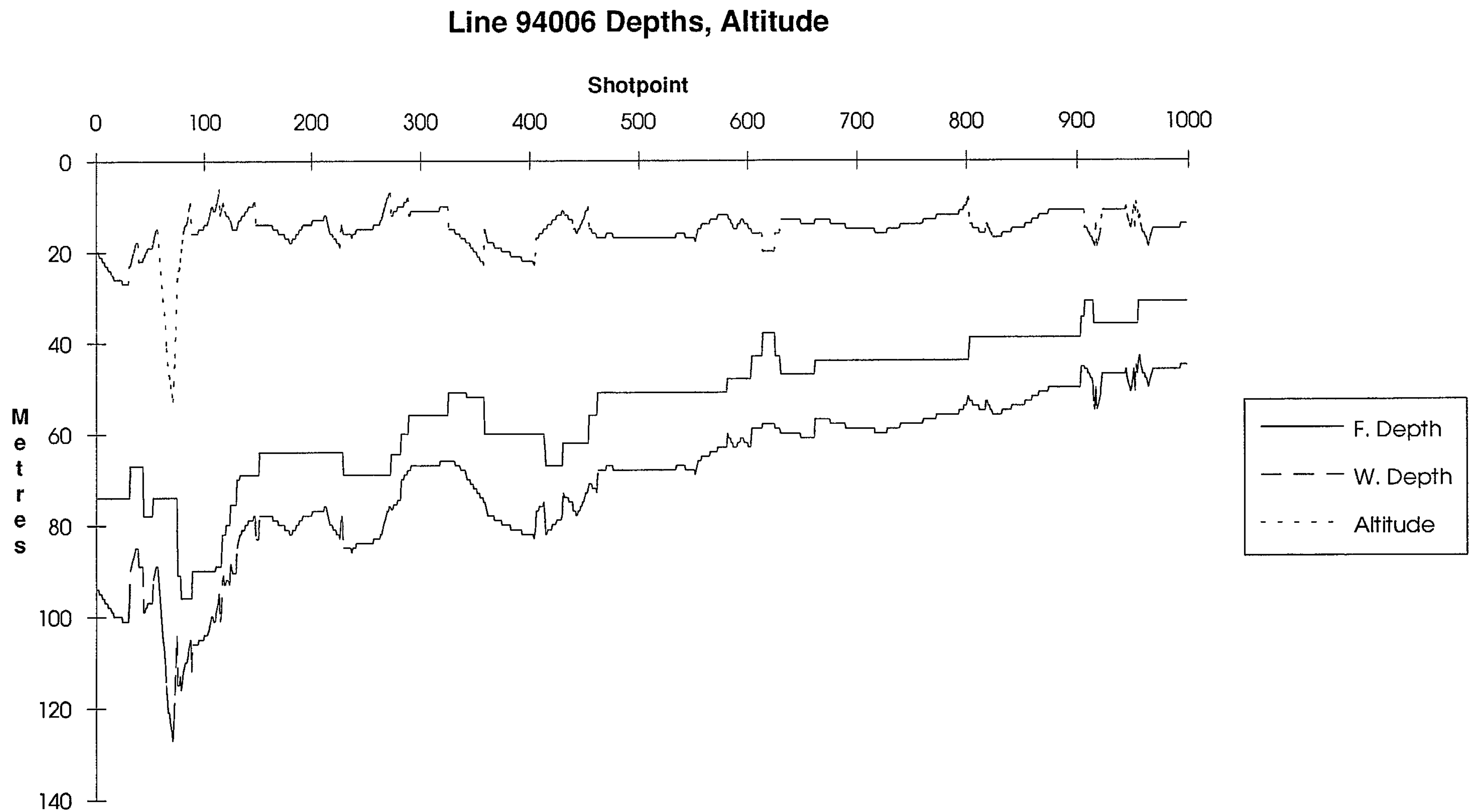




Line 94006 Methane, Ethane, Ethylene
ppm Hydrocarbons
100.00
10.00
1.00
0.10
0.01
0.00
0
100
200
300
400
500
600
700
800
900
1000
Shotpoint
Methane
Ethane
Ethylene

Line 94006 Methane, Propane, Propylene





Line 94006 Depths, Altitude
Shotpoint
0
100
200
300
400
500
600
700
800
900
1000
0
20
40
60
80
100
120
140
Metres
F. Depth
W. Depth
Altitude

Line Summary

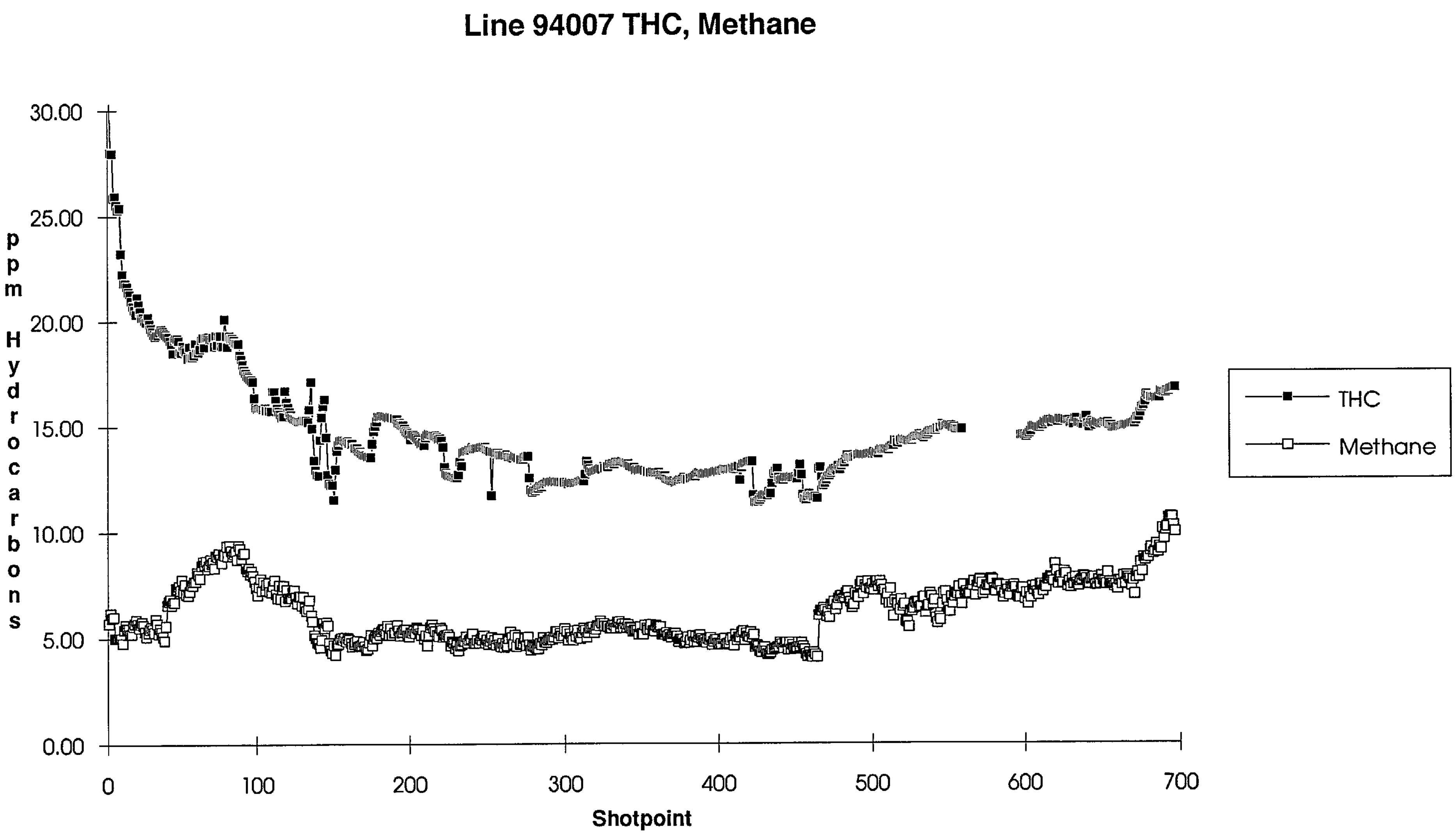
Line Number	94007
No. of Shotpoints	697

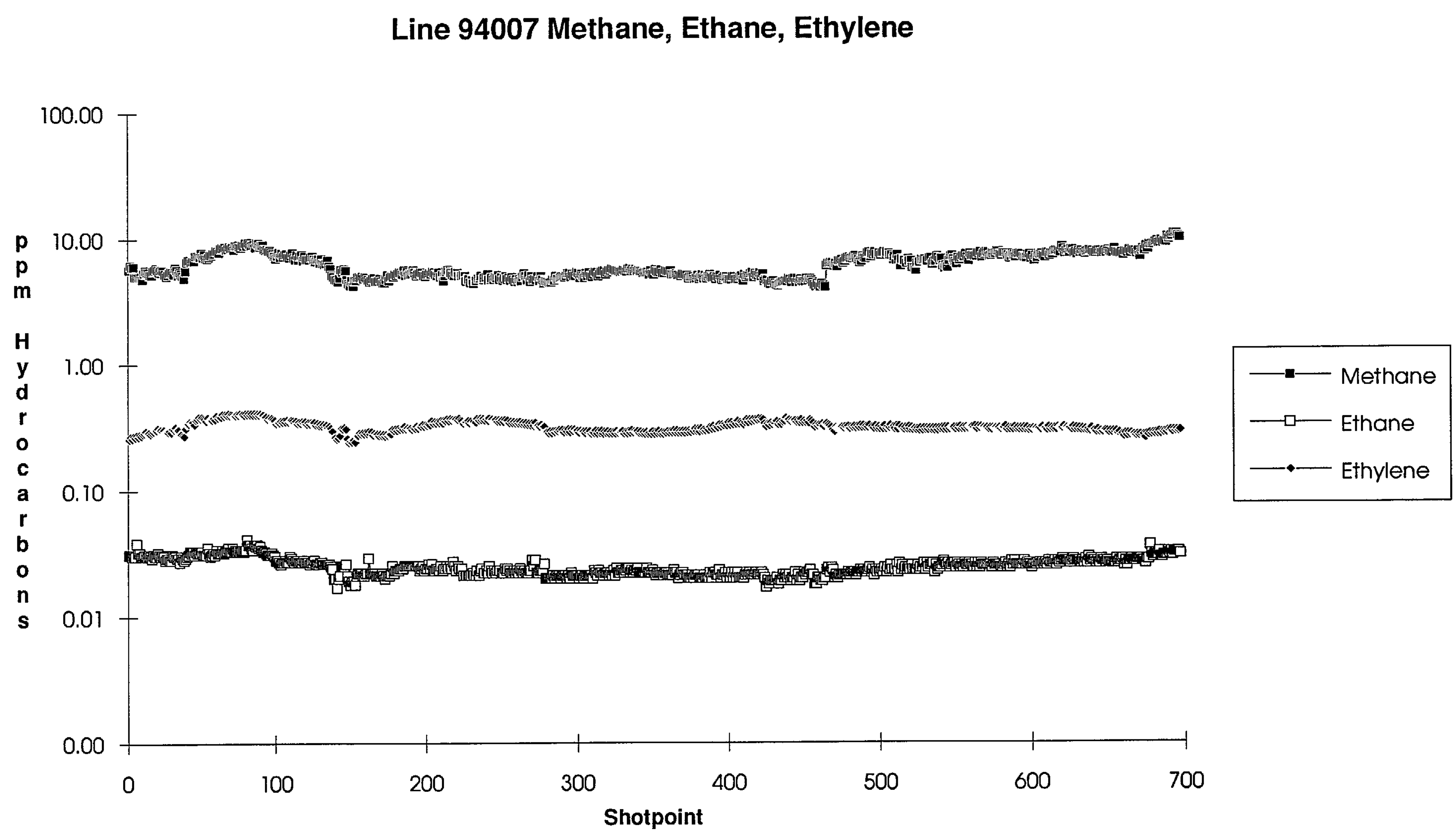
	Shotpoint	Date	Time	Latitude		Longitude	
Start	15	14-Mar-90	05:30:03	11	28.762	134	05.664
End	712	15-Mar-90	05:16:32	10	16.896	134	25.673

	THC	Methane	Ethane	Ethylene	Propane	Propylene	i-Butane	n-Butane	i-Pentane	n-Pentane	i-Hexane	n-Hexane	%Wetness
Mean	14.772	6.174	0.025	0.316	0.017	0.041	0.000	0.000	0.000	0.000	0.000	0.000	0.685
Std. Dev.	2.621	1.392	0.004	0.034	0.005	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.120
Minimum	11.343	4.062	0.017	0.241	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.320
Maximum	30.633	10.636	0.041	0.414	0.032	0.057	0.009	0.006	0.000	0.000	0.000	0.000	1.283

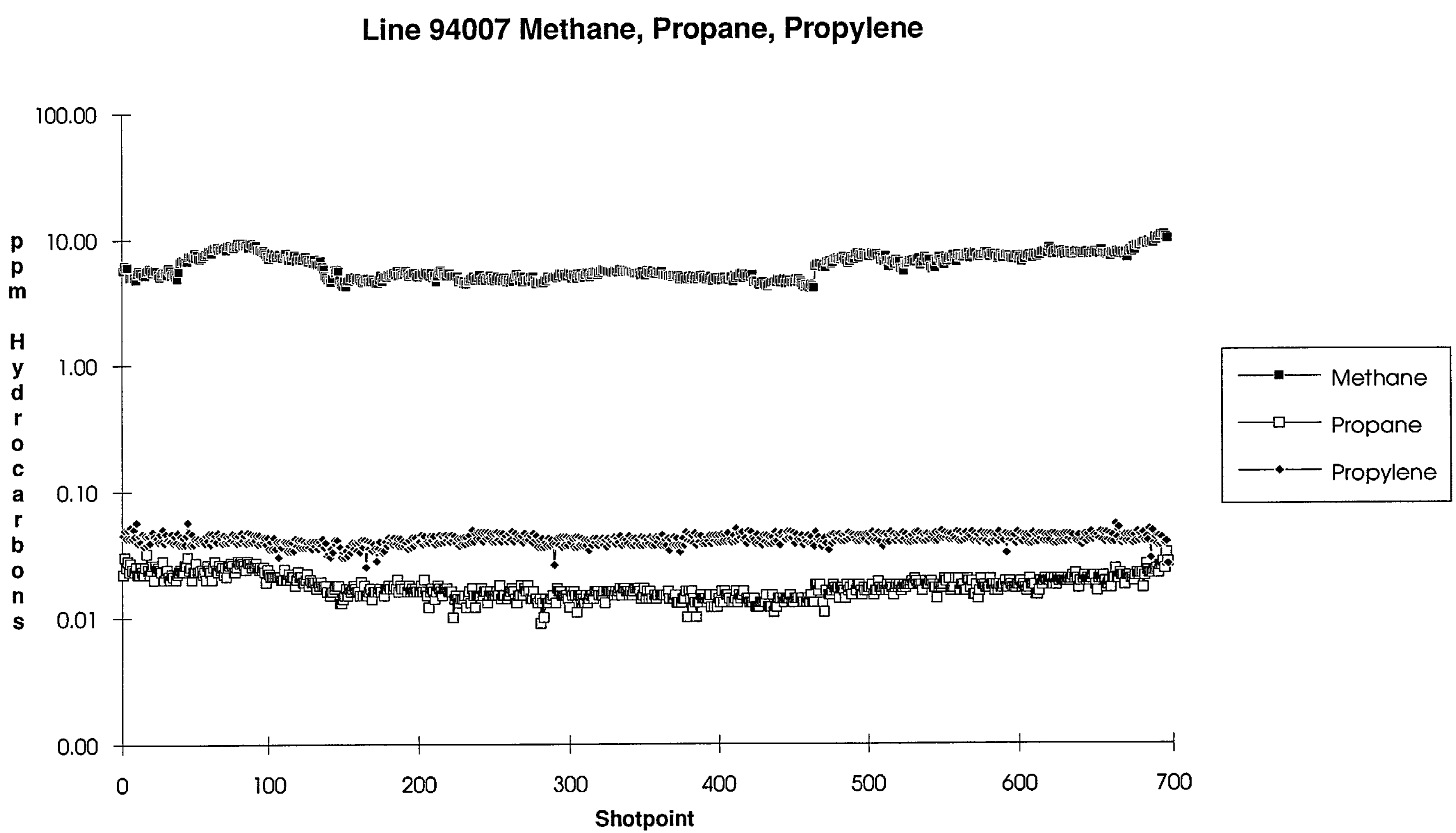
	Cond.	Temp.	F. Depth	W.Depth	Altitude
Mean	58.255	26.503	43.761	56.843	13.082
Std. Dev.	0.676	0.670	8.158	7.716	1.749
Minimum	57.570	25.790	17.500	26.500	9.000
Maximum	59.820	28.590	50.500	64.100	19.000

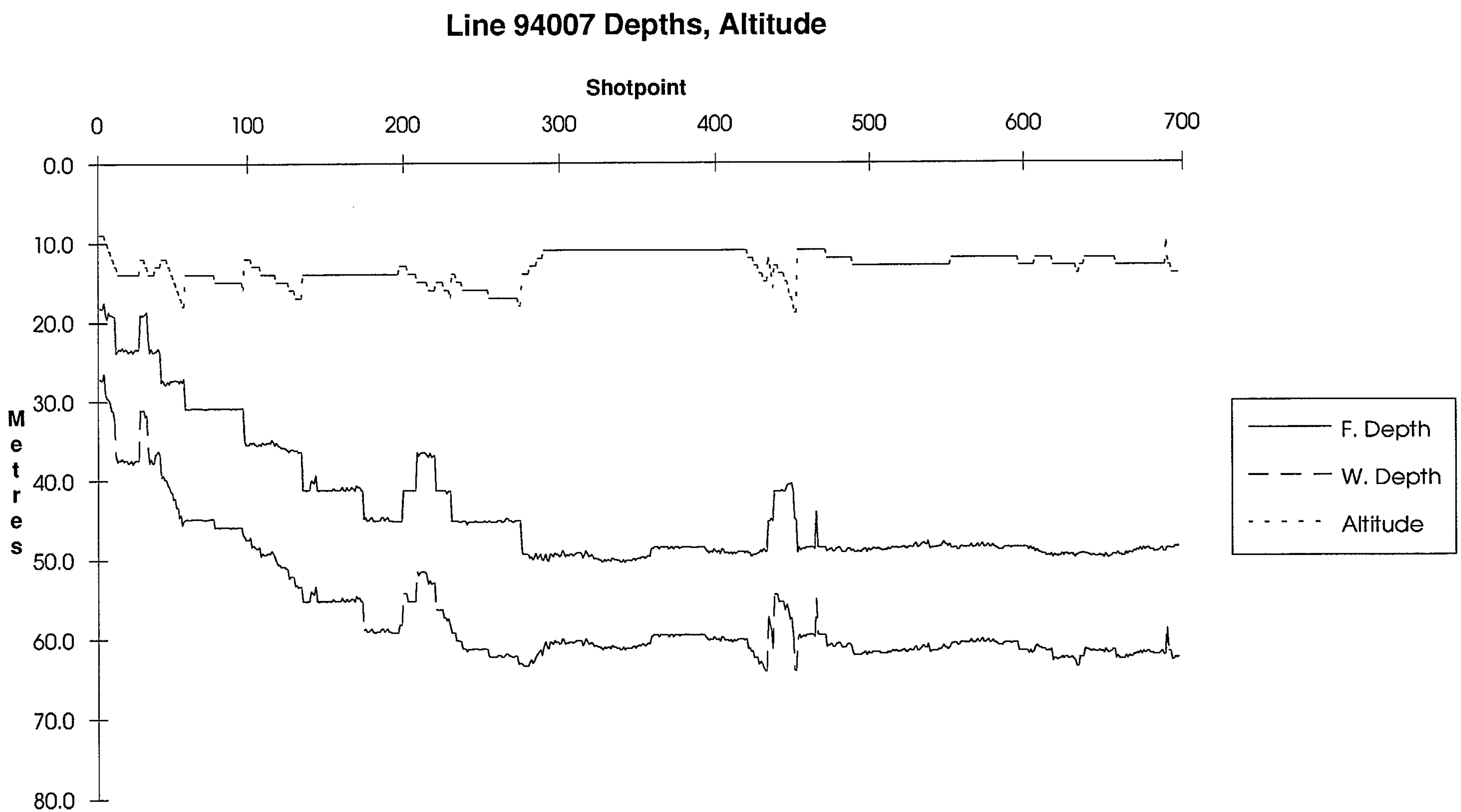
Notes
Weak THC anomaly at the start of line, probably biogenic
Weak methane anomaly at SP106, probably biogenic
Fish altitude has been calculated thus: Altitude=water depth-fish depth
Navigation added to file at post processing stage


Line 94007 THC, Methane
ppm Hydrocarbons
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
100
200
300
400
500
600
700
Shotpoint
THC
Methane



Line 94007 Methane, Ethane, Ethylene
ppm Hydrocarbons
100.00
10.00
1.00
0.10
0.01
0.00
0
100
200
300
400
500
600
700
Shotpoint
Methane
Ethane
Ethylene


Line 94007 Methane, Propane, Propylene
ppm Hydrocarbons
100.00
10.00
1.00
0.10
0.01
0.00
0
100
200
300
400
500
600
700
Shotpoint
Methane
Propane
Propylene



Line 94007 Depths, Altitude
Shotpoint
0
100
200
300
400
500
600
700
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Metres
F. Depth
W. Depth
Altitude

Line Summary

Line Number	94008
No. of Shotpoints	404

	Shotpoint	Date	Time	Latitude		Longitude	
Start	40	15/03/90	10:33:55	10	26.076	134	11.006
End	444	16-Mar-90	12:44:51	10	16.012	132	40.502

	THC	Methane	Ethane	Ethylene	Propane	Propylene	i-Butane	n-Butane	i-Pentane	n-Pentane	i-Hexane	n-Hexane	%Wetness
Mean	15.905	10.763	0.034	0.268	0.027	0.036	0.000	0.000	0.000	0.000	0.000	0.000	0.571
Std. Dev.	1.842	2.331	0.006	0.020	0.009	0.006	0.000	0.001	0.000	0.000	0.000	0.000	0.081
Minimum	11.537	5.358	0.017	0.181	0.012	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.374
Maximum	21.052	15.153	0.049	0.314	0.058	0.061	0.009	0.017	0.000	0.000	0.000	0.000	0.890

	Cond.	Temp.	F. Depth	W.Depth	Altitude
Mean	57.042	25.637	52.437	64.676	12.239
Std. Dev.	0.845	0.727	2.486	2.127	2.473
Minimum	54.920	24.200	45.000	60.000	8.000
Maximum	58.230	26.960	57.800	81.000	27.000

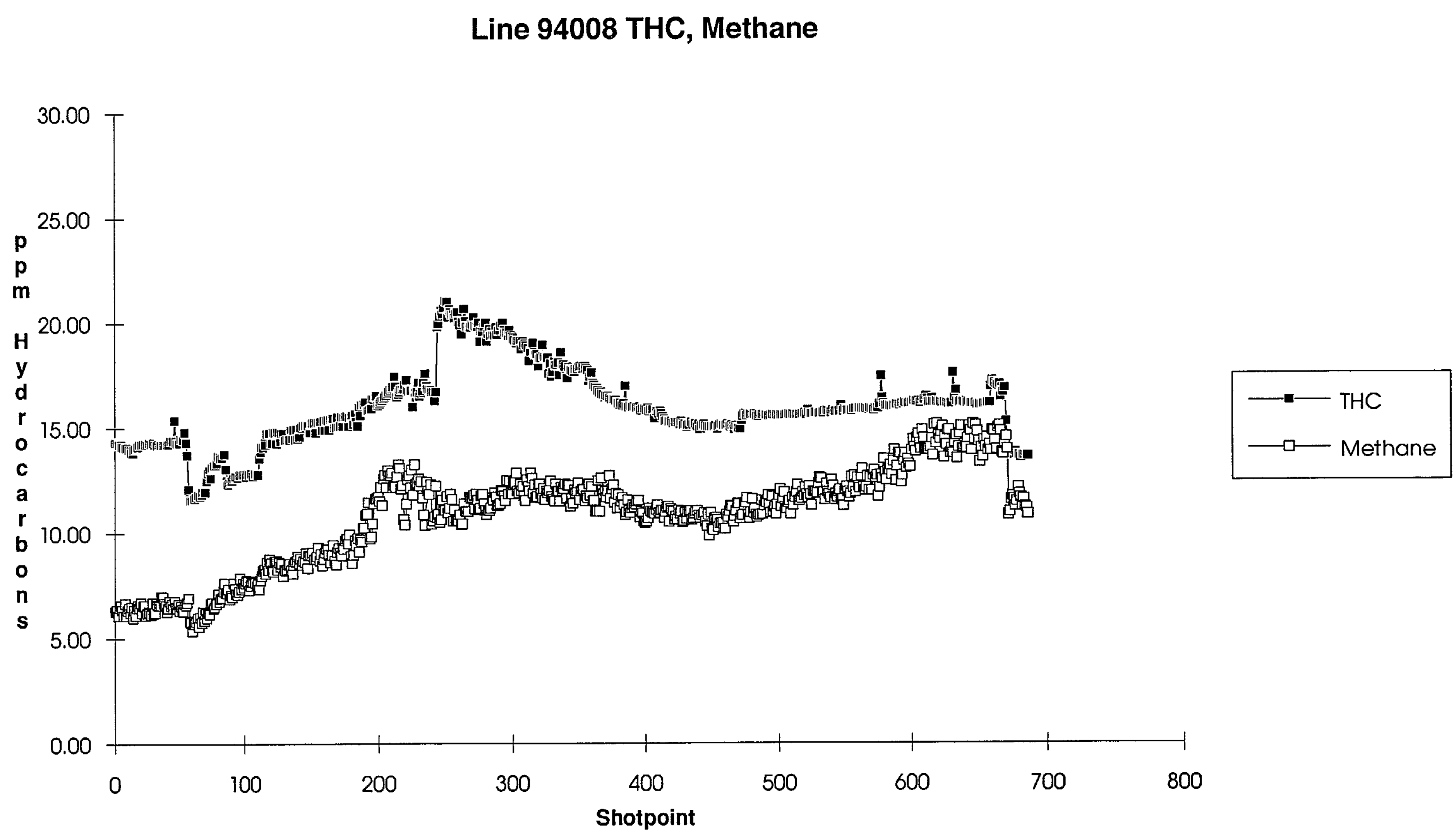
Notes

Methane, and to a lesser degree ethane and propane, increases towards the end of line (westwards)

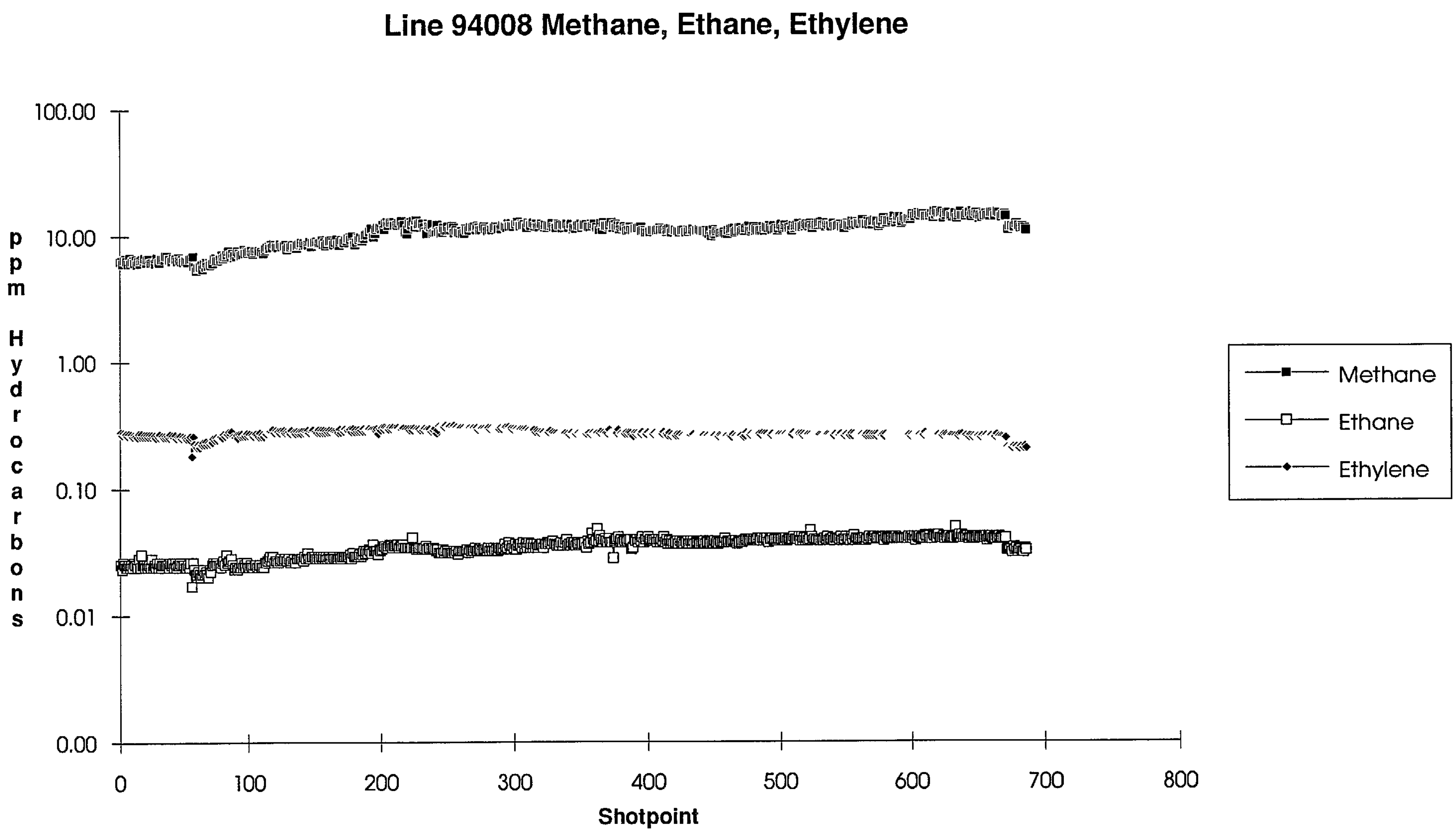
Sudden shift in THC at SP 282 due to break in acquisition due to system faults

Fish altitude has been calculated thus: Altitude=water depth-fish depth

Navigation added to file at post processing stage

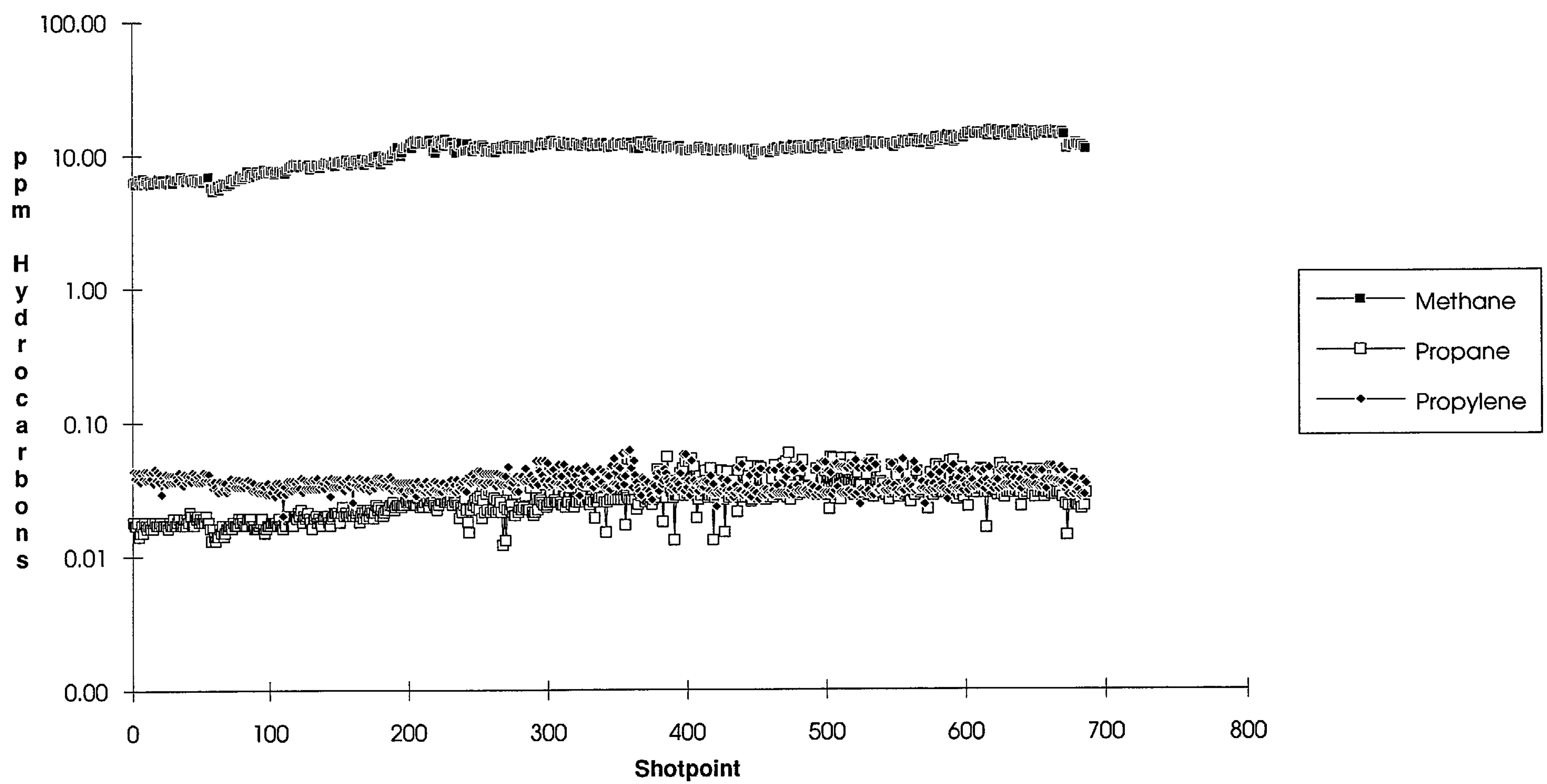


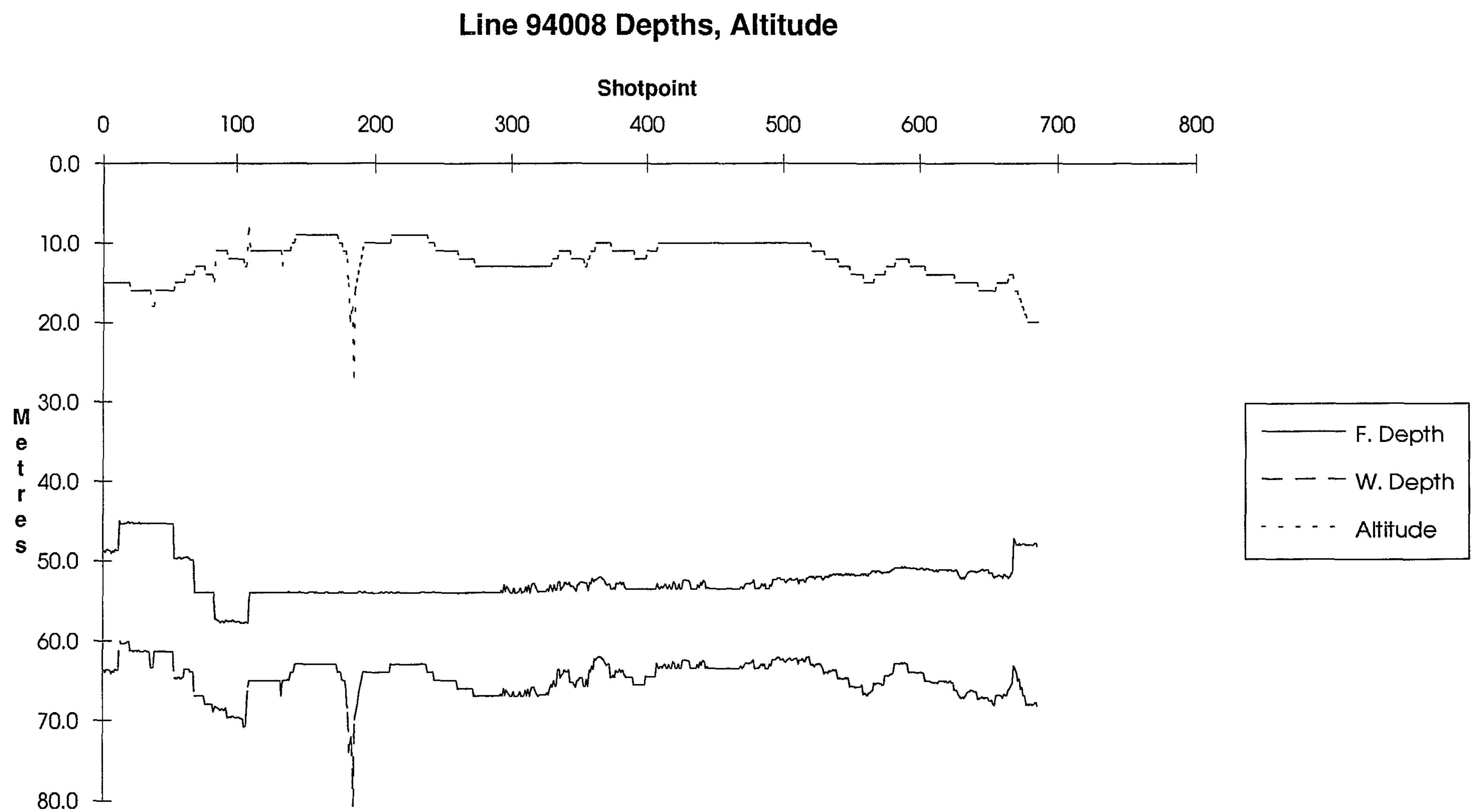
Line 94008 THC, Methane
ppm Hydrocarbons
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
100
200
300
400
500
600
700
800
Shotpoint
THC
Methane



Line 94008 Methane, Ethane, Ethylene
100.00
10.00
1.00
0.10
0.01
0.00
ppm Hydrocarbons
0
100
200
300
400
500
600
700
800
Shotpoint
Methane
Ethane
Ethylene

Line 94008 Methane, Propane, Propylene





Line 94008 Depths, Altitude
Shotpoint
0
100
200
300
400
500
600
700
800
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Metres
F. Depth
W. Depth
Altitude

Line Summary

Line Number	94009
No. of Shotpoints	671

	Shotpoint	Date	Time	Latitude		Longitude	
Start	2	16-Mar-90	20:13:33	10	04.213	132	27.130
End	672	17-Mar-90	18:34:13	10	19.619	133	57.766

	THC	Methane	Ethane	Ethylene	Propane	Propylene	i-Butane	n-Butane	i-Pentane	n-Pentane	i-Hexane	n-Hexane	%Wetness
Mean	16.749	11.774	0.037	0.274	0.032	0.044	0.001	0.000	0.000	0.000	0.000	0.000	0.599
Std. Dev.	1.481	2.471	0.006	0.044	0.009	0.008	0.003	0.001	0.000	0.000	0.000	0.000	0.106
Minimum	12.188	6.508	0.017	0.164	0.005	0.025	0.000	0.000	0.000	0.000	0.000	0.000	0.373
Maximum	20.335	15.785	0.046	0.392	0.061	0.076	0.041	0.013	0.000	0.000	0.000	0.000	1.173

	Cond.	Temp.	F. Depth	W.Depth	Altitude
Mean	57.160	25.715	64.029	75.281	11.252
Std. Dev.	0.962	0.905	2.511	2.772	1.295
Minimum	55.200	24.030	52.500	62.500	8.000
Maximum	58.680	27.280	67.700	79.300	17.000

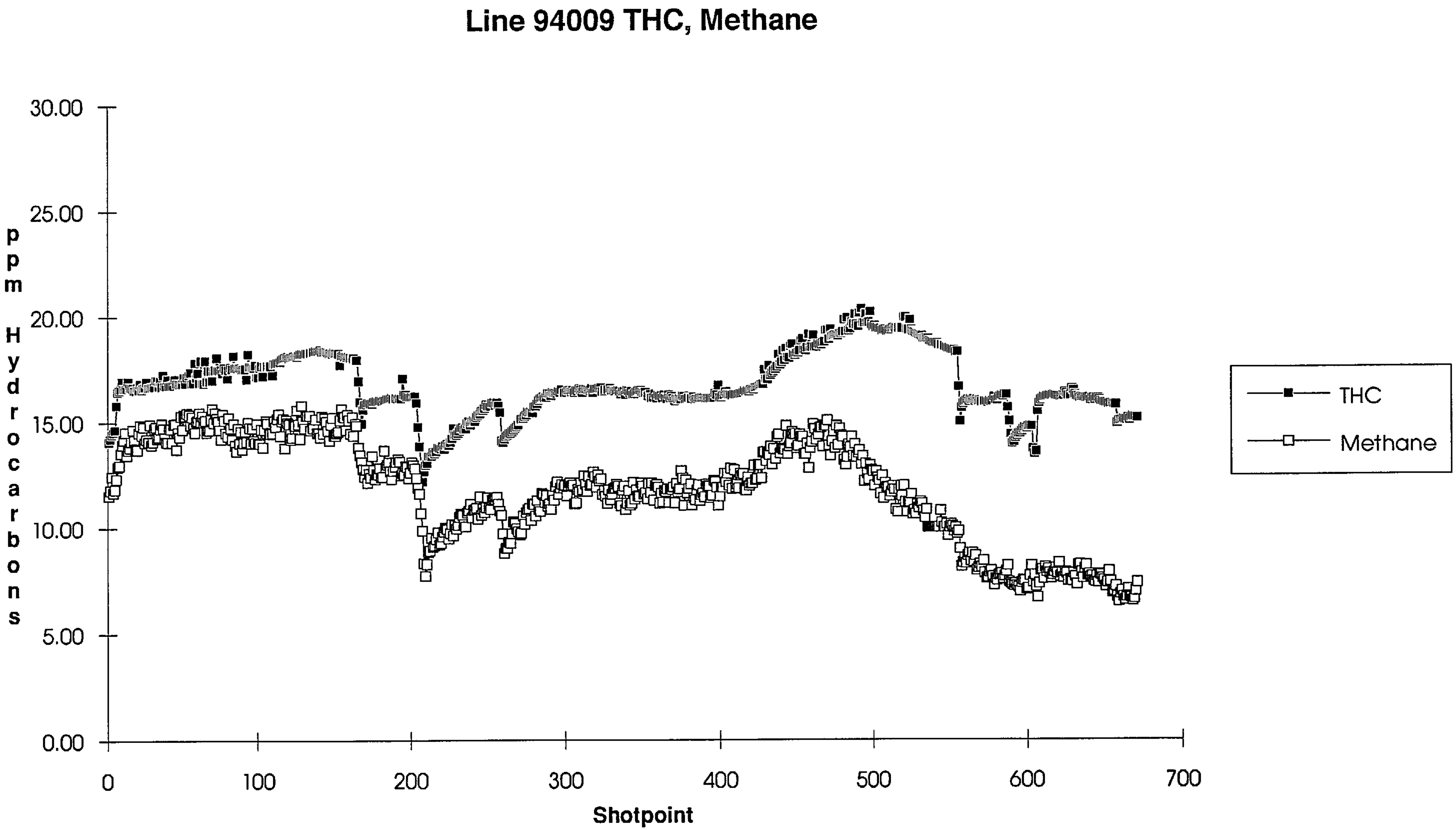
Notes

Variations in hydrocarbon values at SP's 168,202, 259, 557, 590, 605, 659 caused by gas leakage at the water rotary joint at the winch

Weak THC and methane anomaly at SP 453, SP 469, trend to lower methane, ethane and propane values to end of line (eastward).

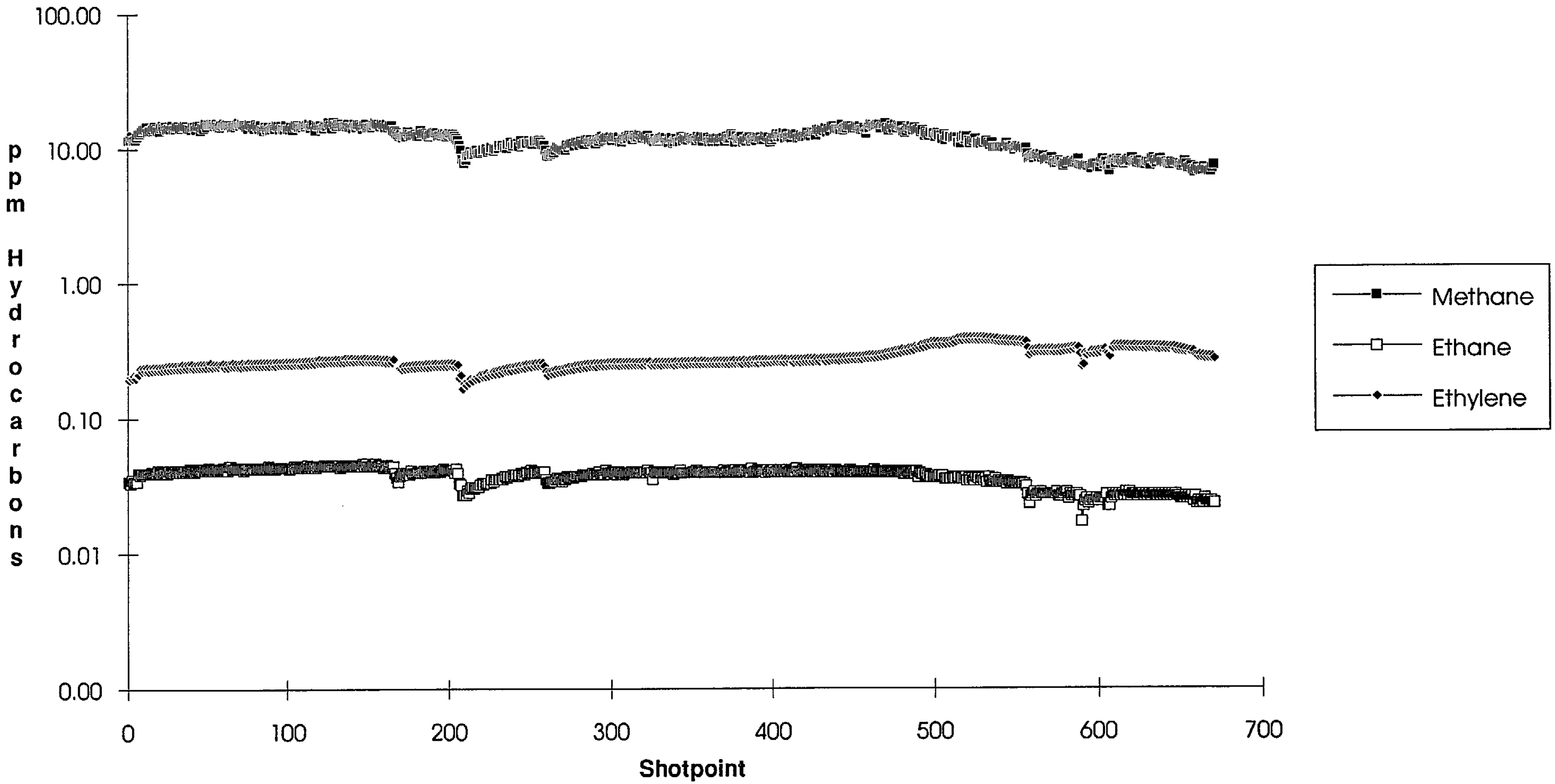
Fish altitude has been calculated thus: Altitude=water depth-fish depth

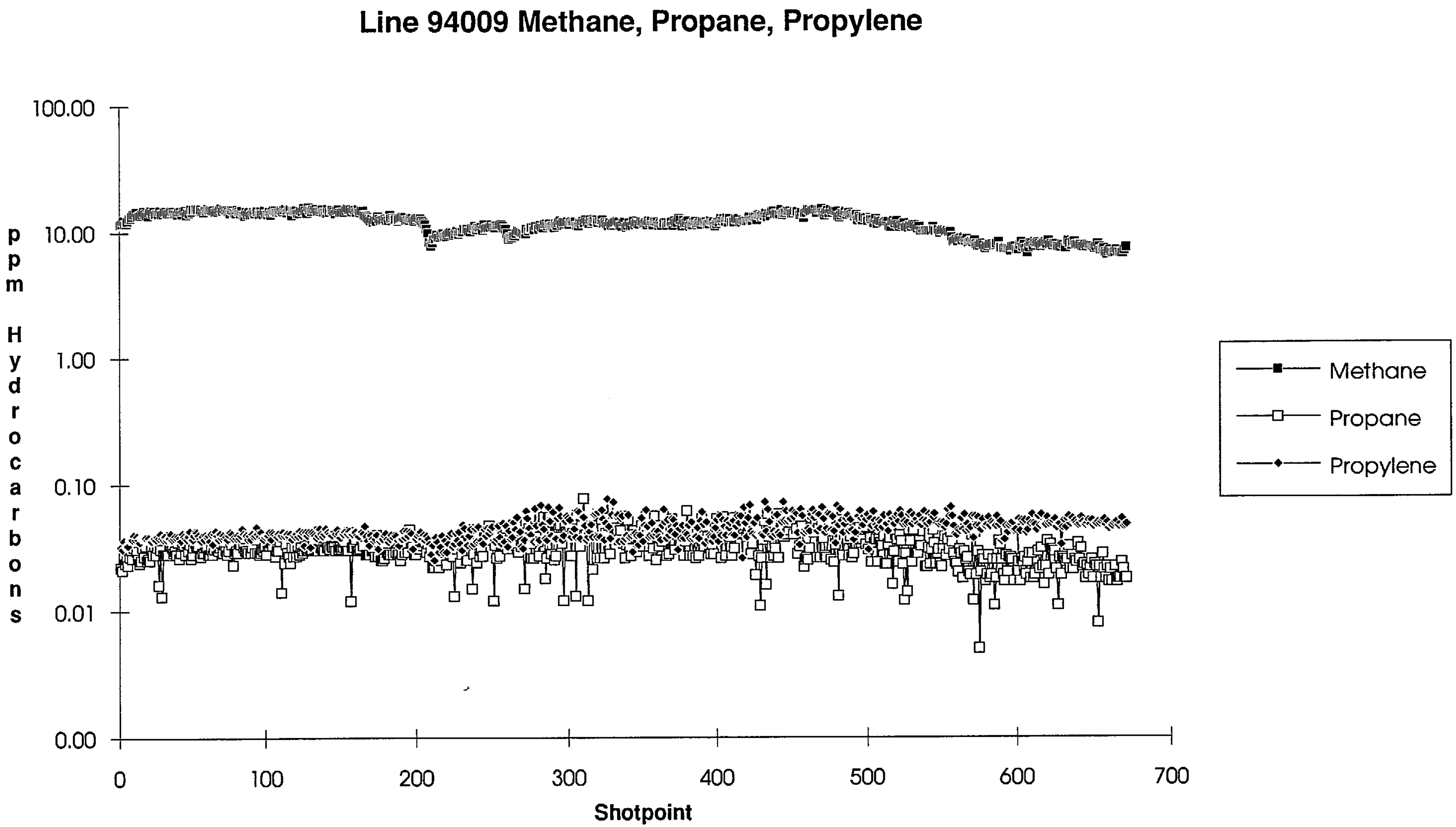
Navigation added to file at post processing stage

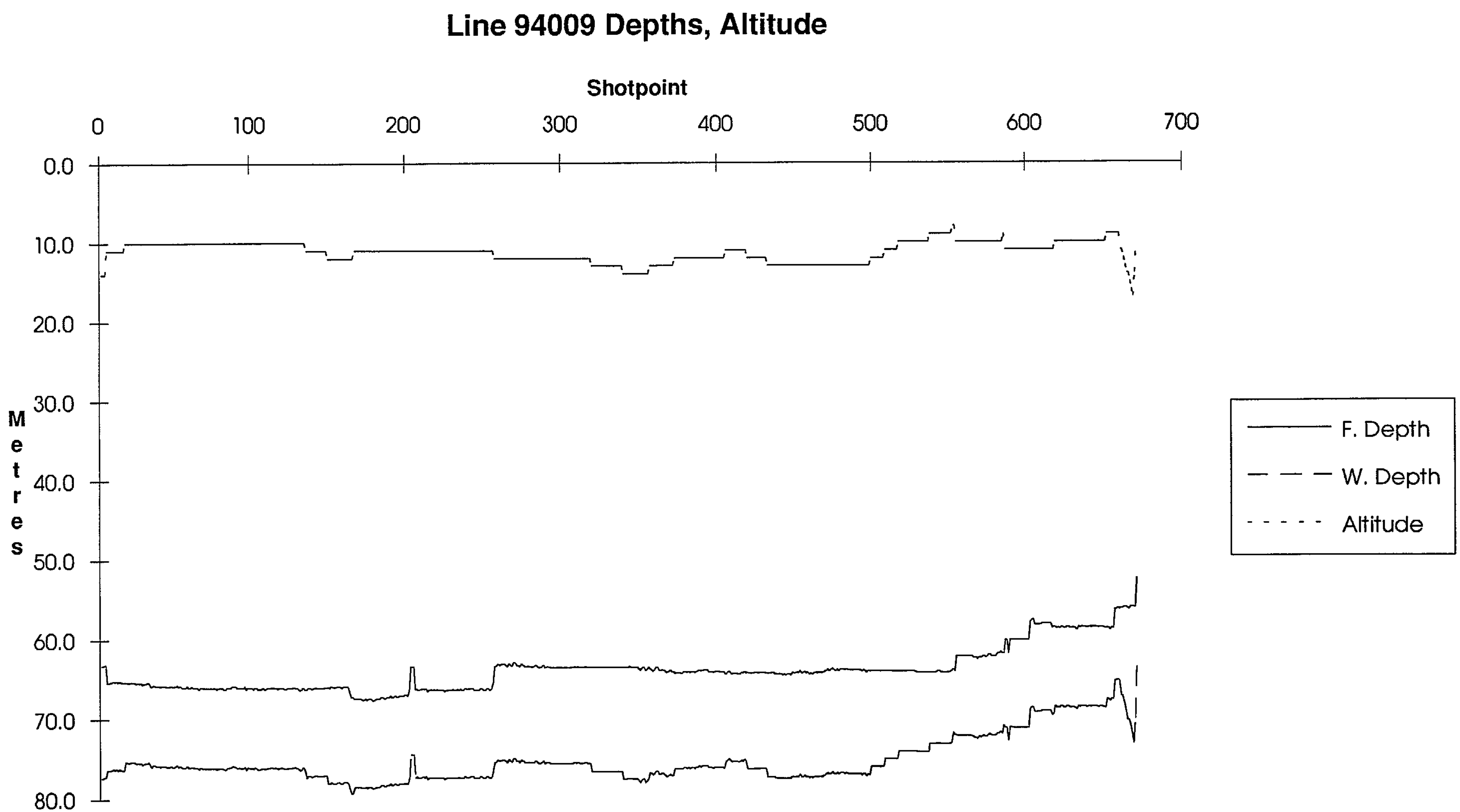


Line 94009 THC, Methane
30.00
25.00
20.00
15.00
10.00
5.00
0.00
ppm Hydrocarbons
0
100
200
300
400
500
600
700
Shotpoint
THC
Methane

Line 94009 Methane, Ethane, Ethylene




Line 94009 Methane, Propane, Propylene
ppm Hydrocarbons
100.00
10.00
1.00
0.10
0.01
0.00
0
100
200
300
400
500
600
700
Shotpoint
Methane
Propane
Propylene


Line 94009 Depths, Altitude
Shotpoint
0
100
200
300
400
500
600
700
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Metres
F. Depth
W. Depth
Altitude

Line Summary

Line Number	94010
No. of Shotpoints	205

	Shotpoint	Date	Time	Latitude		Longitude	
Start	1	17-Mar-90	19:37:44	10	23.148	134	00.488
End	205	18-Mar-90	02:28:28	10	44.987	134	17.966

	THC	Methane	Ethane	Ethylene	Propane	Propylene	i-Butane	n-Butane	i-Pentane	n-Pentane	i-Hexane	n-Hexane	%Wetness
Mean	16.097	6.621	0.025	0.317	0.020	0.051	0.000	0.000	0.000	0.000	0.000	0.000	0.691
Std. Dev.	0.636	0.496	0.001	0.024	0.004	0.005	0.000	0.002	0.000	0.000	0.000	0.000	0.085
Minimum	14.656	5.336	0.021	0.271	0.005	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.443
Maximum	16.999	7.586	0.028	0.361	0.032	0.065	0.007	0.023	0.000	0.000	0.000	0.000	0.933

	Cond.	Temp.	F. Depth	W.Depth	Altitude
Mean	58.612	26.503	52.060	63.704	11.644
Std. Dev.	0.966	0.845	1.222	1.129	0.937
Minimum	57.260	25.300	49.900	62.800	9.000
Maximum	59.930	27.680	54.800	68.200	14.000

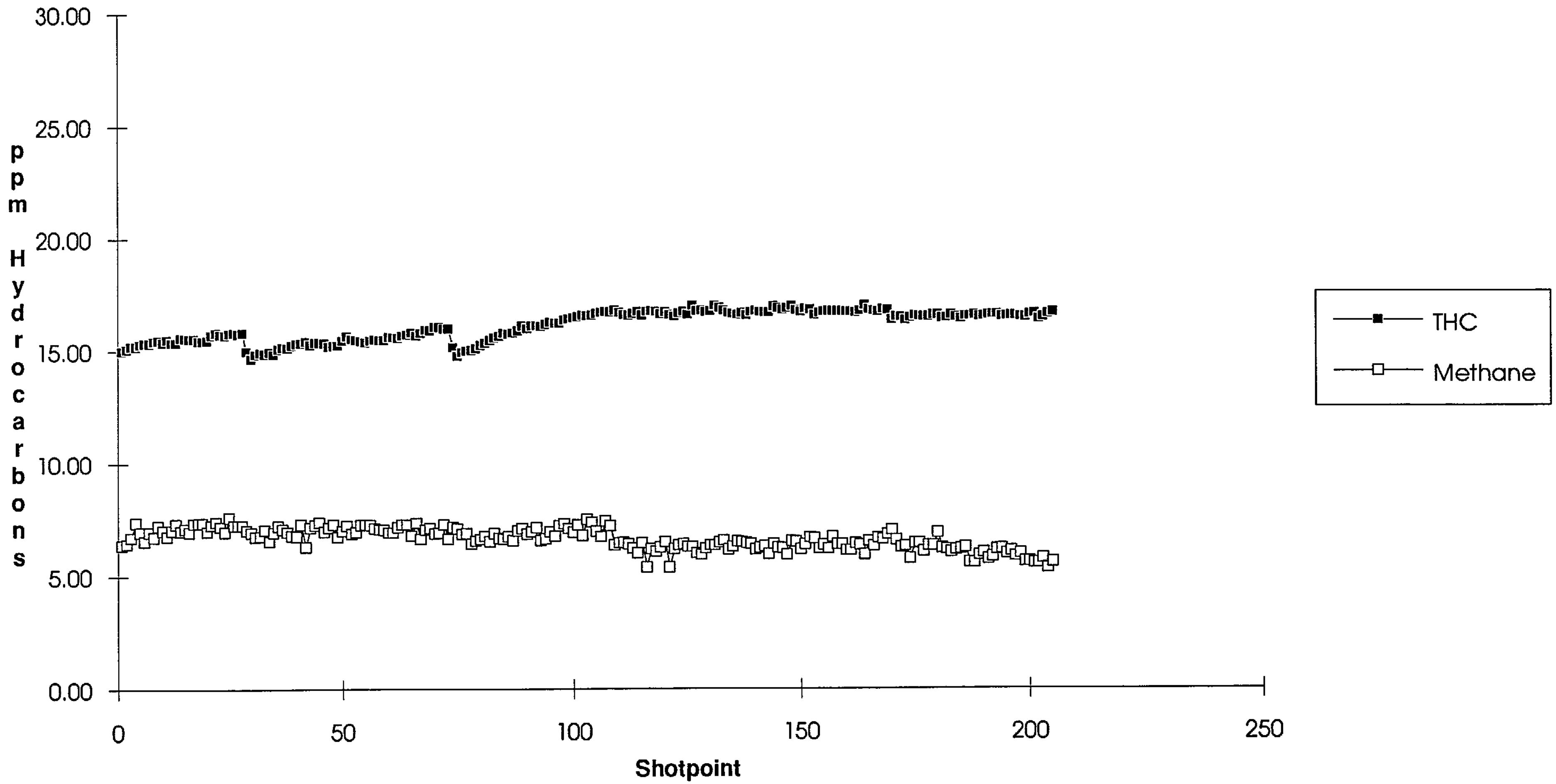
Notes

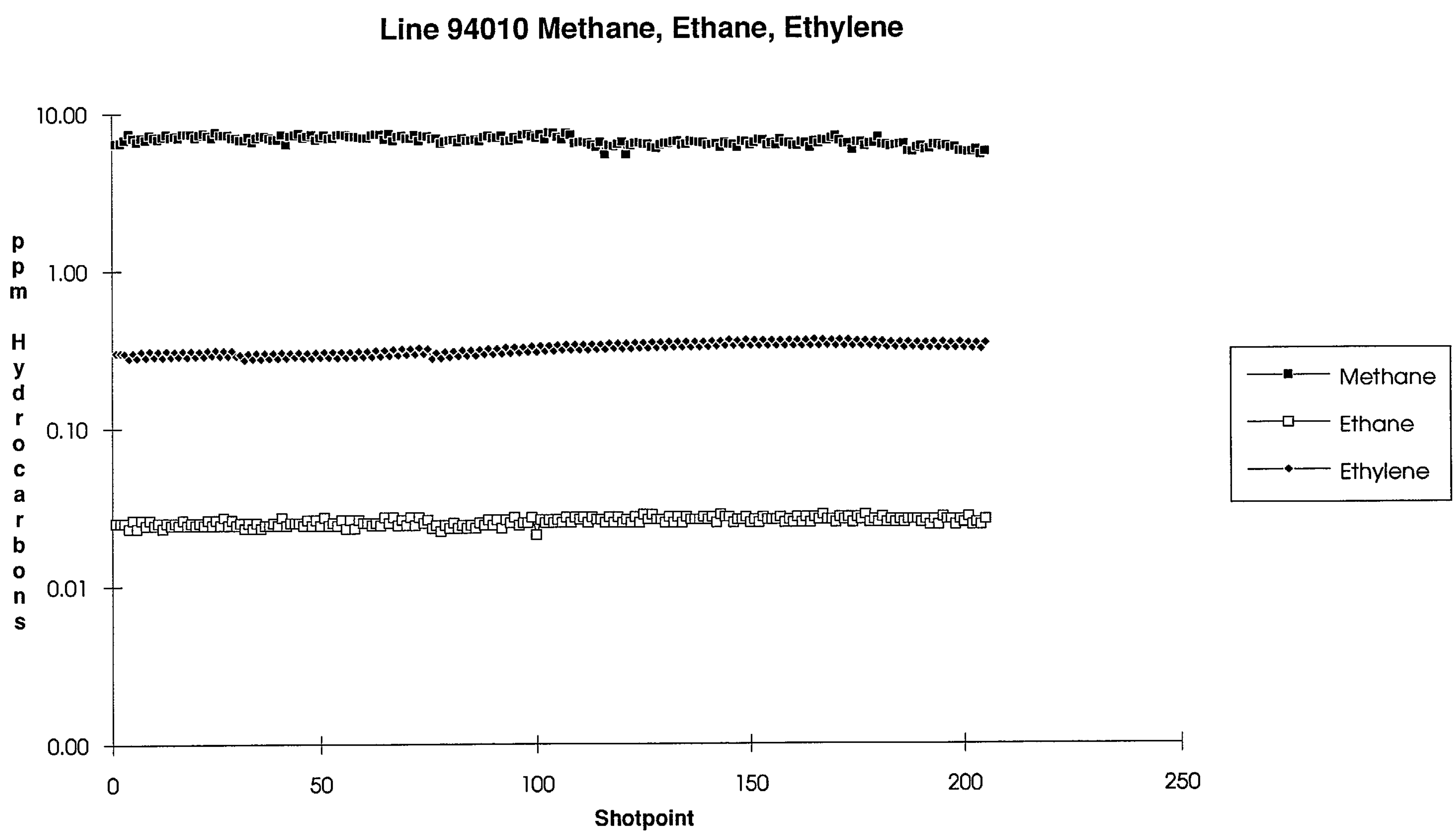
Variations in hydrocarbon values at SP's 29 and 74 caused by gas leakage at the water rotary joint at the winch

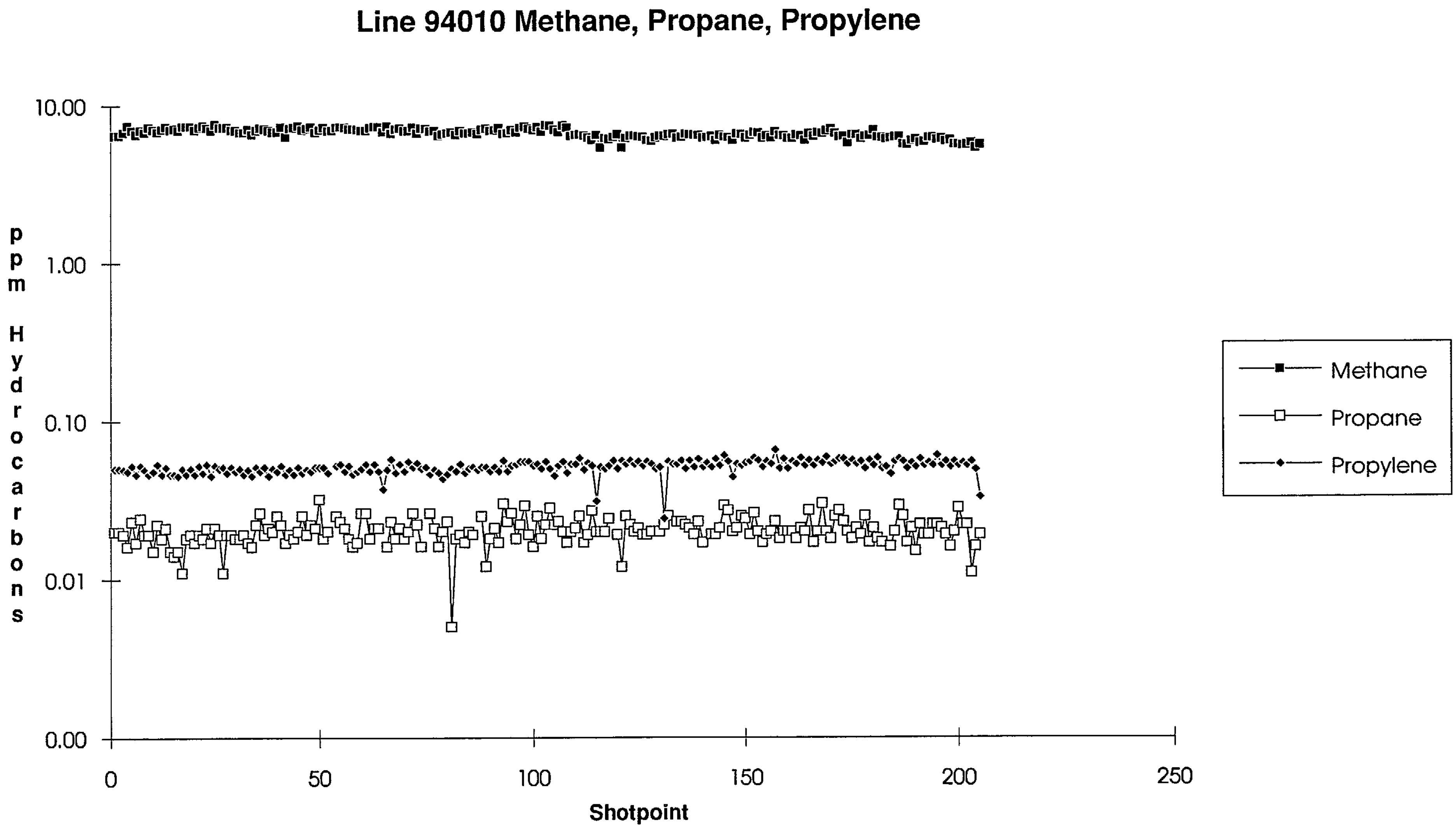
Fish altitude has been calculated thus: Altitude=water depth-fish depth

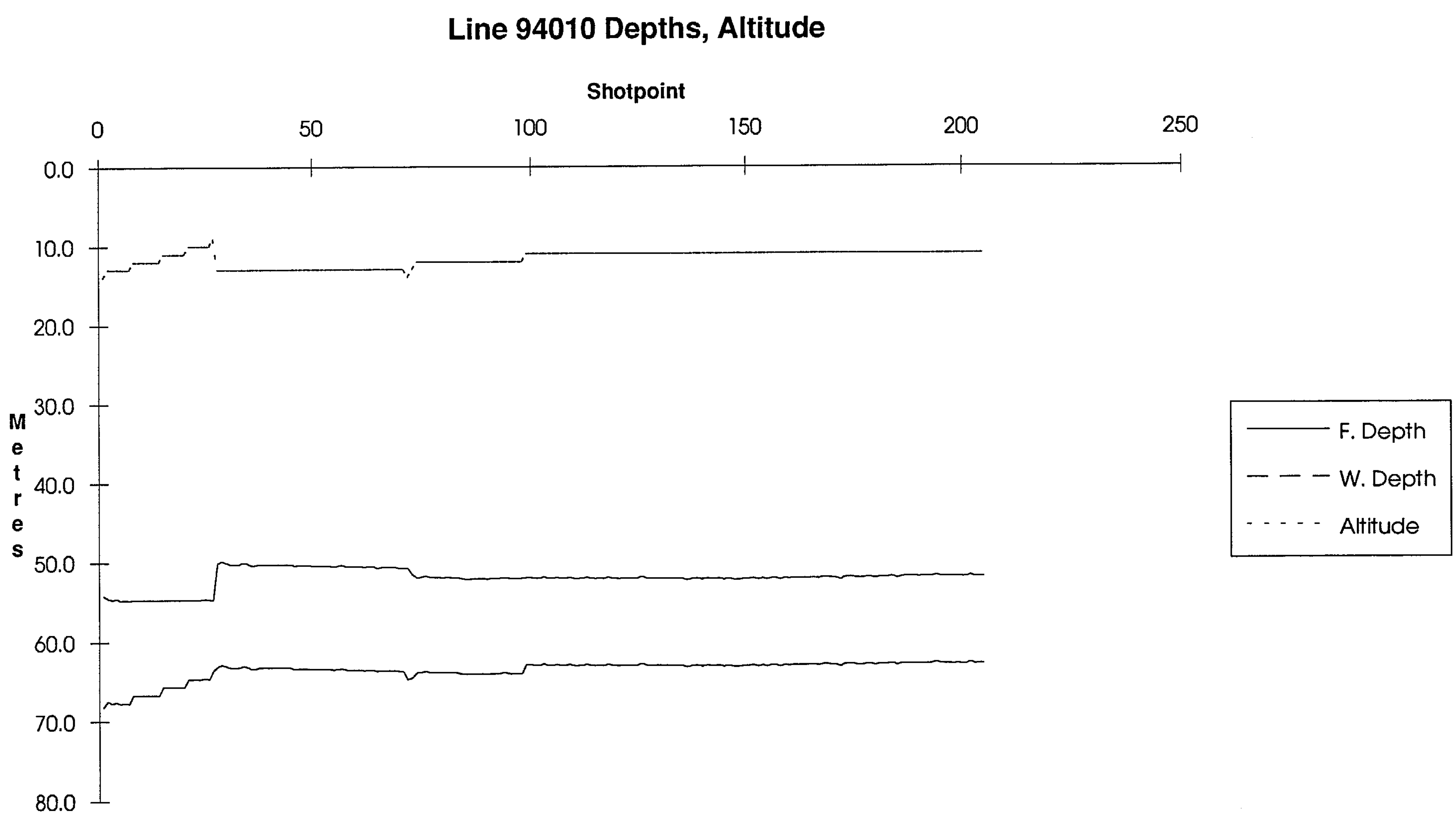
Navigation added to file at post processing stage

Line 94010 THC, Methane




Line 94010 Methane, Ethane, Ethylene
10.00
1.00
0.10
0.01
0.00
ppm Hydrocarbons
0
50
100
150
200
250
Shotpoint
Methane
Ethane
Ethylene


Line 94010 Methane, Propane, Propylene
ppm Hydrocarbons
10.00
1.00
0.10
0.01
0.00
0
50
100
150
200
250
Shotpoint
Methane
Propane
Propylene



Line 94010 Depths, Altitude
Shotpoint
0
50
100
150
200
250
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Metres
F. Depth
W. Depth
Altitude

Line Summary

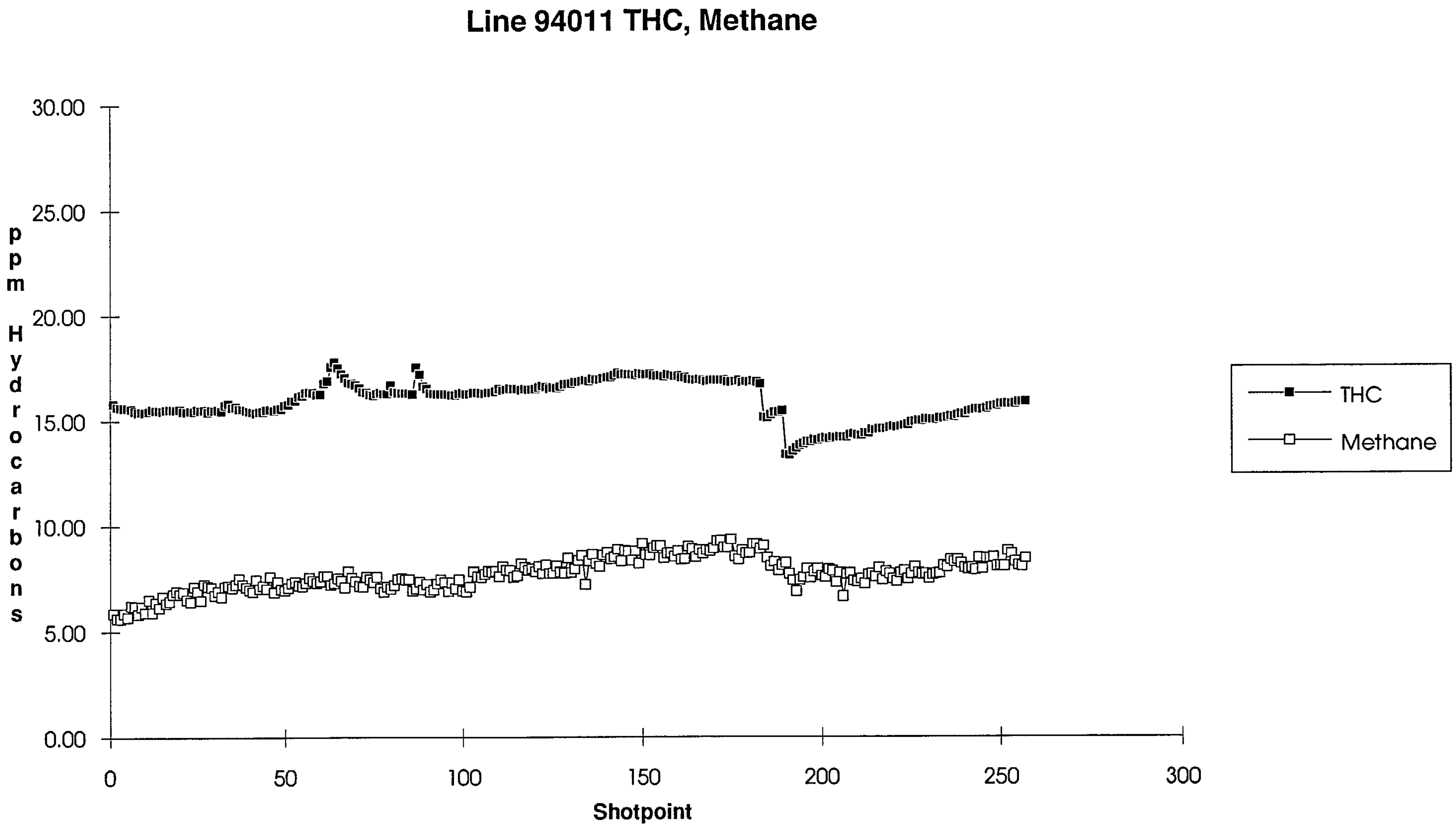
Line Number	94011
No. of Shotpoints	257

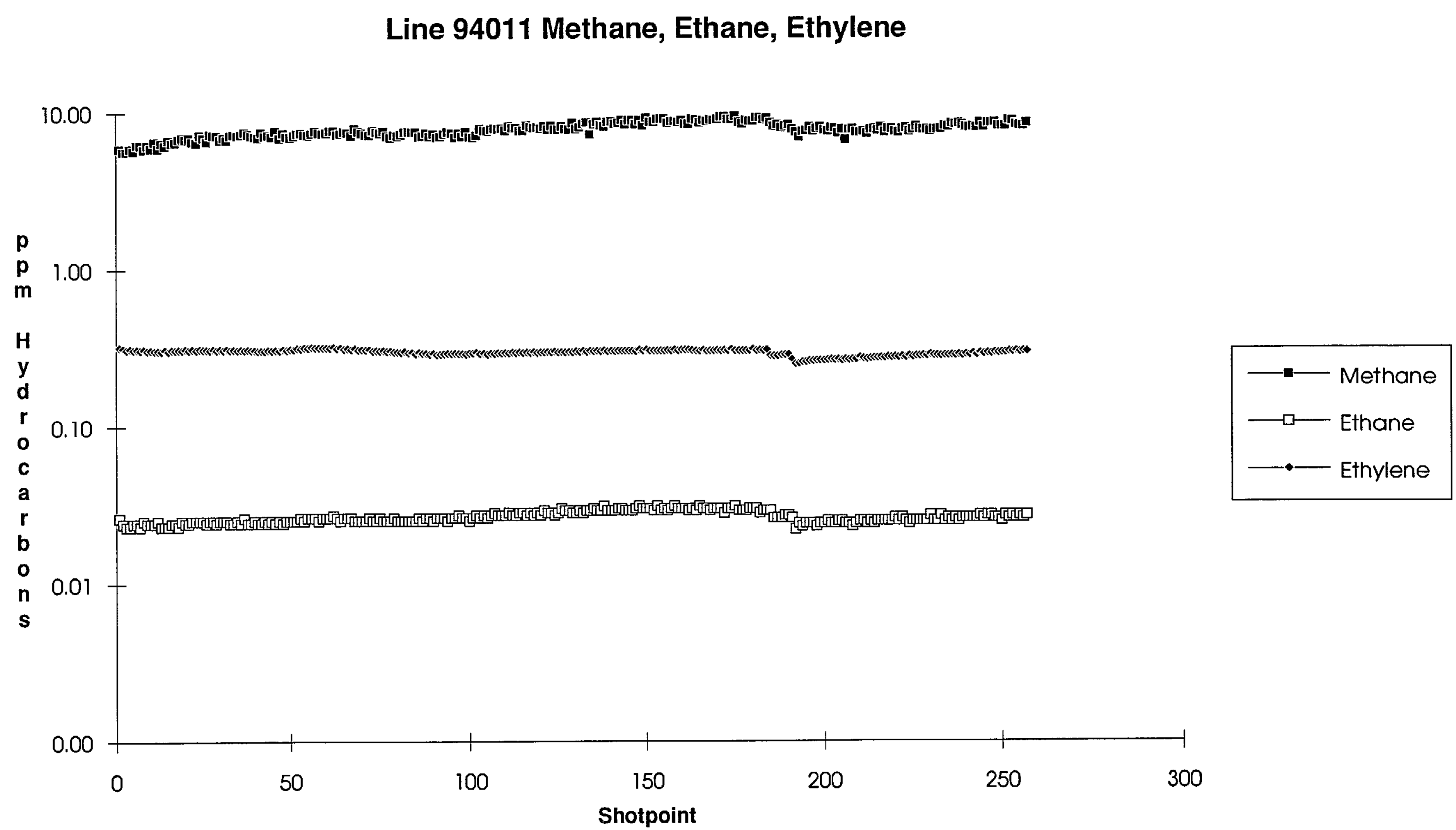
	Shotpoint	Date	Time	Latitude		Longitude	
Start	21	18-Mar-90	09:21:38	10	44.621	134	17.738
End	277	18-Mar-90	17:53:28	10	54.740	134	55.498

	THC	Methane	Ethane	Ethylene	Propane	Propylene	i-Butane	n-Butane	i-Pentane	n-Pentane	i-Hexane	n-Hexane	%Wetness
Mean	15.926	7.683	0.026	0.295	0.025	0.054	0.000	0.000	0.000	0.000	0.000	0.000	0.669
Std. Dev.	0.941	0.771	0.002	0.015	0.009	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.119
Minimum	13.335	5.608	0.022	0.248	0.000	0.030	0.000	0.000	0.000	0.000	0.000	0.000	0.294
Maximum	17.771	9.336	0.031	0.321	0.053	0.068	0.004	0.000	0.000	0.000	0.000	0.000	0.991

	Cond.	Temp.	F. Depth	W.Depth	Altitude
Mean	57.777	25.760	48.376	59.983	11.607
Std. Dev.	0.167	0.175	3.492	4.165	1.342
Minimum	57.570	25.540	42.500	51.800	9.000
Maximum	58.280	26.230	51.100	63.800	13.000

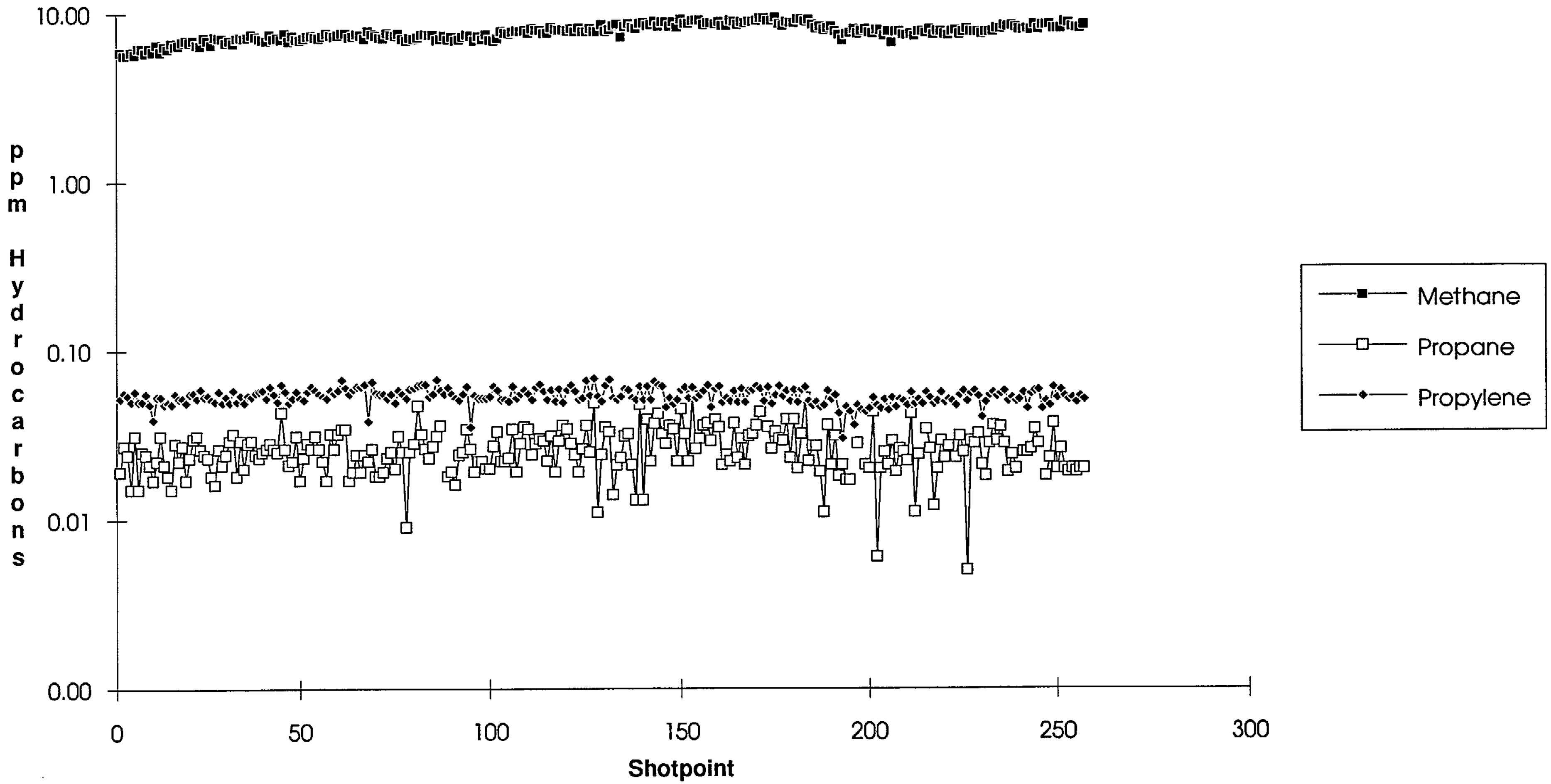
Notes
Variations in hydrocarbon values at SP's 204 and 210 caused by gas leakage at the water rotary joint at the winch
No hydrocarbon anomalies, but a trend towards higher methane concentrations at the end of line (eastwards).
Fish altitude has been calculated thus: Altitude=water depth-fish depth
Navigation added to file at post processing stage

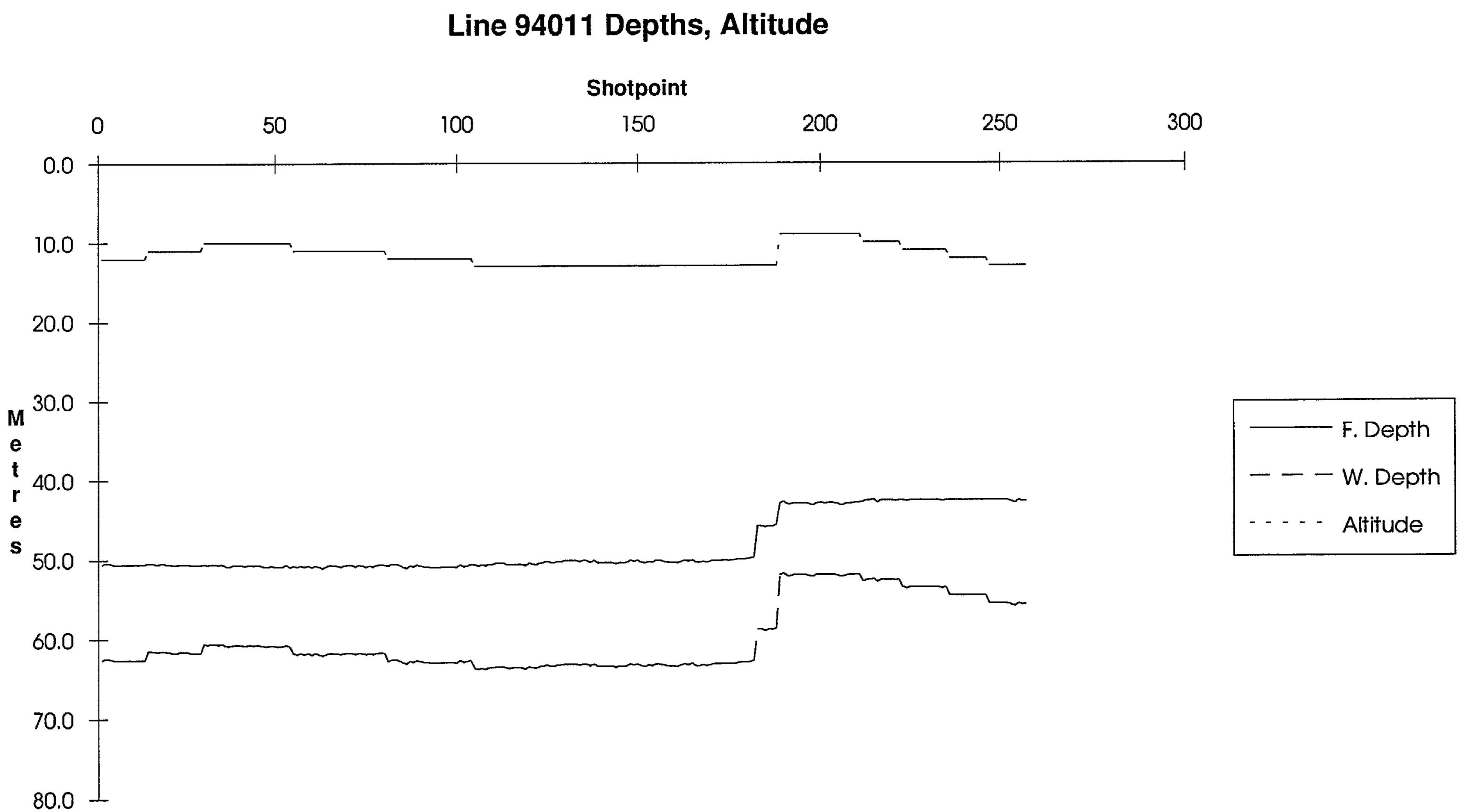

Line 94011 THC, Methane
ppm Hydrocarbons
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
50
100
150
200
250
300
Shotpoint
THC
Methane



Line 94011 Methane, Ethane, Ethylene
ppm Hydrocarbons
10.00
1.00
0.10
0.01
0.00
0
50
100
150
200
250
300
Shotpoint
Methane
Ethane
Ethylene

Line 94011 Methane, Propane, Propylene





Line 94011 Depths, Altitude
Shotpoint
0
50
100
150
200
250
300
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Metres
F. Depth
W. Depth
Altitude

Line Summary

Line Number	94012
No. of Shotpoints	393

	Shotpoint	Date	Time	Latitude		Longitude	
Start	1	18-Mar-90	17:55:27	10	54.850	134	55.594
End	397	19-Mar-90	06:59:26	11	39.301	135	39.189

	THC	Methane	Ethane	Ethylene	Propane	Propylene	i-Butane	n-Butane	i-Pentane	n-Pentane	i-Hexane	n-Hexane	%Wetness
Mean	15.600	6.203	0.022	0.309	0.022	0.056	0.000	0.000	0.000	0.000	0.000	0.000	0.712
Std. Dev.	1.925	0.757	0.002	0.065	0.008	0.008	0.001	0.002	0.000	0.000	0.000	0.000	0.148
Minimum	12.006	4.428	0.016	0.204	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.319
Maximum	22.370	8.868	0.028	0.450	0.046	0.077	0.013	0.021	0.000	0.000	0.000	0.000	1.193

	Cond.	Temp.	F. Depth	W.Depth	Altitude
Mean	58.937	26.827	32.330	44.317	11.987
Std. Dev.	0.765	0.791	9.188	8.564	1.841
Minimum	57.690	25.630	9.500	28.600	8.000
Maximum	60.250	28.030	42.800	56.600	21.000

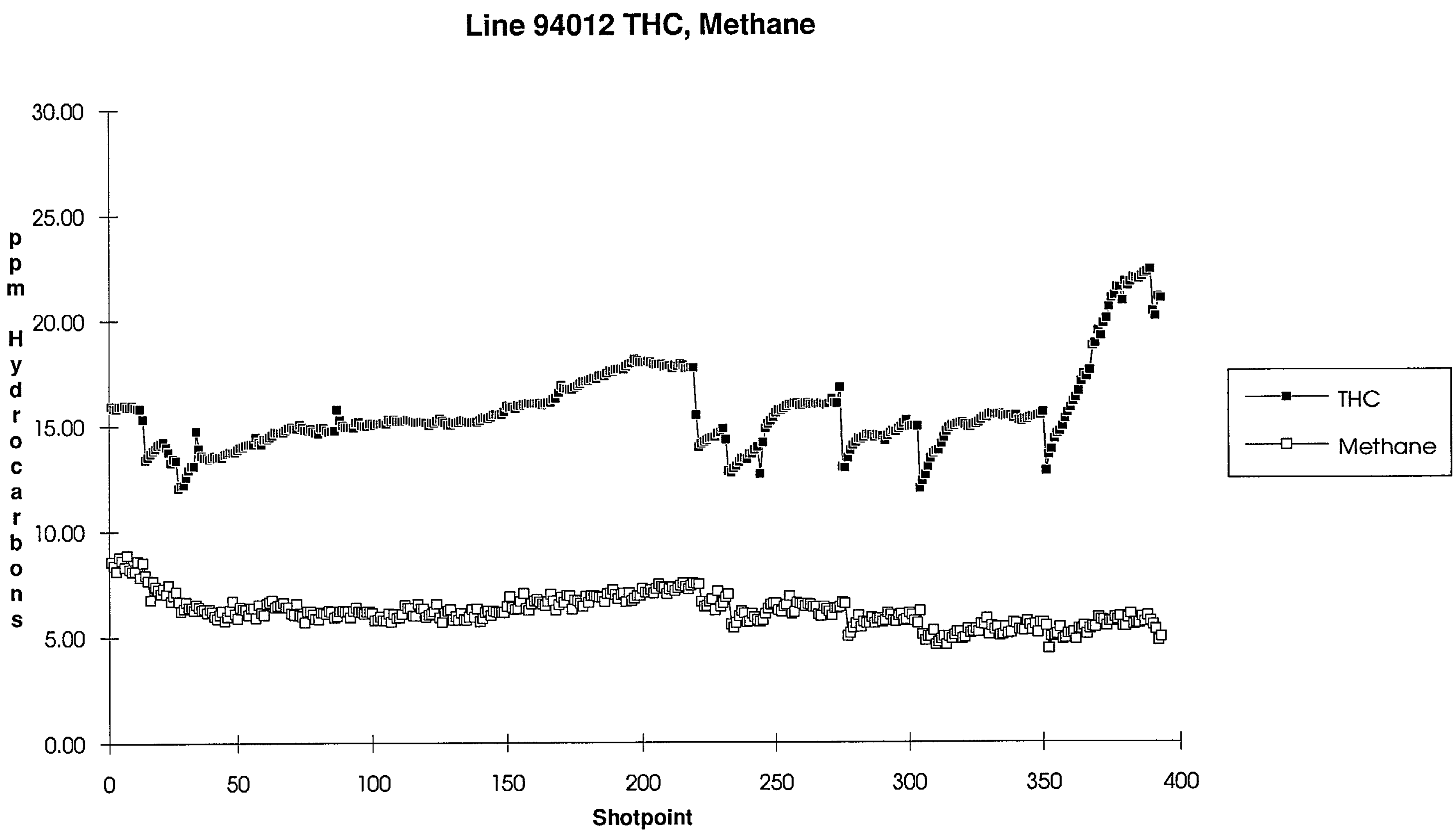
Notes

Variations in hydrocarbon values at SP's 17,26,29,210,225,235,248,280,310,356 and 399 caused by gas leakage at the water rotary joint at the winch

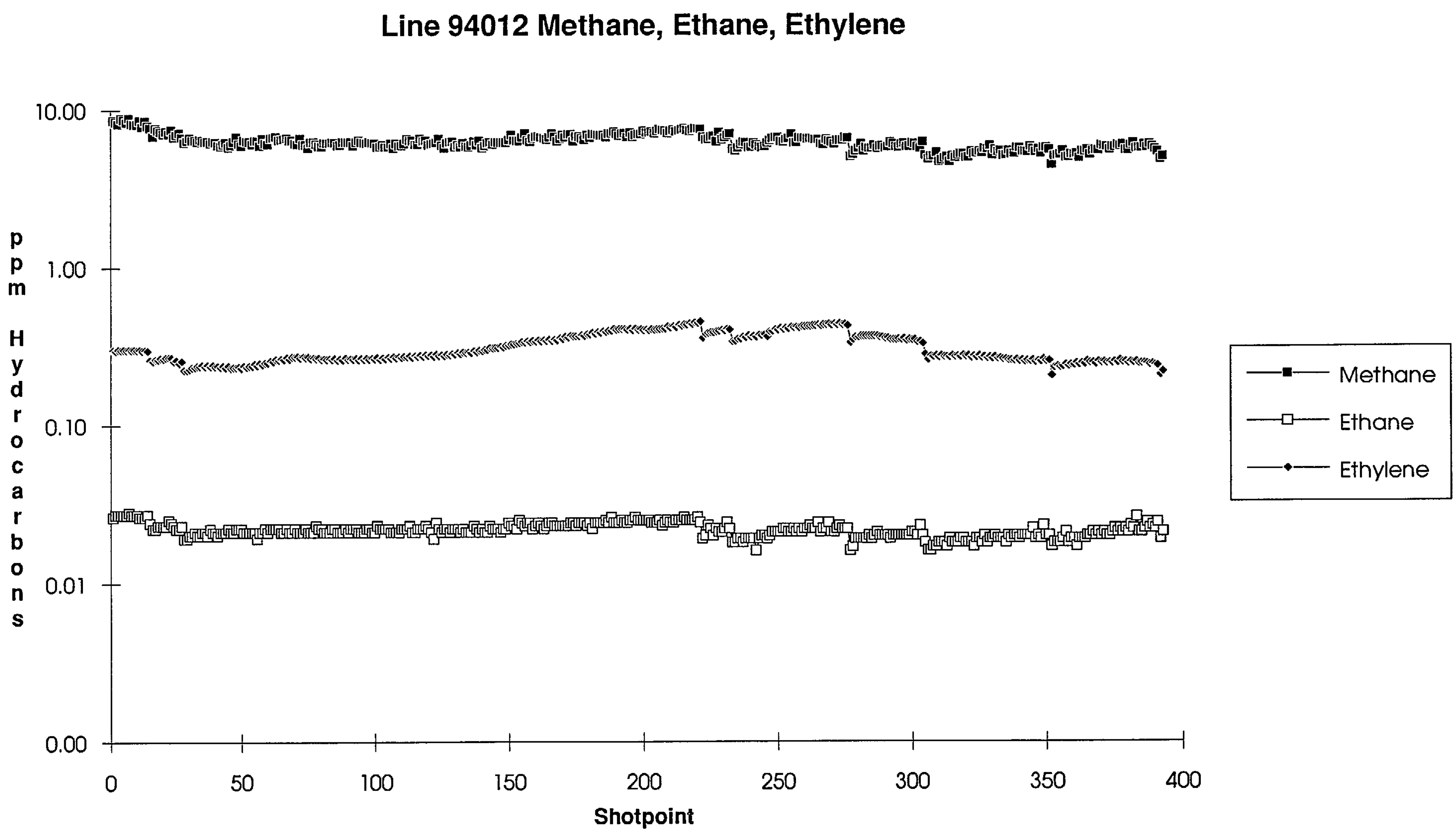
No hydrocarbon anomalies, but a trend to lower methane concentrations toward the end of line. Apparent THC anomaly at end of line.

Fish altitude has been calculated thus: Altitude=water depth-fish depth

Navigation added to file at post processing stage

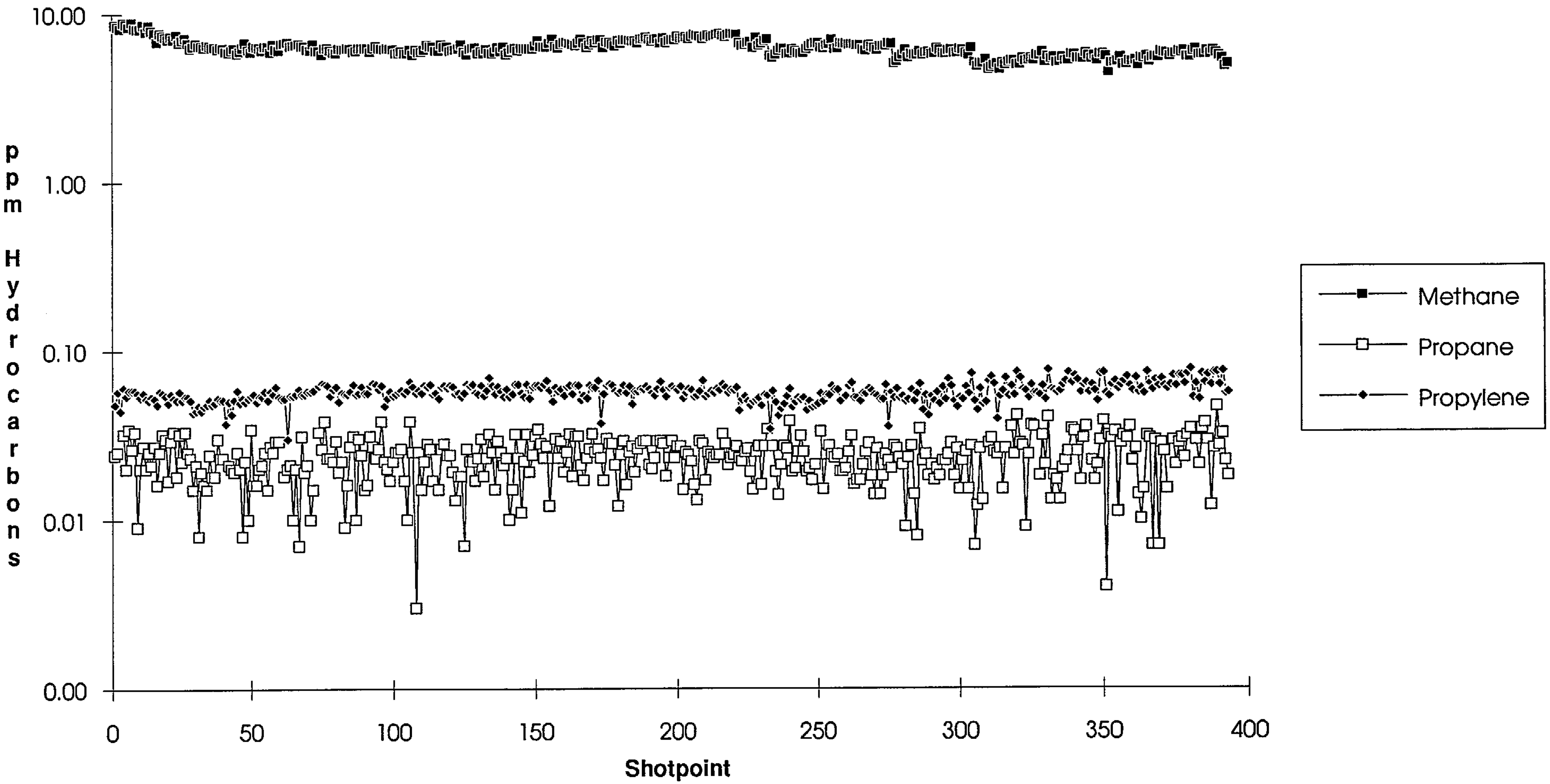


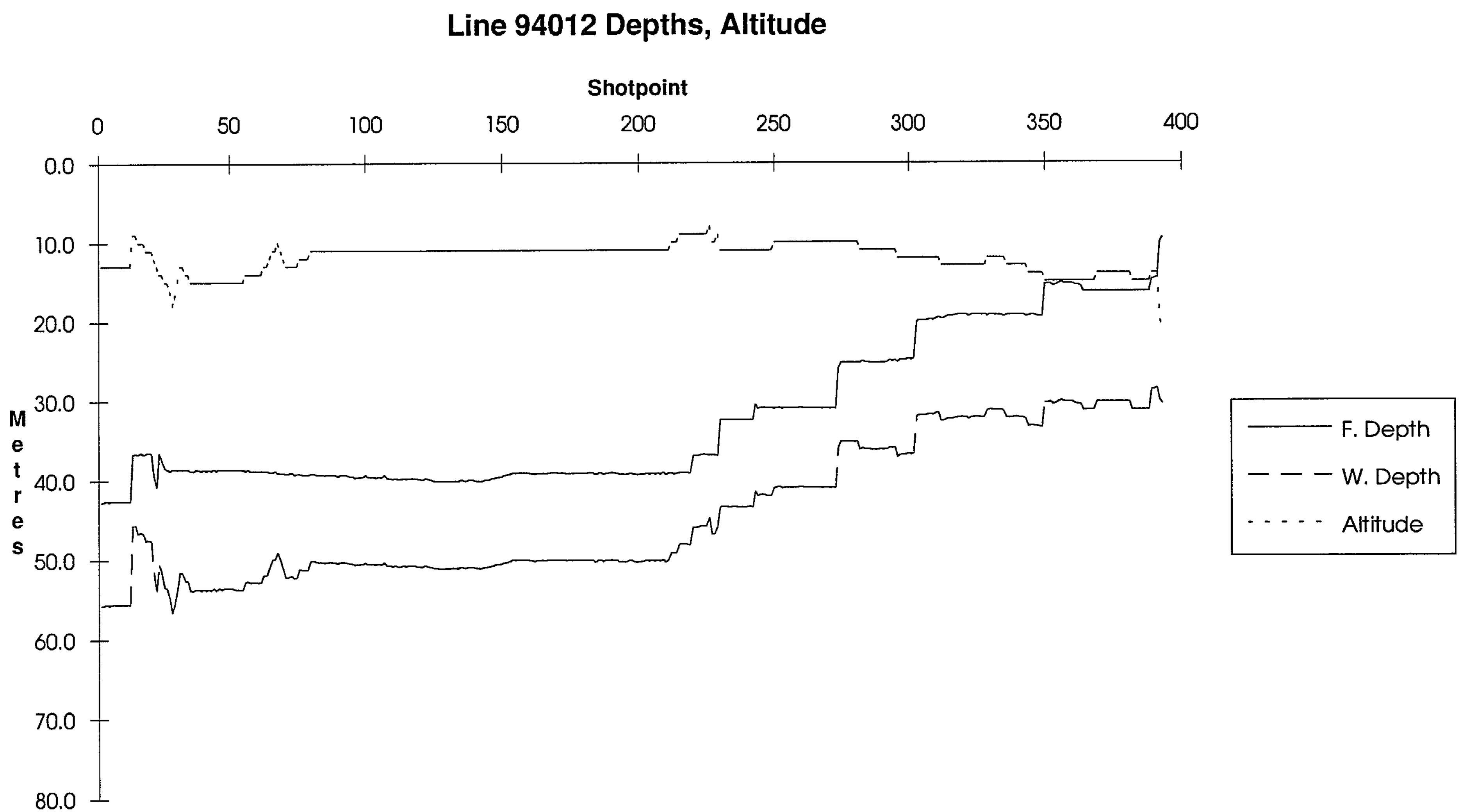
Line 94012 THC, Methane
ppm Hydrocarbons
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
50
100
150
200
250
300
350
400
Shotpoint
THC
Methane



Line 94012 Methane, Ethane, Ethylene
10.00
1.00
0.10
0.01
0.00
ppm Hydrocarbons
0
50
100
150
200
250
300
350
400
Shotpoint
Methane
Ethane
Ethylene

Line 94012 Methane, Propane, Propylene




Line 94012 Depths, Altitude
Shotpoint
0
50
100
150
200
250
300
350
400
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Metres
F. Depth
W. Depth
Altitude

Line Summary

Line Number	94013
No. of Shotpoints	733

	Shotpoint	Date	Time	Latitude		Longitude	
Start	1	19-Mar-90	21:17:56	11	54.795	135	21.562
End	733	20-Mar-90	21:49:34	10	40.037	136	40.730

	THC	Methane	Ethane	Ethylene	Propane	Propylene	i-Butane	n-Butane	i-Pentane	n-Pentane	i-Hexane	n-Hexane	%Wetness
Mean	22.273	5.679	0.019	0.231	0.018	0.060	0.000	0.000	0.000	0.000	0.000	0.000	0.640
Std. Dev.	3.360	0.469	0.001	0.032	0.005	0.006	0.001	0.001	0.000	0.000	0.000	0.000	0.128
Minimum	16.015	3.658	0.013	0.149	0.007	0.042	0.000	0.000	0.000	0.000	0.000	0.000	0.266
Maximum	28.359	7.114	0.024	0.328	0.037	0.075	0.008	0.021	0.000	0.000	0.000	0.000	1.109

	Cond.	Temp.	F. Depth	W.Depth	Altitude
Mean	58.605	25.937	23.402	36.198	12.798
Std. Dev.	0.756	3.689	9.023	8.682	1.176
Minimum	55.460	17.060	8.900	22.900	10.000
Maximum	60.640	35.340	44.900	57.700	16.000

Notes

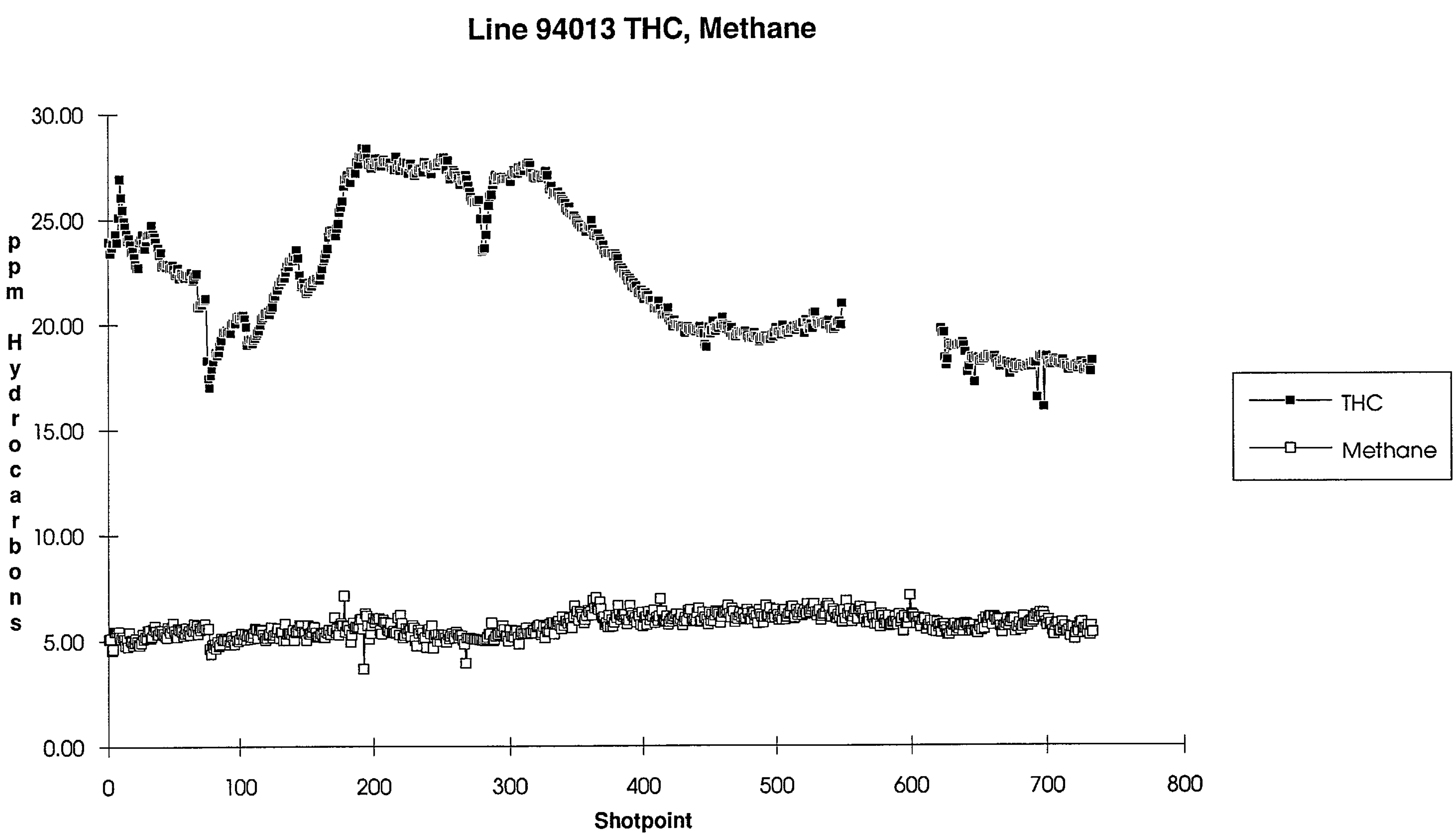
Variations in hydrocarbon values at SP's 23,76,208,500,635,665 and 678 caused by gas leakage at the water rotary joint at the winch

Break in THC data collection from SP550 to 621. Break in propane data collection from SP163 to 199. Several breaks in conductivity and temperature data collection.

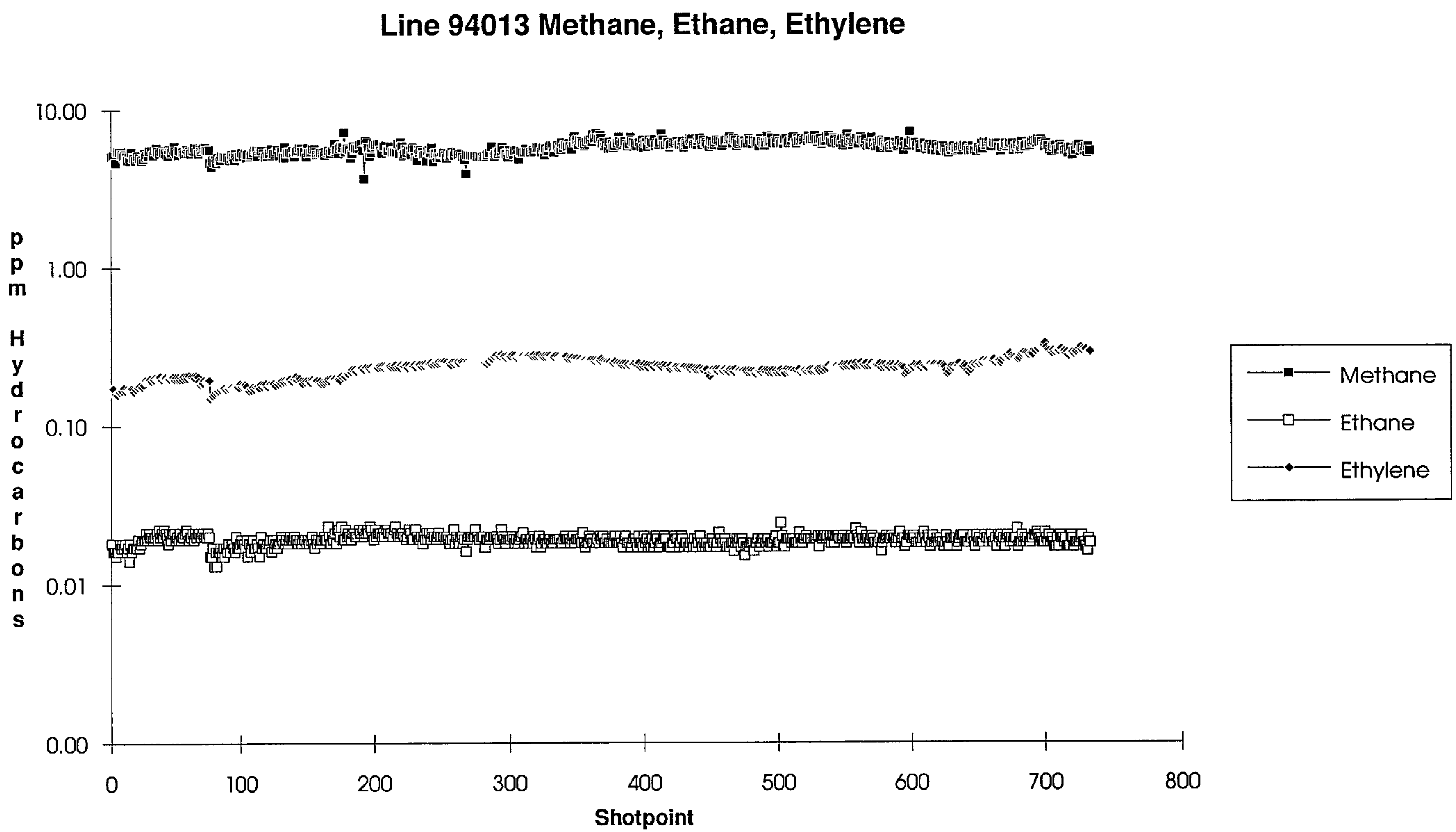
Fish altitude has been calculated thus: Altitude=water depth-fish depth

Navigation added to file at post processing stage

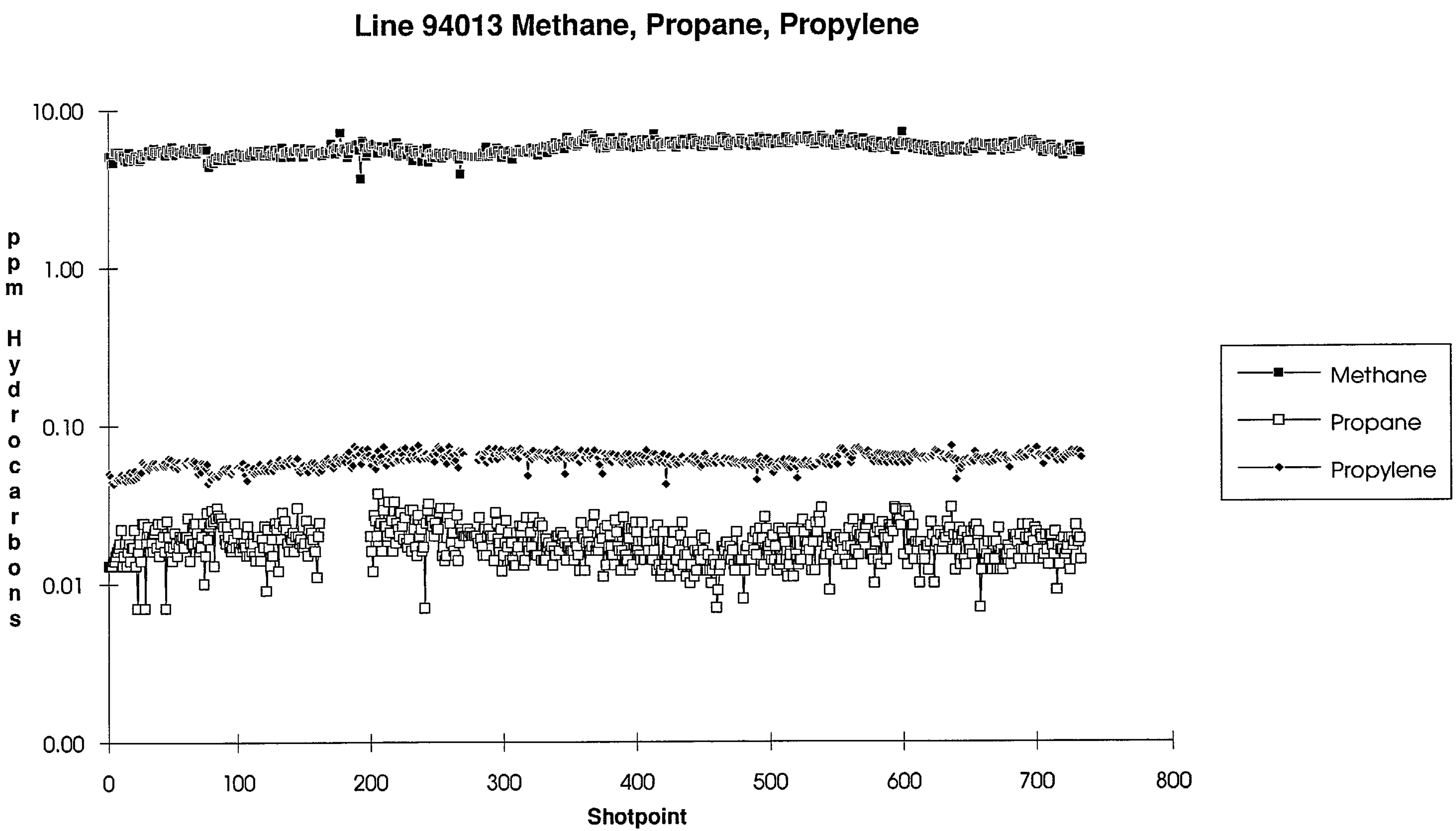
No hydrocarbon anomalies



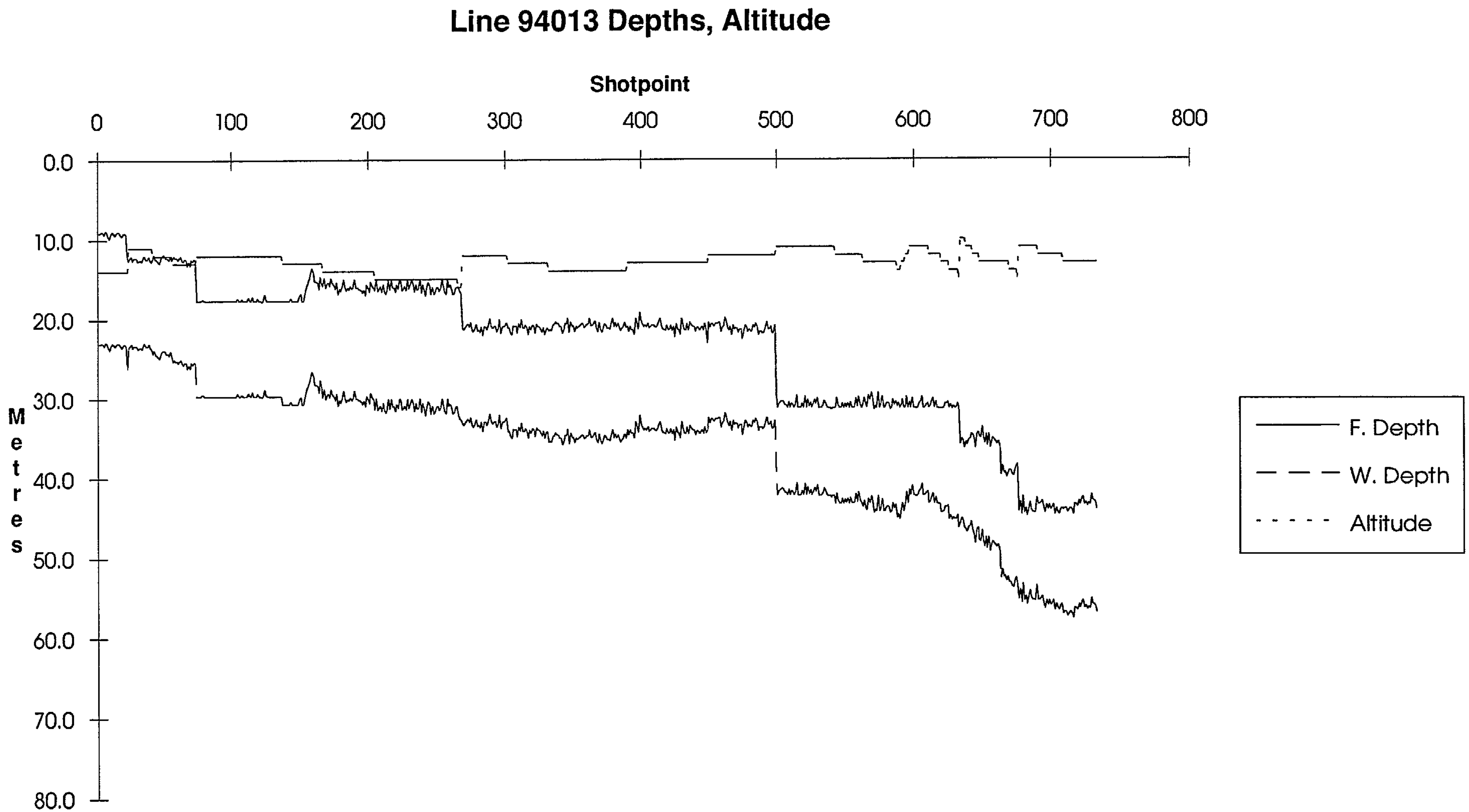
Line 94013 THC, Methane
ppm Hydrocarbons
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
100
200
300
400
500
600
700
800
Shotpoint
THC
Methane



Line 94013 Methane, Ethane, Ethylene
10.00
1.00
0.10
0.01
0.00
ppm Hydrocarbons
0
100
200
300
400
500
600
700
800
Shotpoint
Methane
Ethane
Ethylene



Line 94013 Methane, Propane, Propylene
10.00
1.00
0.10
0.01
0.00
ppm Hydrocarbons
0
100
200
300
400
500
600
700
800
Shotpoint
Methane
Propane
Propylene



Line 94013 Depths, Altitude
Shotpoint
0
100
200
300
400
500
600
700
800
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Metres
F. Depth
W. Depth
Altitude

Line Summary

Line Number	94014
No. of Shotpoints	875

	Shotpoint	Date	Time	Latitude		Longitude	
Start	21	21-Mar-90	04:12:12	10	40.165	136	44.354
End	106	22-Mar-90	16:34:03	10	43.830	134	48.402

	THC	Methane	Ethane	Ethylene	Propane	Propylene	i-Butane	n-Butane	i-Pentane	n-Pentane	i-Hexane	n-Hexane	%Wetness
Mean	15.464	5.474	0.017	0.230	0.018	0.057	0.000	0.000	0.000	0.000	0.000	0.000	0.632
Std. Dev.	0.838	0.436	0.001	0.024	0.005	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.136
Minimum	12.567	4.580	0.011	0.159	0.005	0.037	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	18.094	6.956	0.026	0.285	0.042	0.077	0.004	0.005	0.000	0.000	0.000	0.000	1.141

	Cond.	Temp.	F. Depth	W.Depth	Altitude
Mean	58.980	32.598	40.032	52.752	14.389
Std. Dev.	0.968	3.067	2.468	2.671	1.663
Minimum	57.860	26.550	22.800	35.800	12.000
Maximum	61.160	39.100	45.400	65.000	25.000

Notes

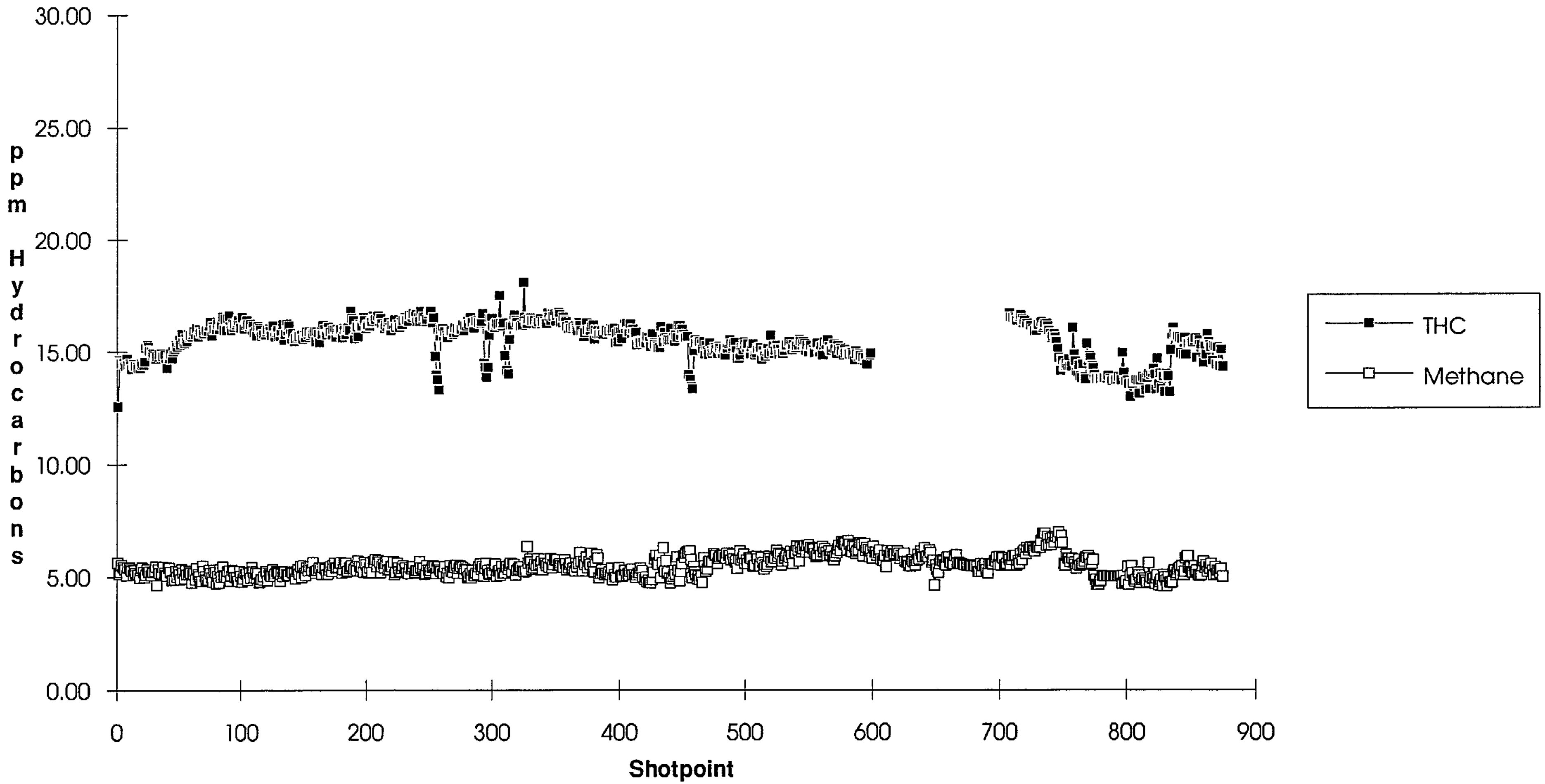
Break in THC data collection from SP 619 to 660. Break in ethane, ethylene, propane, propylene data collection from SP 703 to 765.

No hydrocarbon anomalies

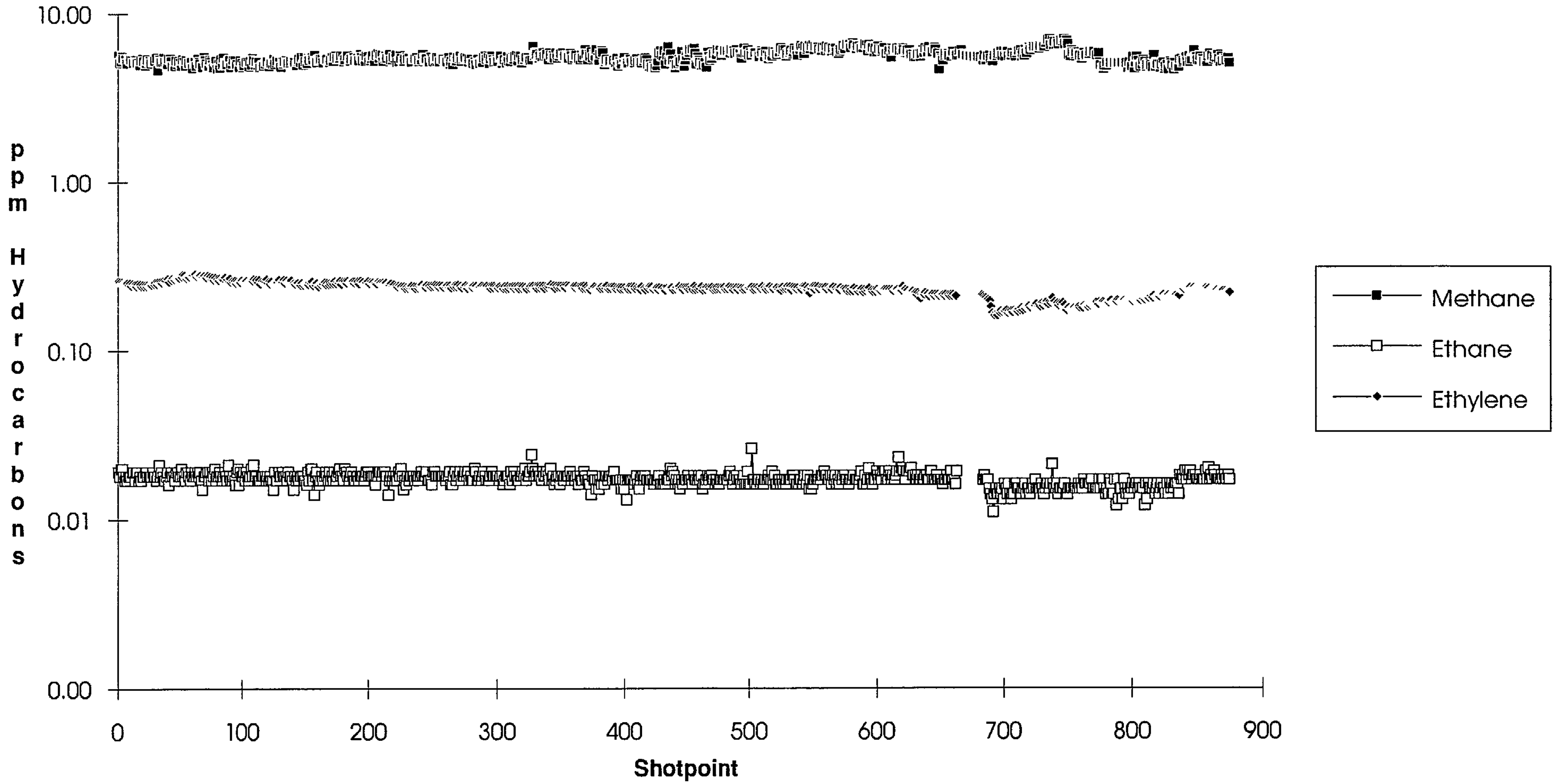
Fish altitude has been calculated thus: Altitude=water depth-fish depth

Several breaks in conductivity and temperature data collection, data considered unreliable.

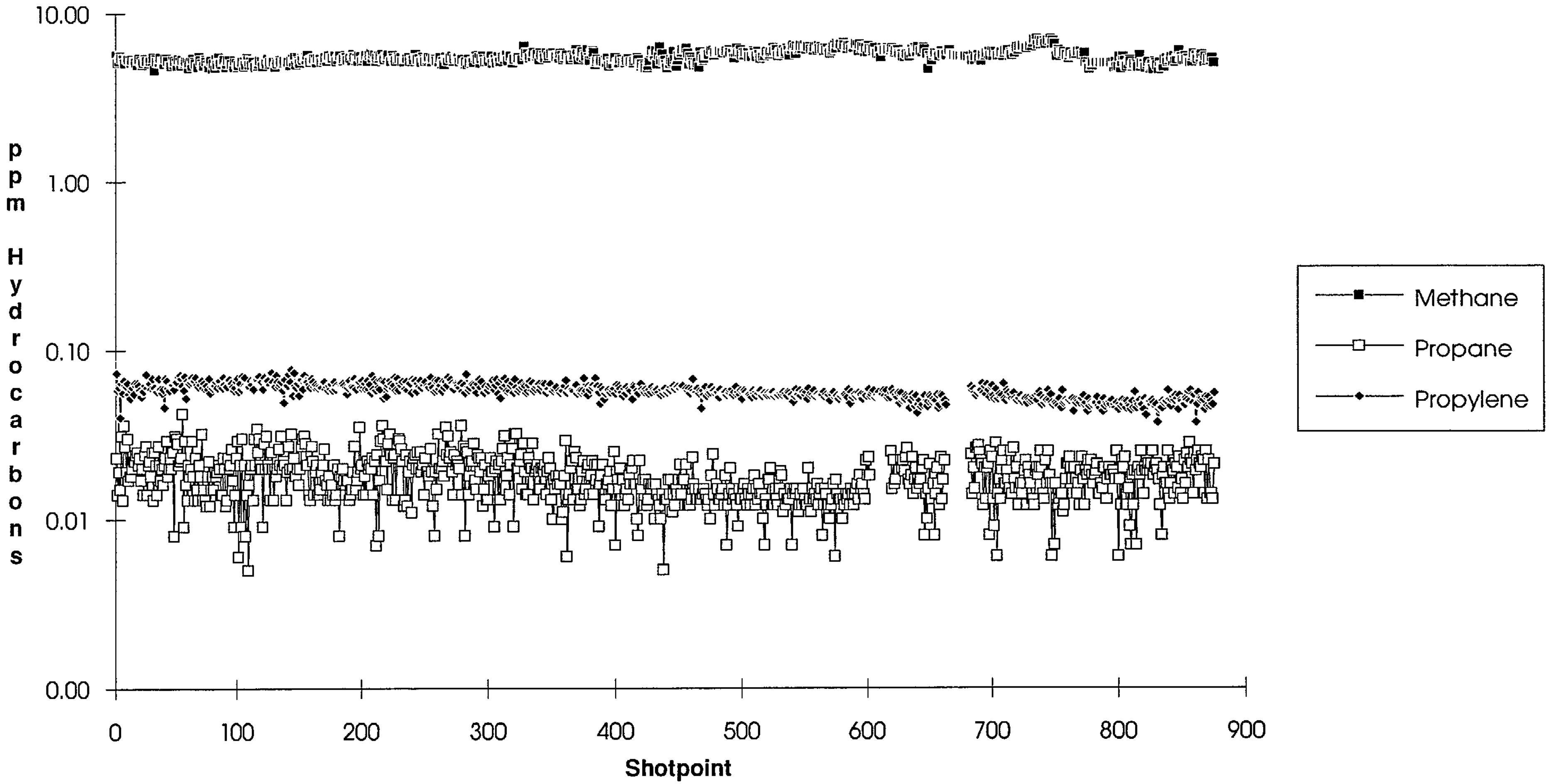
Line 94014 THC, Methane

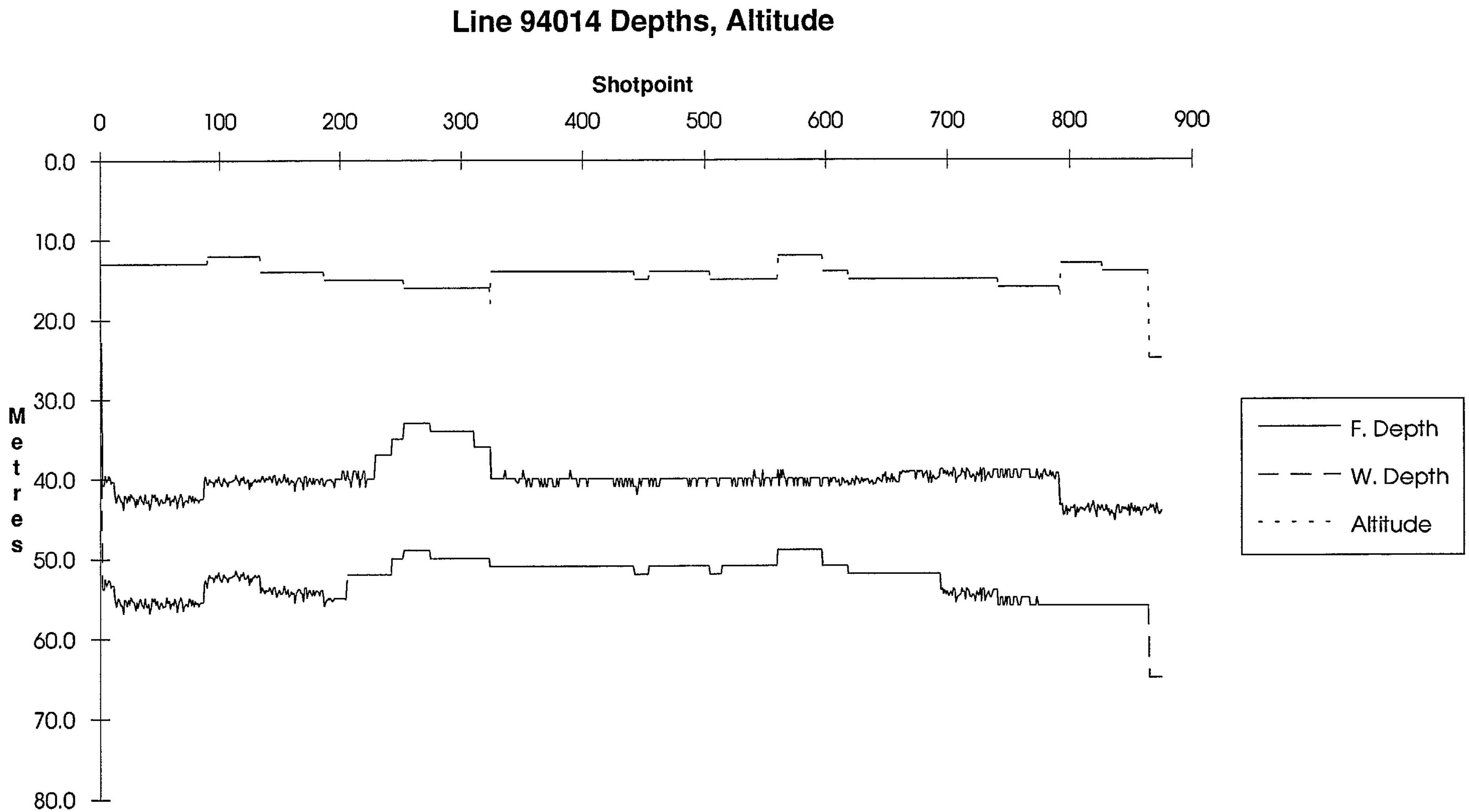


Line 94014 Methane, Ethane, Ethylene



Line 94014 Methane, Propane, Propylene





Line 94014 Depths, Altitude
Shotpoint
0
100
200
300
400
500
600
700
800
900
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Metres
F. Depth
W. Depth
Altitude

Line Summary

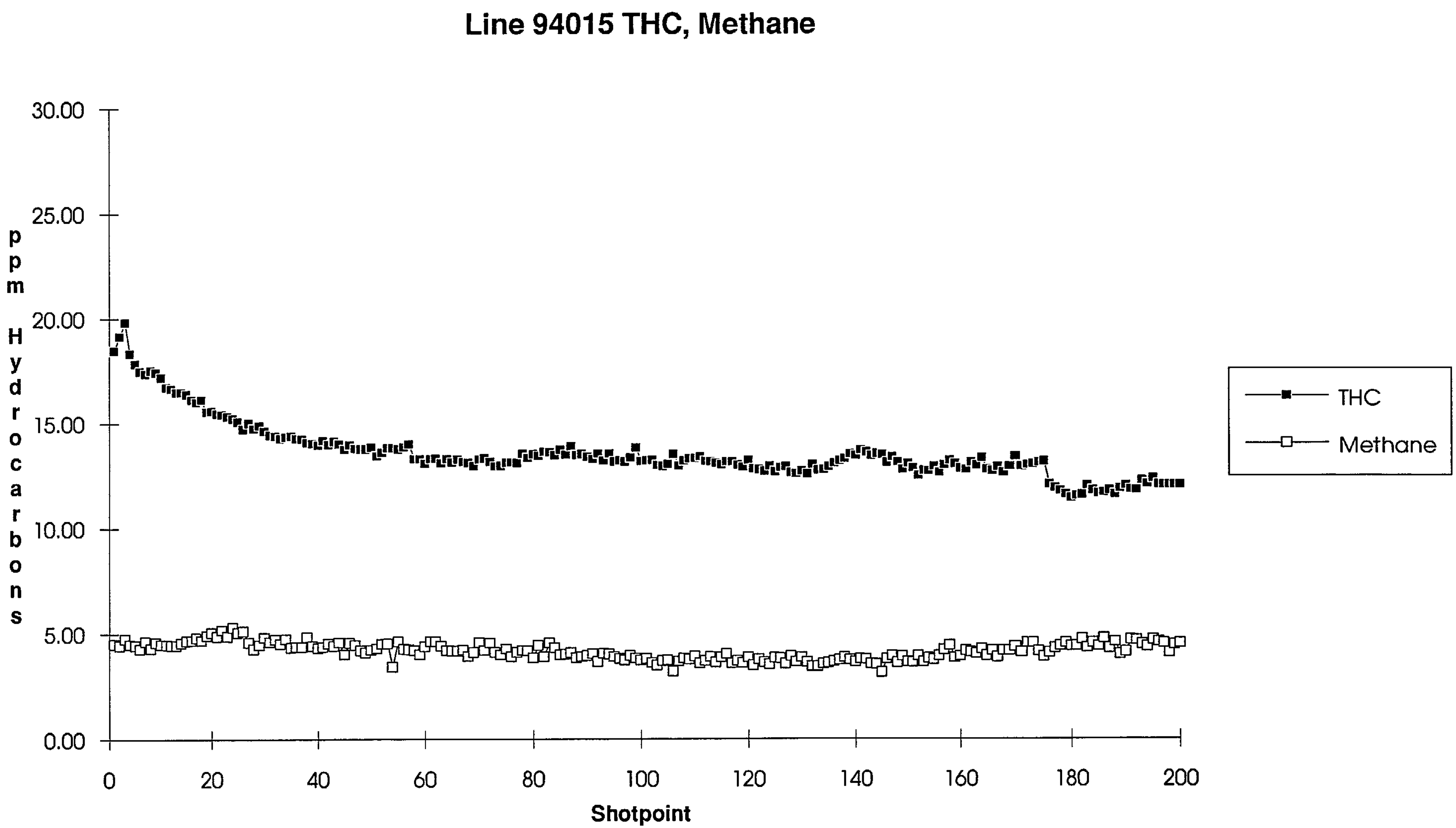
Line Number	94015
No. of Shotpoints	200

	Shotpoint	Date	Time	Latitude		Longitude	
Start	1	22-Mar-90	21:08:23	10	53.990	134	51.001
End	200	23-Mar-90	03:48:50	10	27.451	134	55.366

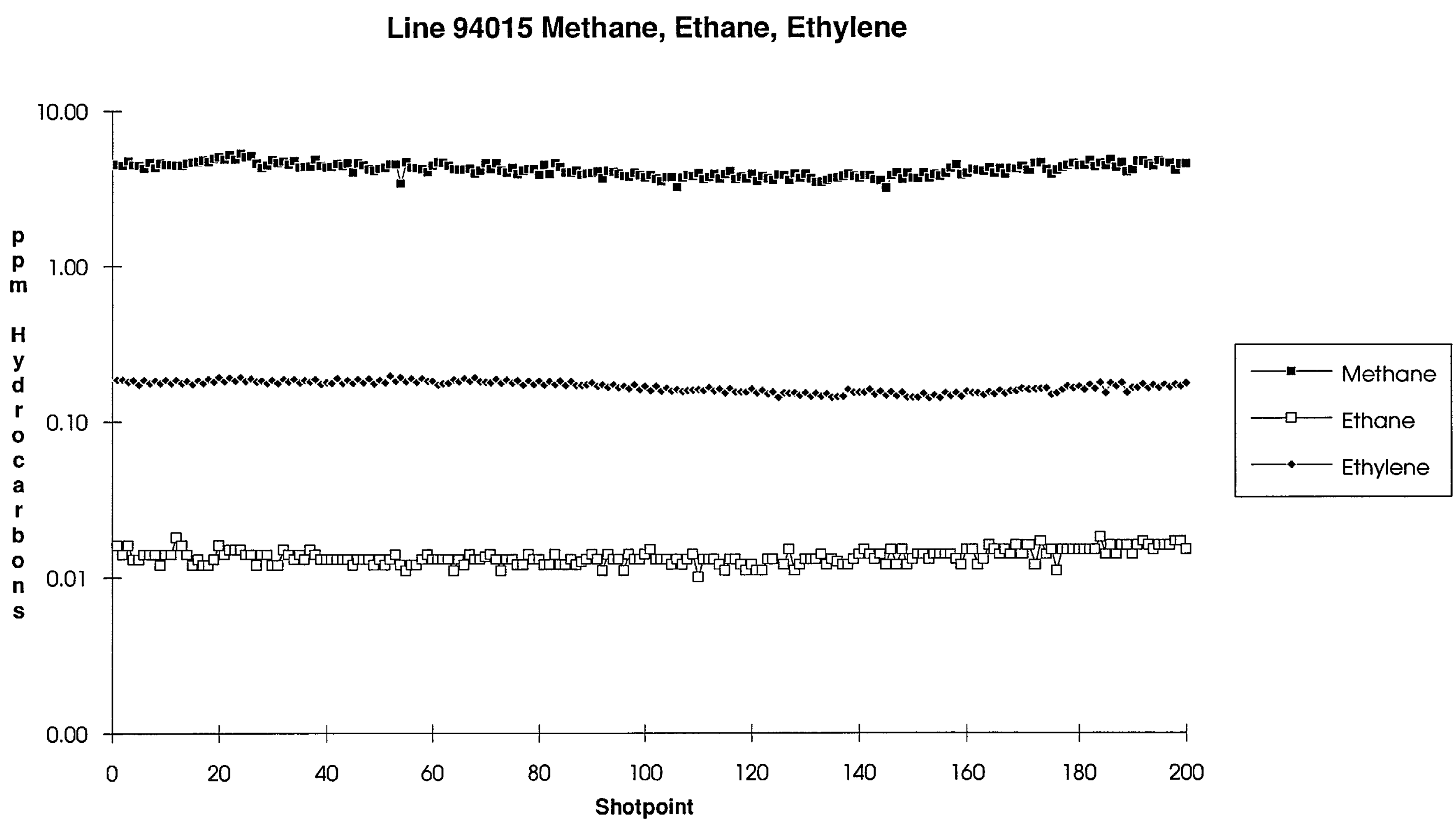
	THC	Methane	Ethane	Ethylene	Propane	Propylene	i-Butane	n-Butane	i-Pentane	n-Pentane	i-Hexane	n-Hexane	%Wetness
Mean	13.588	4.167	0.013	0.168	0.016	0.040	0.001	0.003	0.000	0.000	0.000	0.000	0.790
Std. Dev.	1.440	0.411	0.002	0.014	0.006	0.003	0.003	0.006	0.000	0.000	0.000	0.000	0.248
Minimum	11.425	3.157	0.000	0.141	0.000	0.030	0.000	0.000	0.000	0.000	0.000	0.000	0.284
Maximum	19.821	5.290	0.018	0.197	0.030	0.050	0.017	0.029	0.000	0.000	0.000	0.000	1.921

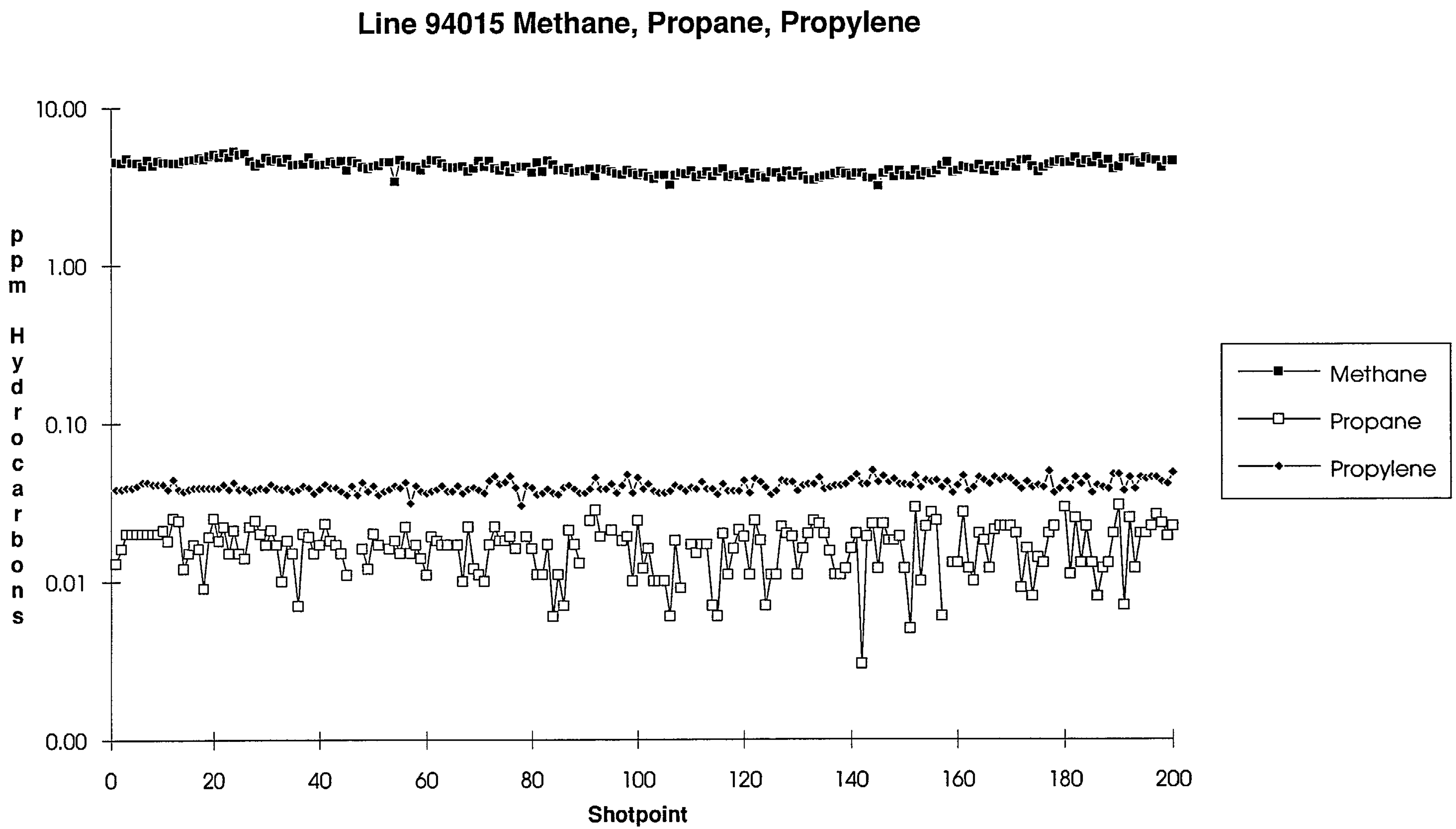
	Cond.	Temp.	F. Depth	W.Depth	Altitude
Mean	58.620	26.780	44.102	53.560	11.955
Std. Dev.	0.509	0.865	1.121	2.684	2.113
Minimum	57.750	25.490	39.400	52.000	8.000
Maximum	59.310	30.070	48.300	62.000	20.000

Notes
No hydrocarbon anomalies
Fish altitude has been calculated thus: Altitude=water depth-fish depth



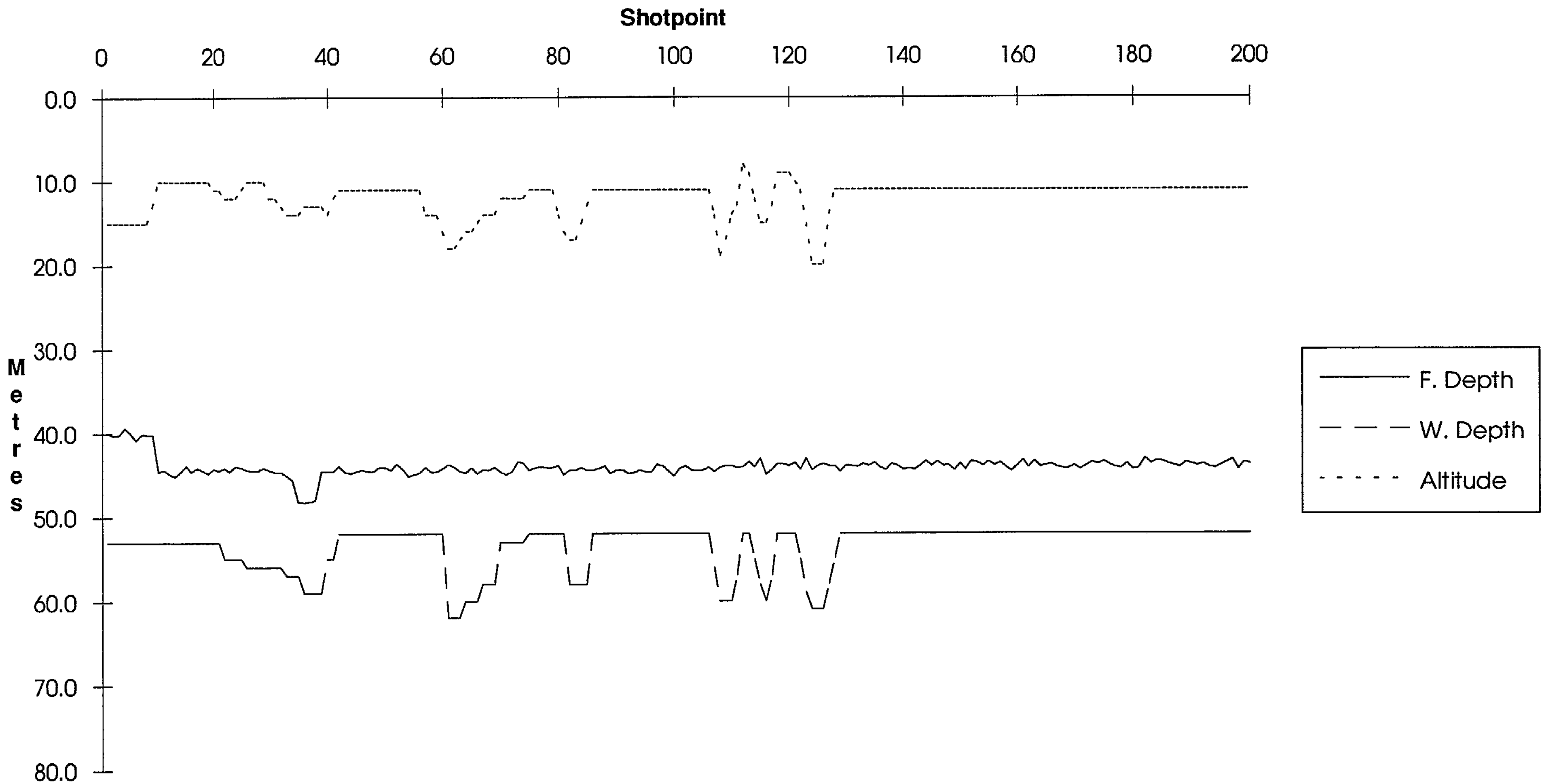
Line 94015 THC, Methane
30.00
25.00
20.00
15.00
10.00
5.00
0.00
ppm Hydrocarbons
0
20
40
60
80
100
120
140
160
180
200
Shotpoint
THC
Methane


Line 94015 Methane, Ethane, Ethylene
10.00
1.00
0.10
0.01
0.00
ppm Hydrocarbons
0
20
40
60
80
100
120
140
160
180
200
Shotpoint
Methane
Ethane
Ethylene



Line 94015 Methane, Propane, Propylene
10.00
1.00
0.10
0.01
0.00
ppm Hydrocarbons
0
20
40
60
80
100
120
140
160
180
200
Shotpoint
Methane
Propane
Propylene

Line 94015 Depths, Altitude



Line Summary

Line Number	94016
No. of Shotpoints	257

	Shotpoint	Date	Time	Latitude		Longitude	
Start	24	23-Mar-90	10:29:00	10	44.664	134	51.729
End	281	23-Mar-90	19:12:30	10	35.331	134	16.456

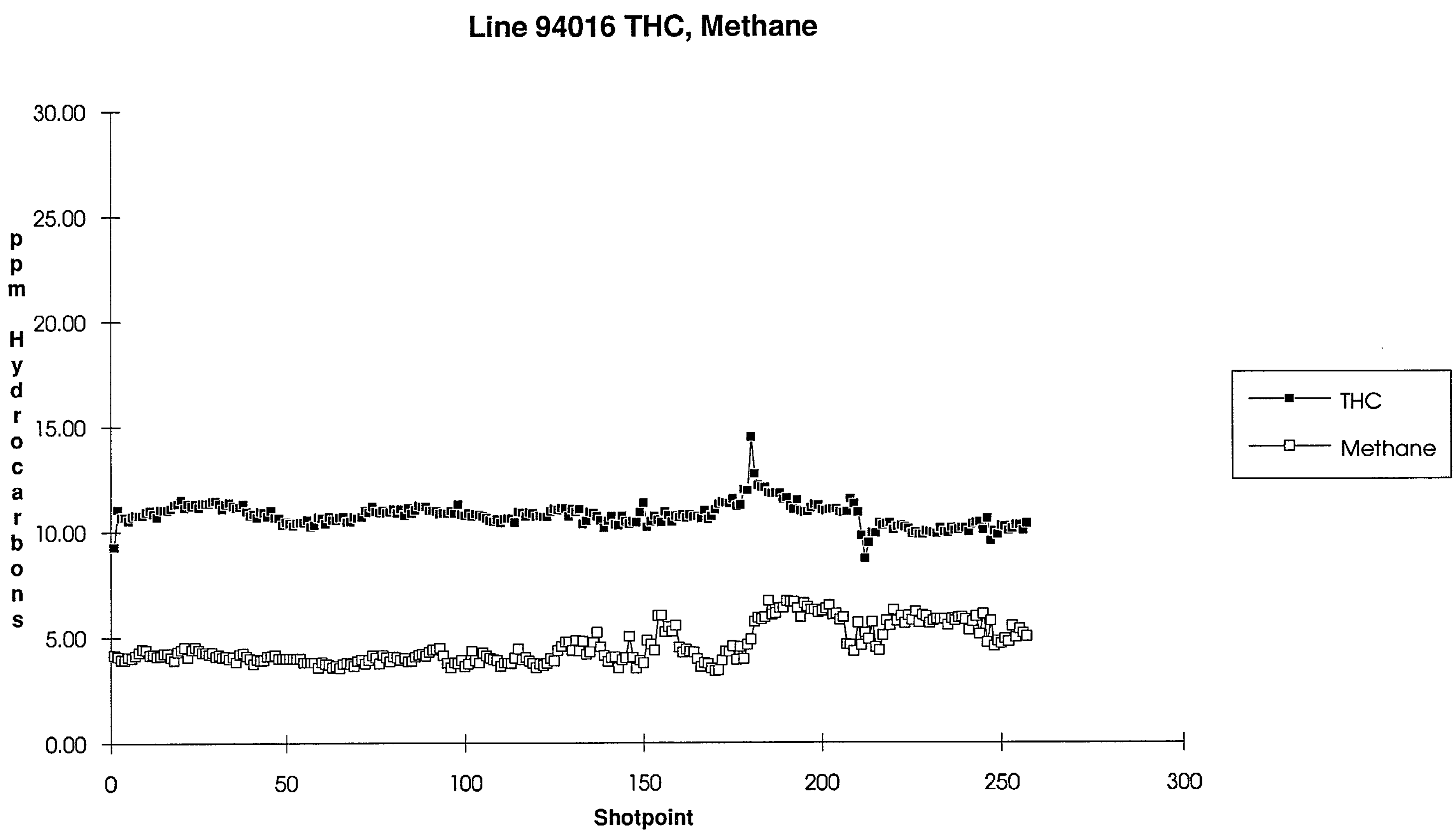
	THC	Methane	Ethane	Ethylene	Propane	Propylene	i-Butane	n-Butane	i-Pentane	n-Pentane	i-Hexane	n-Hexane	%Wetness
Mean	10.775	4.589	0.014	0.155	0.017	0.036	0.000	0.000	0.000	0.000	0.000	0.000	0.671
Std. Dev.	0.565	0.874	0.002	0.009	0.005	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.140
Minimum	8.709	3.404	0.010	0.127	0.003	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.359
Maximum	14.492	6.719	0.020	0.178	0.033	0.050	0.002	0.000	0.000	0.000	0.000	0.000	1.061

	Cond.	Temp.	F. Depth	W.Depth	Altitude
Mean	57.800	25.953	46.359	57.696	11.222
Std. Dev.	0.141	0.273	5.342	3.916	1.269
Minimum	56.840	25.410	39.900	52.000	8.000
Maximum	57.960	26.500	54.800	65.000	15.000

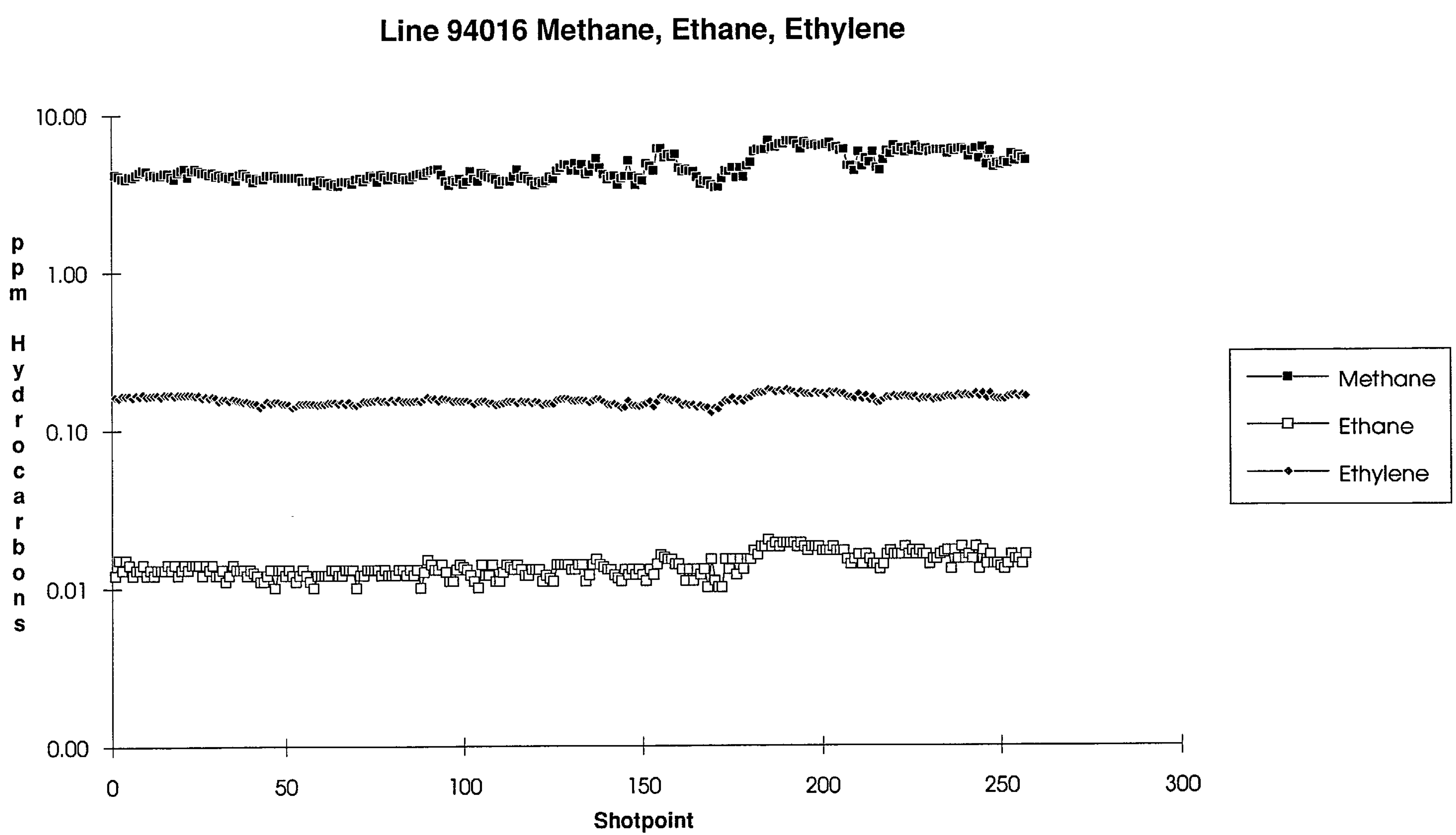
Notes

No hydrocarbon anomalies, although a slight increase in methane and ethane towards the end of line

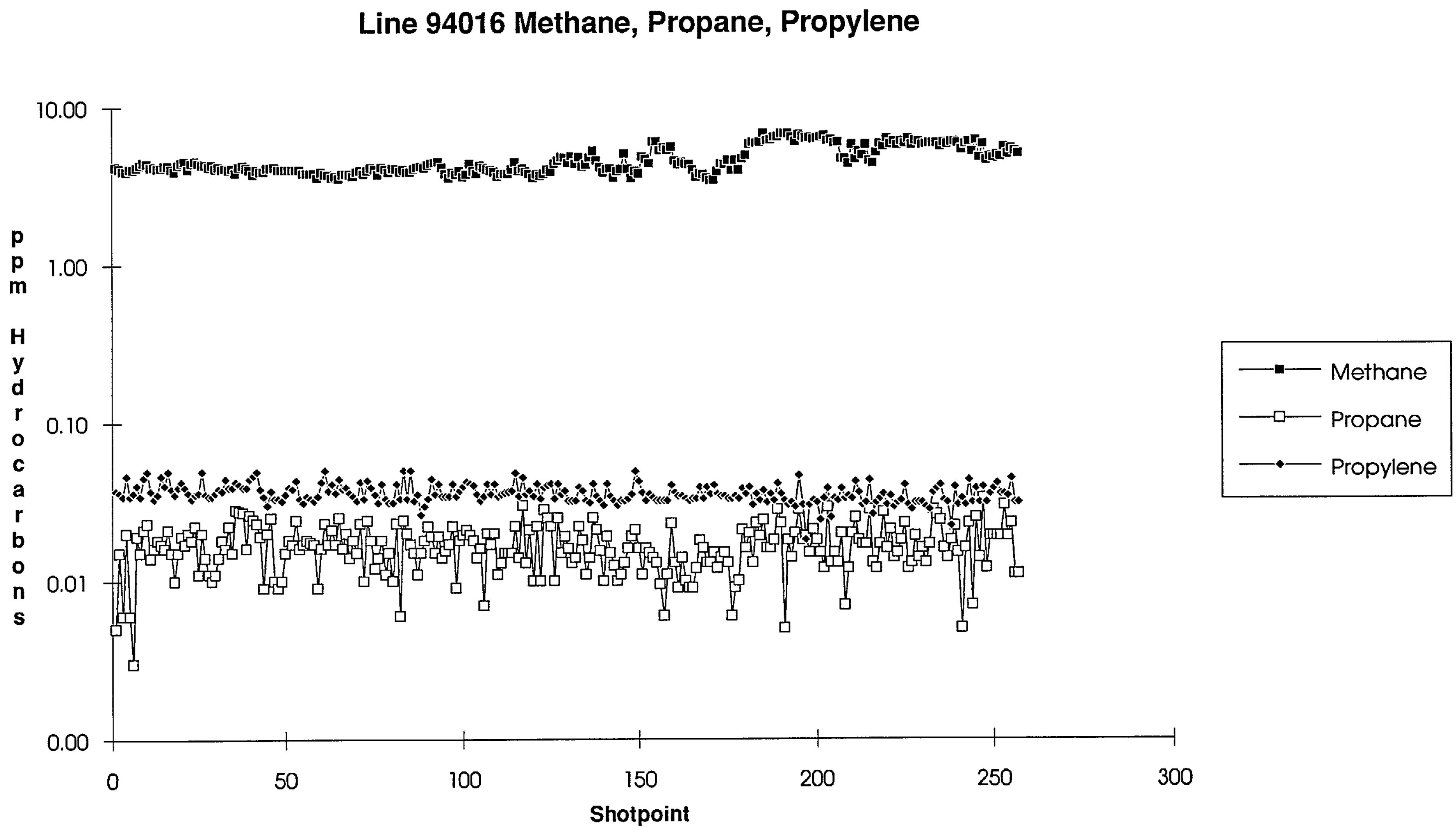
Fish altitude has been calculated thus: Altitude=water depth-fish depth



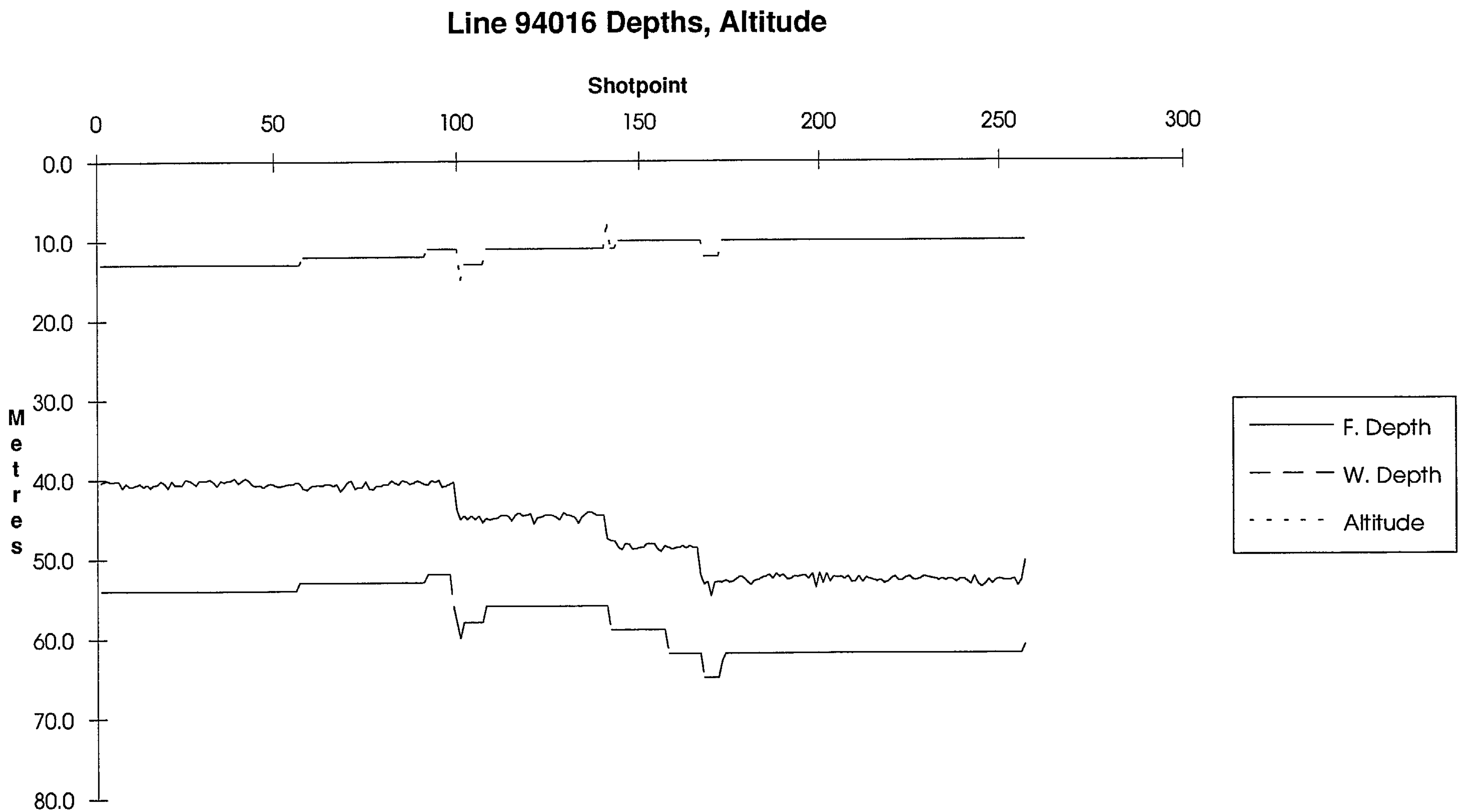
Line 94016 THC, Methane
ppm Hydrocarbons
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
50
100
150
200
250
300
Shotpoint
THC
Methane



Line 94016 Methane, Ethane, Ethylene
10.00
1.00
0.10
0.01
0.00
ppm Hydrocarbons
0
50
100
150
200
250
300
Shotpoint
Methane
Ethane
Ethylene



Line 94016 Methane, Propane, Propylene
10.00
1.00
0.10
0.01
0.00
ppm Hydrocarbons
0
50
100
150
200
250
300
Shotpoint
Methane
Propane
Propylene


Line 94016 Depths, Altitude
Shotpoint
0
50
100
150
200
250
300
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Metres
F. Depth
W. Depth
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 stern from the Mermaid Searcher. 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 headspace 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

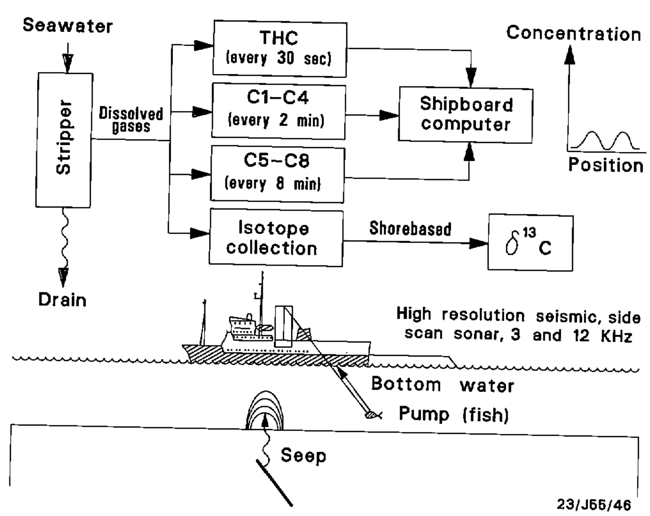


Figure II -1. Schematic of the geochemical equipment aboard Rig Seismic for the continuous profiling of hydrocarbons in seawater: the bottom-water DHD technique.

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 (i.e., 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 (e.g., 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 (e.g., 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.

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 (e.g., 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.

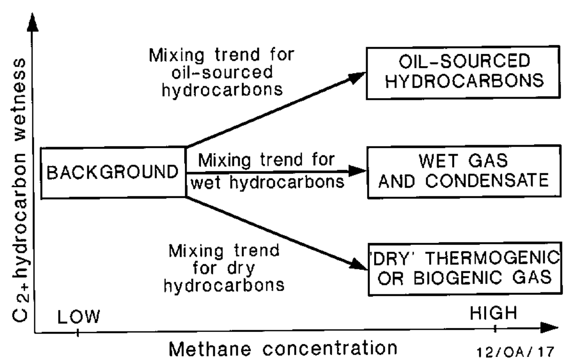


Figure III-1. Cross-plot of methane versus hydrocarbon wetness, showing the general decrease in wetness with increasing methane for gas-prone or biogenic sources. Conversely, oil-prone sources are indicated by increasing wetness with increasing wetness with increasing methane. Gas-condensate sources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

APPENDIX III REFERENCES

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APPENDIX IV

SYSTEMS OPERATION REPORT

The following is the system report detailed at the time of the cruise.

The BMR has signed a co-operative agreement with Transglobal Exploration and Geoscience (TEG) to evaluate the use of the "sniffer" system to detect hydrocarbon gases in sea water. This method involves the direct hydrocarbon detection (DHD) of hydrocarbon gases in sea water. Gases are obtained by towing a submersible fish 10-20 metres above the sea floor and continually pumping sea water into a gas stripper located in the laboratory on board. The gases are stripped from the sea water under vacuum and then continuously analysed by gas chromatography. Light hydrocarbon (LHC) gases, C1 to C4 are analysed every two minutes. Total hydrocarbons (THC) are analysed every 30 seconds and heavy hydrocarbons (HHC) analysed every eight minutes. All data is recorded and displayed continuously to the acquisition computer.

The Rig Seismic has recently undergone a refit that included the mounting of an A Frame midships on the port side. The A Frame has an outreach of 10 metres at 45 degrees. This enables the DHD tow fish to be deployed simultaneously with arrays towed from the stern. The DHD system recently underwent sea trials off Newcastle to establish the operational viability of the system on Rig Seismic. Following the success of these trials, an extensive shakedown cruise in conjunction with seismic acquisition was undertaken.

The Arafura Sea cruise (BMR Cruise number 94) is a seismic survey undertaken in the Arafura Sea using air gun arrays with a 3600 metre cable. The water depths in the area are 20 metres to 250 metres. The sea floor topography is mostly of a low gradient away from the coast.

EQUIPMENT

a)Towfish

The towfish is a 300Kg stainless steel fish containing the following components:

Submersible pump and motor - to pump water to the gas stripper.

Pressure transducer - to determine depth of the fish.

Koden Echo Sounder - to determine the altitude of the fish from the sea floor

b)Cable

The water is pumped to the gas stripper via a 12mm nylon tube. This tube is surrounded by electrical conductors and finally by two stainless steel sheaths. The present cable length is 375 metres. The cable is covered with plastic fairings to reduce the drag of the cable through the water.

c)Gas Stripper

The water is pumped into the laboratory based gas stripper. The stripper consists of a glass chamber evacuated to 26" of Mercury. The gas is continuously stripped from the water and passes to a series of gas chromatographs. The waste water is then pumped over the side. Temperature and conductivity are measured on the waste water in the laboratory.

d)Gas Chromatographs

The sea water gases are passed continuously to three gas chromatographs. The gases are analysed for hydrocarbon content (C1 to C8) using flame ionisation detectors (FID), with detection levels of parts per billion. Each gas chromatograph has two FIDs. The results are recorded both as a graphical output (on intergrators) and digitally to disk on a personal computer.

e)Computer

Results for hydrocarbon gas, conductivity, temperature, navigation, time, shotpoint, fish depth are all recorded digitally on an IBM compatible PC.

PRELIMINARY RESULTS

Operationally the use of over the side DHD in conjunction with seismic acquisition is very successful. Data acquisition was undertaken in varying weather conditions and at no time was there any concern regarding the viability of the DHD system. The tow fish was tested at speeds of 4 to 7.5 knots. Technically the equipment works well with a few problems that need addressing befor the next DHD cruise.

The hydrocarbon gas levels in the vicinity of the graben are higher than those background values found in prior surveys in the Gippsland Basin and offshore Western Australia. However, initial interpretation of values obtained indicate that the gases are of biogenic origin. Methane values did not exceed 30ppm and were commonly 5-20 ppm. No major bottom water hydrocarbon anomalies were detected..

DHD

Navigation data was not obtained directly from the navigation computer until survey line 13. Navigation data has been included for survey lines 1 to 12 at the post processing/editing stage.

Digital fish altitude could not be collected (due to a faulty altimeter) and was calculated by subtracting fish depth from the water depth.

Some hydrocarbon contamination occurred due to contaminated water pump hoses and this data has been deleted. Data was not collected on survey line 5 due to electrical faults and the need to re-terminate the cable. During the survey a leak developed in the rotary water joint at the winch and caused a dilution of the gases in solution when the winch was turned. These leaks have an immediate effect on the data values and do not effect the overall trends in the data. These specific instances are referred to in the individual line summary sheets (Appendix I). The temperature themistor was at times unreliable and therefore the temperature data on occassions are also unreliable.

There is a time lag from when the water is pumped from the fish until when it is actually analysed in the gas chromatograph. This time lag is of the order of six minutes. The data contained in this record has not been corrected for this time lag.

NON GEOCHEMICAL SYSTEMS

Navigation was acquired using:

GPS System - Magnavox T-Set GPS navigator

Primary Transit System

Magnavox MX1107RS dual channel satellite receiver

Magnavox MX610D dual-axis sonar doppler speed log

Sperry gyro-compass

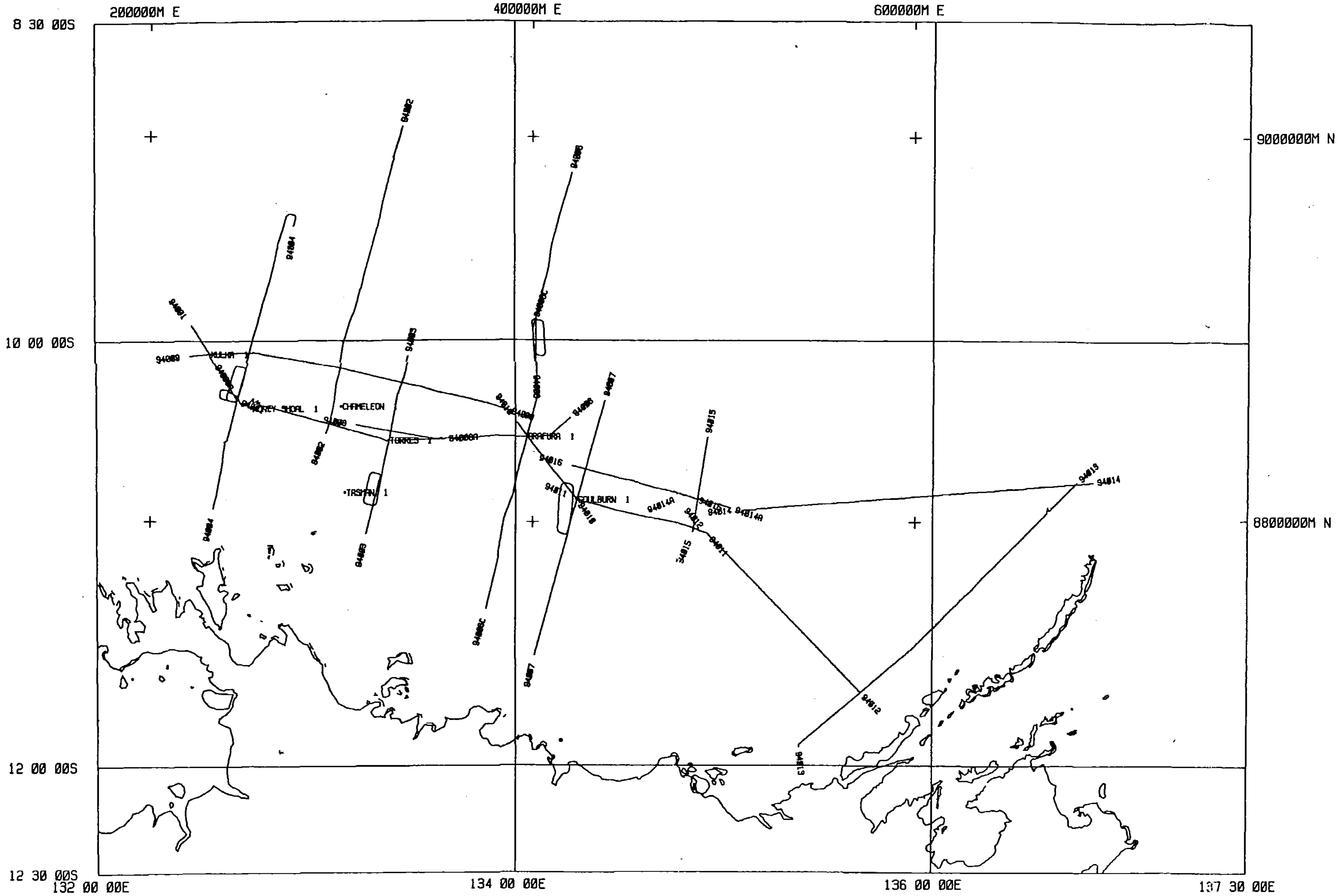
Secondary Transit System

Magnavox MX1142 single channel satellite receiver

Raytheon DSN450 dual-axis sonar doppler speed log

Robertson gyro-compass

ARAFURA SEA



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0 38 76 114 152 190

KILOMETRES

0 20 40 60 80 100

MILES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 135 00 00E

DHD SURVEY LINES

ARAFURA BASIN SURVEY

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