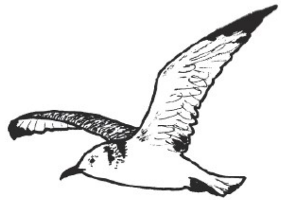
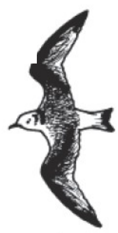
SOTEAG



Chemical and macrobenthic monitoring in Sullom Voe Sediments

2021

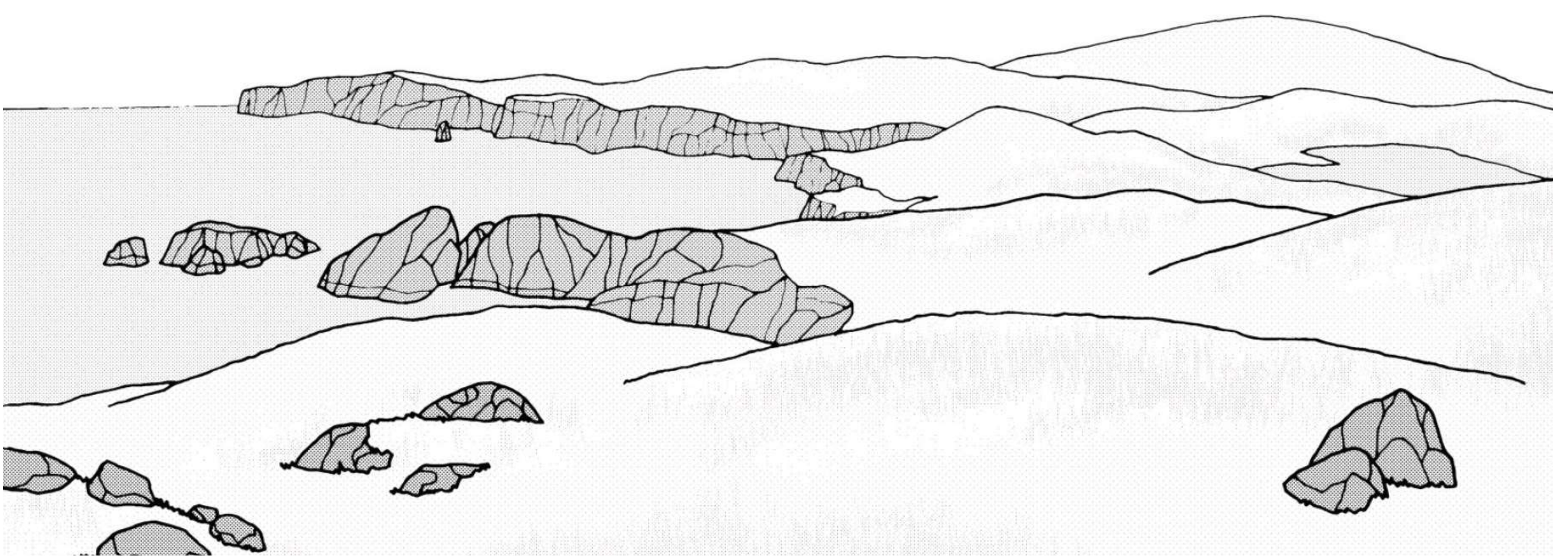


A report to the Shetland Oil Terminal

Environmental Advisory Group

by

SGS United Kingdom Limited



TITLE:	**Chemical and Macrobenthic Monitoring in Sullom Voe Sediments - 2021**
SUB-TITLE:	**Chemical Report – Total Aliphatic Hydrocarbons and Poly-Aromatic Hydrocarbons**
CLIENT:	**The Sullom Voe Association Limited**
REPORT REF:	**MD21-00516**
STATUS:	**Final Draft**

Prepared on behalf of SGS United Kingdom Limited

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NON-TECHNICAL SUMMARY

As part of an ongoing monitoring programme, SGS United Kingdom Limited was commissioned by the SOTEAG (Shetland Oil Terminal Environmental Advisory Group), representing the Sullom Voe Association, to undertake a combined benthic and chemistry survey in Sullom Voe to determine the status of infaunal communities and seafloor sediments in June 2021.

The results and findings of the chemical analysis are presented within this report, the benthic elements of the survey are covered in a separate report by Eco Marine Consultants. The sediment samples that were analysed were collected during the Sullom Voe survey conducted 14th to 18th June 2021. 19 subtidal samples were taken aboard the *MV Sullom Shearwater* using a Day Grab and 6 intertidal samples were taken using a handheld core.

The main findings of this report are:

- All sample taken from subtidal and intertidal stations were analysed for Total Aliphatic Hydrocarbon content (TAH). The TAH concentrations in 2021 were broadly consistent with the trend in concentrations since 2004, were there had been some change had been observed in the TAH concentration (SV1, SV5) this was following a decreasing trend. The characteristic chromatographic pattern of hydrocarbons at each station appears unchanged since previous surveys.

- The Total Aliphatic Hydrocarbons content of the sediment consists of a large number of individual chemicals originating from natural and petrochemical sources. The potion of the unresolved complex mixture continued to be observed as a greater proportion of the TAH. This indicates that there are no new input of crude oil and that the oil present in the sediment is chemically degrading.

- At 9 subtidal stations the Poly Aromatic Hydrocarbons (PAH) content of the sediments was determined. In 2021 the PAH concentrations were similar to the concentrations since 2004 and there was little evidence of change in the concentrations of PAHs in the sediments.

- In 2021, the Total Aliphatic Hydrocarbons and the Poly Aromatic Hydrocarbons at the Orka Voe stations were lower than those observed in 2018, the stations had been re-established in 2016 and there is limited historic data to assess if this change is significant.

- The Intertidal stations at Houb of Scatsta and Gluss Voe continue to have very low Total Aliphatic Hydrocarbon content and do not appear to be affected by terminal activity.

- Sediment composition across the Sullom Voe area has been variable over recent years, especially in relation to the mud content. Changes in sediment composition reflect natural variability, which is observed in the dataset over the duration of the monitoring period.

- The major and trace elements analysis was performed in 2021, this analysis was last performed in 2014 and is typically performed every 6 years. The sediments from all subtidal stations were analysed. The results presented in this report were determined using the methodology used in the analysis of the 2014 samples, although this was performed by a different laboratory. The un-normalised concentrations for the trace elements were similar to the 2014 concentrations indicating that there had been little change.

- The Following survey protocols and in order to minimise the effect for particle size changes the on-going data set for trace elements is recorded as a normalised value against the aluminium content at the same station. At some stations significantly higher aluminium concentrations were detected in the sediments (especially at SV1), this may have resulted in a false negative bias in the 2021 trace elements results. However, with the exception of station SV1, the normalised concentrations of trace elements were in the same range as the historic dataset and there was little evidence of a significant change. For all stations, all individual trace element concentrations were <10 mg/Kg.

- From the analysis of subtidal and intertidal stations around the Sullom Voe taken in 2021, there has been no detectable fresh input of crude oil or other petrochemical products from the terminal or associated activities.

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1 INTRODUCTION

This is one of two reports detailing the findings of the 30th chemical and macrobenthic monitoring survey carried out in June 2021 on marine sediments around the oil terminal at Sullom Voe which was conducted by SGS United Kingdom Limited for the Shetland Oil Terminal Environmental Advisory Group. This report details the findings of a monitoring survey and the scope of the survey is not dictated by regulatory bodies. This report covers the chemical analysis, including the particle size analysis, major and trace elements, the aliphatic hydrocarbon content and the poly aromatic hydrocarbon content of sediments taken from the Sullom Voe area.

The survey comprised of 31 stations in Sullom Voe. The survey consisted sampling the sediment of six soft shore stations from the Houb of Scatsta and Gluss Voe and twenty five subtidal sediment stations obtained by Day grab, (5 from Orka Voe, and 20 from Sullom Voe, Garths Voe and southern Yell Sound). In 2018, seven of the stations (SV36, SV37 and OV1-OV5) were identified as being within a 200m proximity zone of underwater pipeline assets and hence the location of these stations was re-established at the nearest point to the original station which was outside the proximity zone. In 2021 samples were taken at the re-established stations for OV1B-5B. Sediment samples were not obtained at the re-established stations SV36B and SV37B, but investigative work was performed to understand the seabed at these locations and to propose a suitable position for a station in this area. Seabed samples were taken for hydrocarbon, major and trace elements, sediment grain size, organic matter content and macrofaunal analyses. The survey was conducted from the Shetland Island Council work vessel *MV Sullom Shearwater* by SGS United Kingdom Limited and Eco Marine Consultants personnel. The hydrocarbon analysis was performed by SGS United Kingdom Limited and the macrobenthic analysis was performed by Eco Marine Consultants Limited.

2 METHODOLOGY

2.1 SAMPLE STATION LOCATIONS

The positions and depths of the sampling stations are described in Table 1 and illustrated in Figures 1A and 1B. In 2016 revised coordinates were established for stations SV36, SV37 and OV1-OV5, these stations have been labelled with post-fix B. The revised coordinates were prepared by overlaying maps containing the assets, the sediment bed and the 2014 coordinates. In 2021 three satisfactory grabs were obtained at the Orka Voe re-established stations. At station SV36B no satisfactory grabs were retrieved from the five grab sample attempts. At station SV37B 2 unsatisfactory grabs were retrieved from the five grab sample attempts, the station was later determined to be at the edge of a brittle star bed. The samples taken from SV37B were not analyse for hydrocarbon or elemental analysis.

The soft shore stations were sampled at the lowest tidal position during the survey dates. Gluss Voe GV1 and Housta Scatsa HS1 were identified as being under the tide position at low tide. The stations were sampled at the closest position to the target coordinates and the coordinates recorded, these stations were labelled GV1B (2 positions were identified as the tide reached its lowest point) and HS1A. The sediment type is unlikely to be significantly different between the original and the revised station.

The station locations were determined using the *MV Sullom Shearwater* dGPS and the soft shore locations were determined using handheld GPS.

Table 1 - Positions of sampling stations, June 2021

Station	Location	Station Position				Depth (m)
Yell Sound and north of Calback Ness						
SV1	Inner Basin	60°	24.091'N	001°	22.167'W	46m
SV3	Southern Sullom Voe	60°	25.512'N	001°	20.966'W	24m
SV4	Southern Sullom Voe	60°	26.003'N	001°	20.635'W	26m
SV5	Fugla Ness	60°	26.689'N	001°	19.246'W	25m
SV7	Jetty Grid	60°	27.195'N	001°	16.832'W	19m
SV8	Jetty Grid	60°	27.177'N	001°	17.834'W	24m
SV8A	Jetty Grid	60°	27.784'N	001°	18.971'W	26m
SV9	Outer Voe	60°	27.895'N	001°	19.494'W	15m
SV10	Outer Voe	60°	28.547'N	001°	18.875'W	32m
SV11	Outer Voe	60°	28.793'N	001°	17.706'W	38m
SV17	Jetty Grid	60°	27.483'N	001°	18.178'W	28m
SV12	Little Roe	60°	30.260'N	001°	17.168'W	50m
SV33	Calbeck Ness	60°	29.511'N	001°	17.616'W	52m
SV34	Calbeck Ness	60°	29.593'N	001°	17.252'W	51m
SV35	Calbeck Ness	60°	27.442'N	001°	15.813'W	18m
SV36B	Calbeck Ness	60°	29.640'N	001°	14.764'W	20m
SV37B	Calbeck Ness	60°	28.833'N	001°	14.794'W	36m
SV6	Garths Voe	60°	26.779'N	001°	16.221'W	8.7m
SV6A	Garths Voe	60°	26.761'N	001°	16.213'W	5.9m
SV6F	Garths Voe	60°	26.694'N	001°	16.133'W	4.5m
SV32	Garths Voe	60°	26.976'N	001°	16.289'W	11m
Orka Voe						
OV1B	Orka Voe	60°	28.688'N	001°	16.157'W	9.4m
OV2B	Orka Voe	60°	27.786'N	001°	16.054'W	15m
OV3B	Orka Voe	60°	28.833'N	001°	16.003'W	19m
OV4B	Orka Voe	60°	28.897'N	001°	15.956'W	20m
OV5B	Orka Voe	60°	28.942'N	001°	15.991'W	18m
Gluss Voe						
GV1B	Gluss Voe	60°	28.817'N	001°	21.011'W	Intertidal
GV2	Gluss Voe	60°	28.805'N	001°	21.069'W	Intertidal
GV3	Gluss Voe	60°	28.760'N	001°	21.190'W	Intertidal
Houb of Scatsta						
HS1A	Houb of Scatsta	60°	26.423'N	001°	16.995'W	Intertidal
HS2	Houb of Scatsta	60°	26.369'N	001°	16.852'W	Intertidal
HS3	Houb of Scatsta	60°	26.355'N	001°	16.753'W	Intertidal

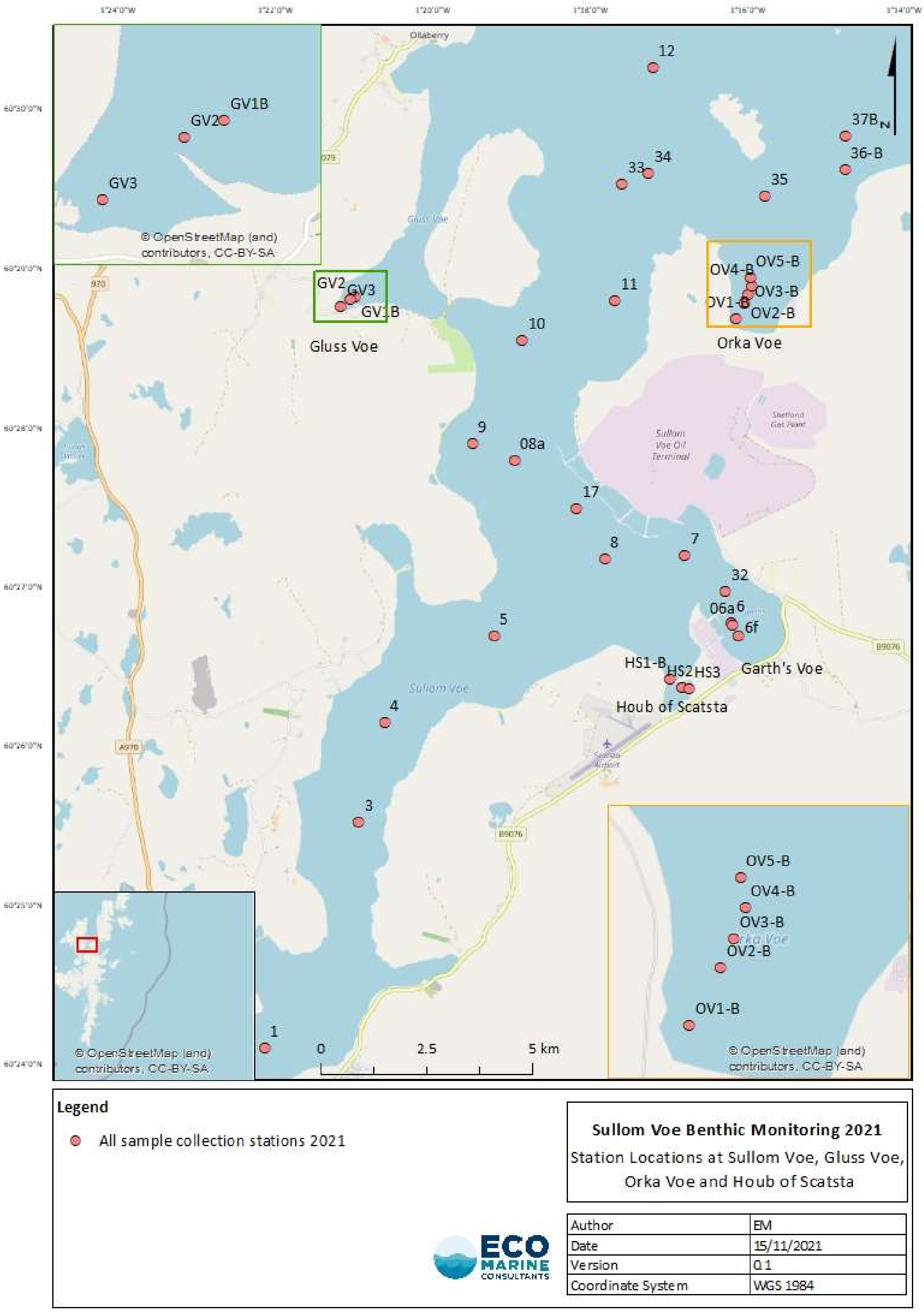

Figure 1A - The location and distribution of target stations at Sullom Voe in 2021.

Figure 1B - The location and distribution of target intertidal stations at Sullom Voe in 2021.

2.2 Field sampling methods

The sampling methods for the core parameters were the same as those used in previous surveys. Method details are provided in more depth within the “Terms of Reference” document.

In summary, seabed sediment samples were collected using a Day grab which had a surface area of 0.1m^2. Grabs were taken and sub-sampled for the analysis of the following parameters: sediment grain size; organic matter, major and trace elements and total aliphatic hydrocarbons and aromatic hydrocarbons.

As in previous surveys the subsamples for sediment grain size and organic matter were taken from each of the grab samples to make a composite sample. A sub-sample for trace elemental analysis was taken from this composite sample following the homogenisation of the sample with plastic handling tools. It was not clear from the 2014 report which sampling protocols were implemented for the elemental sub-sample, therefore there is uncertainty as to if the same sampling protocols have been used in 2021. This variation may impact on the major and trace elemental analysis.

Individual sub-samples of sediment for hydrocarbon analysis were taken from each of the three Day grab samples identified for macrobenthic analysis. The hydrocarbon subsample was taken from the top 2 cm of sediment in the Day grab sampler as per previous surveys.

Particle size analysis, organic carbon, elemental and hydrocarbon samples were frozen after collection, and were kept frozen during transportation to the analytical laboratory.
Once the particle size, organic carbon and hydrocarbon subsamples had been obtained from the Day grab sample the remaining sediment was used for the analysis of benthic macrofauna. The sediment was carefully washed through a 1mm mesh stainless steel sieve and preserved in approximately 5-10% solution of buffered formalin in seawater.

Samples of sediment for hydrocarbon analysis and grain size distribution were taken at each of the soft shore stations in Gluss Voe and the Houb of Scatsta.

2.3 Laboratory methods

The laboratory method details are provided in more depth within the “Terms of Reference” document.

A summary of each method and a discussion of the approach to the interpretation of the data are given below.

2.3.1 Sediment grain size analysis and organic matter

The particle size analysis for the 2021 survey was subcontracted to Ocean Ecology Limited. The 2021 particle size analysis was performed using NMBAQC methodology and Oceans Ecology participate in the NMBAQC proficiency testing protocols.

The differences between the NMBAQC protocols and the historic protocols (pre 2016) for particle size analysis are summarised in the 2016 chemistry report.

Ocean Ecology Limited achieved a “good” status in each aspect of their analysis of the 2021 PSA NMBAQC proficiency testing scheme.

As in the 2016 survey the total organic carbon was determined by test method BS 13137. Prior to 2016 the total organic carbon has been determined gravimetrically by loss on heating at 450ºC and presented as percent weight of sample. This year the total organic content has been determined using British Standard method BS 13137, which involves acid treatment of the sediment to remove any inorganic carbon (such as carbonates), then combustion of the sample at 1300ºC and subsequent detection of the carbon dioxide generated by non-dispersive infrared detection.

For method BS 13137 there are a number of quality control measures; each sample is analysed in duplicate and both results must be with 10% of the mean of the two results, blanks and control samples are ran with the samples and have to be within 10% of the method specified values.

2.3.2 SEDIMENT HYDROCARBON ANALYSIS

The analytical procedures used in the present study are the same as those used since 1992 when gravimetric analyses were replaced by improved methods, which are detailed in the “terms of reference” document reference.

The hydrocarbon analysis was performed by SGS United Kingdom. In previous surveys up to 2014, the hydrocarbon analysis had been performed by SGS M-Scan limited.

In order to ensure that the effects of changing laboratory were minimised, a copy of the extraction method was given to SGS United Kingdom and validated by analysing certified reference materials and also by performing spike and recovery experiments. The quality control requirements were taken from Marine Management Organisation guidance for chemical determinands January 2015.

To improve the quality of the hydrocarbon measurement, blanks and certified reference materials were extracted alongside the samples, at a frequency of 1 per 10 sediment samples.

SGS United Kingdom participates in the LGC CONTEST proficiency testing scheme for total petroleum hydrocarbon testing in soil samples and achieved a “good” status in the 2021 round using their in-house method.

The hydrocarbon analysis was performed at an ISO 17025 accredited laboratory, and while the test method itself was not within the scope of the ISO 17025 accreditation the analysis was performed under the same quality management system.

The concentrations of total aliphatic hydrocarbons (TAH), unresolved complex mixture (UCM), and other selected parameters have been calculated by integration of Gas chromatography (GC) data.

The concentrations of 2-6 ring polycyclic aromatic hydrocarbons (PAH; parent PAH and alkylated homologues) in nine selected sediments were determined using Gas Chromatography with Mass Selective Detection (GC-MS).

2.3.3 SEDIMENT MAJOR AND TRACE ELEMENT ANALYSIS

Major and trace element analysis was performed in the 2021 survey. The analysis was performed by SGS United Kingdom Limited.

The method includes the following: 0.2g of dried and ground sample is fully digested with a 2-stage acid extraction, initially with a mixed acid digestion including hydrofluoric acid and then a hydrochloric acid digestion. Once cooled the extract is filtered and pre-diluted before being analysed. Analysis is performed by ICP-MS or ICP-OES and quantified by comparing the results against a calibration curve for each of the target analytes.

Initially, the 2021 samples were analysed for major and trace elements by an ISO 17025 and MMO accredited laboratory. However due to major methodology difference, the full sample matrix was not digested in the extraction process and the results obtained (especially aluminium) were not found to be consistent with the anticipated data ranges in the historic dataset.

The samples were then re-analysed for major and trace elements using the same methodology as in 2014. While the methodology used in 2021 was the same methodology used in 2014, it was performed by a different laboratory and using different make and models of ICP instrument. It is worth noting that there is no reference in the 2014 report to the validation protocols of the method and the laboratory was un-accredited for this analysis. The 2021 analysis was validated using internal quality control, however no certified reference materials or external proficiency testing schemes were analysed to verify the analysis.

3 RESULTS AND DISCUSSION

3.1 INTRODUCTION

The Results and Discussion section will present the raw data for selected test parameters and then present the 2021 data for each station against the historical survey data utilising "control" type charts. It is hoped that the charts will enable a visual assessment of the current data points against the historic data so that changes can be more easily identified.

For each test parameter, basic statistical tools have been used to aid interpretation of the data; mean results and limits based on standard deviations of the historic data set. The charts comprise of the historic and current data points, a trend line (using all the historic data points), and standard deviation lines which are equivalent to -3,-2,-1,+1,+2 and +3 standard deviations. The standard deviations for the hydrocarbon analysis (total aliphatic hydrocarbon content, the percentage unresolved complex mixture to total aliphatic hydrocarbon content, and the poly-aromatic hydrocarbon content) have been calculated using the historic data set from 2004 to 2018.

The standard deviations have been used to help assess if there has been a significant change in the 2021 result against the mean results for 2004-2018. Where historic mean results and standard deviations are referenced in the report they have been calculated from the data set 2004-2018, unless stated otherwise. Stations that have changed position have not been included in this assessment, once more data is available from the re-established sites the trend analysis of the sites will be incorporated into the reports.

The below outlines how the standard deviations are presented and should be interpreted;

-1 and +1 standard deviation lines are coloured yellow.
-2 and +2 standard deviation lines are coloured orange.
-3 and +3 standard deviation lines are coloured red.

-1 to +1 SD	indicates little change against the historic data.
-2 to -1 and +1 to +2 SD	indicates some change against the historic data.
-2 to -3 and +2 to +3 SD	indicates significant change against the historic data.
<-3 and >+3 SD	indicates very significant change against the historic data

Standard deviations lines are not included where the line is outside the scope of the measurement eg <0 concentration or outside 0-100%.

3.2 Sediment characterisation

The results of the analyses of sediment particle distribution for 2021, organic matter and sediment type classification according to Folk (1954) are given in Tables 2, 3 and 4. Combined Particle size distribution (PSD) graphs are included as Appendix 2 *(separate document).*

The 2021 PSD analysis was performed by a different laboratory to the 2016-2018 surveys.

The particle size distribution was performed by the NMBAQC methodology in 2021 which is consistent with the 2016 and 2018 surveys but different from previous years. Now that the methodology is standardised to the NMBAQC methodology, it should enable better interpretation of PSA data trends. Due to potential inconsistencies in PSA methodology in surveys up to 2016, it is difficult to interpret the 2016 -2021 data sets robustly in context of the historical data.

The stations in the Sullom Voe continue to be contain predominantly sand and mud. Although some stations including SV17 in the Jetty area have high gravel contents. The changes in the particle size distribution is very varied between the stations, some stations, particularly more sheltered stations, have demonstrated very little change in their particle distribution while other stations have seen more dramatic changes.

The mud content results for 2016 and 2021 are generally higher than in studies since 2006. The mud content for 2021 are generally comparable to the 2016-2018 results and most do not differ by more than 10%. The noticeable exception to this is at SV1 where the mud content changed from the highest station containing mud 80-85% mud in 2016-2018 to 40.2% mud content in 2021.

Particle size discussion in relation to the macrobenthic analysis is detailed in report MD21-00516 (Report 2 of 2) section 3.2.2 .

For the review of particle size distribution results in context of the historical data, no standard deviation lines have been included on the charts. Standard deviation limits could be included in these charts once more data is available analysed using the NMBAQC protocols.

The total organic content was determined using method British Standard (BS) 13137. The quality control measures were acceptable for all the reported results at each station. Each sample was analysed in duplicate and both results were within 10% of the mean of the two results. Blanks and control samples were ran alongside the sediment samples and were within 10% of the method specified values.

Table 2 - Physical parameters of sediments from Sullom Voe stations, June 2021.

STATION	Phi Mean	Phi Skewness	Phi Kurtosis	% Mud	% Sand	% Gravel	% Organic Content	Textural Group
1	3.545	0.184	0.862	40.2	59.8	0.0	13.2	Muddy Sand
3	2.879	-0.127	0.809	38.3	50.9	10.8	6.9	Gravelly Muddy Sand
4	3.284	-0.124	0.975	42.6	51.4	6.0	4.5	Gravelly Muddy Sand
5	2.985	-0.163	0.926	40.5	46.8	12.7	4.9	Gravelly Muddy Sand
7	3.385	-0.125	1.320	40.7	48.8	10.4	6.2	Gravelly Muddy Sand
8	2.997	0.050	0.918	35.8	57.8	6.4	4.2	Gravelly Muddy Sand
8A	3.502	0.153	1.164	34.8	61.5	3.7	3.6	Slightly Gravelly Muddy Sand
9	3.668	-0.157	1.247	47.8	44.9	7.3	7.3	Gravelly Mud
10	4.539	0.256	0.954	52.8	45.7	1.4	5.2	Slightly Gravelly Sandy Mud
11	4.537	0.359	0.942	51.8	48.2	0.0	5.9	Sandy Mud
17	2.564	0.151	0.727	34.3	57.2	8.4	3.4	Gravelly Muddy Sand
12	1.504	-0.003	1.432	7.8	86.0	6.2	3.4	Gravelly Sand
33	3.759	0.377	1.255	32.6	67.4	0.0	3.9	Muddy Sand
34	3.705	0.399	1.271	31.3	68.7	0.0	4.2	Muddy Sand
35	0.926	0.0034	1.174	8.3	75.0	16.6	1.3	Gravelly Muddy Sand
37B	0.277	0.091	0.903	2.5	83.2	14.3	-	Gravelly Sand
6	2.913	-0.066	1.123	31.5	62.4	6.1	4.9	Gravelly Muddy Sand
6A	2.875	0.002	1.104	28.5	66.4	5.1	7.6	Gravelly Muddy Sand
6F	3.118	0.101	1.029	30.1	68.9	1.0	11.5	Slightly Gravelly Muddy Sand
32	3.652	0.067	1.065	41.6	58.4	0.0	11.6	Muddy Sand

Table 3 - Physical parameters of sediments from Orka Voe shore stations, June 2021.

STATION	Phi Mean	Phi Skewness	Phi Kurtosis	% Mud	% Sand	% Gravel	% Organic Content	Textural Group
OV1B	1.915	0.007	1.127	6.7	89.3	3.9	2.1	Slightly Gravelly Sand
OV2B	2.170	0.015	1.147	9.4	89.2	1.4	0.9	Slightly Gravelly Sand
OV3B	2.307	-0.205	1.709	17.2	70.5	12.3	1.2	Gravelly Muddy Sand
OV4B	2.418	-0.206	1.718	18.9	69.0	12.1	1.5	Gravelly Muddy Sand
OV5B	0.924	-0.227	0.669	21.3	43.5	35.1	1.7	Muddy Sandy Gravel

Table 4 - Physical parameters of sediments from soft shore stations, June 2021

STATION	Phi Mean	Phi Skewness	Phi Kurtosis	% Mud	% Sand	% Gravel	% Organic Content	Textural Group
GV1	-1.413	0.511	0.667	2.3	36.4	61.3	0.8	Sandy Gravel
GV2	-0.264	-0.113	0.671	2.5	56.5	41.0	0.7	Sandy Gravel
GV3	-0.928	-0.015	1.013	3.0	47.9	49.1	0.5	Sandy Gravel
HS1	-1.921	-0.043	0.691	1.7	37.0	61.3	1.5	Sandy Gravel
HS2	2.013	0.107	1.128	5.6	94.4	0.0	2.3	Sand
HS3	1.625	0.078	1.387	4.7	91.8	3.5	1.7	Slightly Gravelly Sand

3.3 HYDROCARBONS

3.3.1 GAS CHROMATOGRAPHY OF ALIPHATIC HYDROCARBONS

The total aliphatic hydrocarbon (TAH) and unresolved complex mixture (UCM) results are detailed in table 5 below. Comparison charts with previous year's data are provided for each station in Section 3.4

3.3.1.1 Quality Control

3.3.1.1.1 Extraction Blanks

Blanks were analysed with each batch of 10 samples and the levels were found to between 0.8 to 1.8 $\mu g.g^{-1}$ based on 50g dry weight basis. There was a small cluster of peaks which were impurities in the solvent which would be present in the sample chromatograms. The amount of total aliphatic hydrocarbon determined in the extraction blank was subtracted when quantifying the results for the sample analysis.

3.3.1.1.2 Quality Control Sample

2.5g certified reference material, which consisted of dried sediment spiked with diesel range organics at 2650 ± 90 mg/Kg was analysed with each batch of 10 samples using the test method. The recoveries for the certified reference material had a mean of 85% (87% in 2018) and standard deviation of 6.7% (8.5% in 2018). The results were within the expected method performance.

Figure 2- Certified Reference Material percentage recovery chart

3.3.1.2 Analysis of Three Grab Samples

In 2021 each grab sample which was to be tested for macrobenthic analysis was sub-sampled and analysed for hydrocarbon analysis. In surveys prior to 2014 a composite sample was prepared and used for the hydrocarbon analysis.

The Inner basin and Southern Sullom Voe stations and some of the Jetty Area and West of Calbeck Ness stations demonstrated the highest degrees of variation between the results obtained from the three grab samples. For stations, SV1, SV3, SV4, SV5, SV8, SV9 the relative standard deviation for the three replicates was 36.4, 27.4, 23.9, 26.1, 29.0, 25.8 percent respectfully. However, the mean of the three grab sample results showed very good correlation to the mean from the historic data period 2004-2018, with the exception of SV1 where a significant change in the particle size may have affected the observed hydrocarbon concentration.

The soft shore stations also demonstrated some variation between the three grab samples but as the concentrations of hydrocarbons were at lower concentrations (<10µg.g^{-1}) where the uncertainty of measurement is higher as it reaches the reporting limit of the method. The relative standard deviation of the stations with <10µg.g^{-1} hydrocarbons were within the acceptable 30 percent relative standard deviation.

3.3.1.3 Total Aliphatic Hydrocarbon Results

The total aliphatic hydrocarbon (TAH) results are detailed in table 6 below.

The GC traces for the current survey are similar to those for the same stations in the 2014, 2016 and 2018 surveys. There is no clear evidence for any fundamental alteration in the distribution of hydrocarbons in the sediments in 2021 compared with the 2016 or 2018 survey. Examination of the GC traces shows selected normal (n-) alkanes in the range of n-C_{12} to n-C_{35} superimposed on an extended molecular weight unresolved complex mixture (UCM). The GC traces of most of the stations are similar with only the relative intensities of various components altering.

The hydrocarbon content observed at SV1 was 1-2 standard deviations from the historic mean and this indicates that there had been some change (decrease) in the hydrocarbons. The result in 2021 was 124 µg.g^{-1}, the 2018 result was 166 µg.g^{-1} and the historic mean was 187 µg.g^{-1}. The particle distribution analysis at SV1 determined that there had been and increase in the sand content which may account for the observed change in the hydrocarbon content.

The total aliphatic hydrocarbon (TAH) results demonstrated little evidence of change across all the other core stations (except Orka Voe). The average TAH result was 28.4 µg.g^{-1} for all stations (except SV36B, SV37B, OV1B-OV5B) in 2021, in 2018 this was 29.9 µg.g^{-1}, in 2016 this was 33.2 µg.g^{-1} for the same stations, the historic mean TAH result for the period 2004-2018 was 37.2 µg.g^{-1} for the same stations. Where a change of >1 standard deviation to the historic mean was observed, the result correlated will with the recent results from 2016-2018.

The trend of the 2021 total aliphatic hydrocarbon (TAH) results fits with the general observation of that the concentration of hydrocarbons in the sediments within the Sullom Voe are decreasing.

The hydrocarbon concentrations at Orka Voe OV2-OV5 showed a significant decrease in concentration compared to the 2018 results. See Table 5.

Table 5 – Total Aliphatic Hydrocarbons concentrations 2018 and 2021 for Orka Voe.

		2021 Survey		2018 Survey		
Area	STATION	Mean Total Aliphatics (µg/g)	Relative Standard Deviation of Total Aliphatics (%)	Mean Total Aliphatics (µg/g)	Relative Standard Deviation of Total Aliphatics (%)	Difference between 2018 result and 2021 result (µg/g)
Orka Voe	OV1B	5.6	*5.7*	6.6	*10*	-1.0
	OV2B	5.1	*9.0*	24.0	*13*	-18.9
	OV3B	5.4	*10.1*	21.5	*22*	-16.1
	OV4B	5.1	*13.8*	18.4	*14*	-13.3
	OV5B	5.4	*7.1*	12.7	*13*	-7.3

3.3.1.4 Unresolved Complex Mixture Results

The unresolved complex mixture (UCM) results are detailed in table 6 below.

The UCM is expressed in the analytical units µg.g^{-1} and also as a percentage of the TAH concentration. The UCM in µg.g^{-1} demonstrated evidence of decreasing on average across all the stations.

The average UCM (µg.g^{-1}) result was 17.0 µg.g^{-1} for all stations (except SV36B, SV37B and OV1B-OV5B) in 2021, In 2018 this was 17.0 µg.g^{-1} in 2016 this was 23.3 µg.g^{-1}, the historic mean UCM result for the period 2004-2018 was 19.5 µg.g^{-1} for the same stations.

For all stations, the relative standard deviation of the historic data set 2004-2016 was <30% for each station. The average UCM as a % of TAH result was 60.8% for all valid stations (except SV36B, SV37B and OV1B-OV5B) in 2021, in 2018 with was 65.4%, in 2016 this was 65.4%, and the historic mean UCM result for the period 2004-2018 was 52.3% for the same stations.

Table 6 - Summary of parameters from GC analysis of aliphatic hydrocarbons in all stations, June 2021

STATION	Mean Total Aliphatics (µg/g)	Relative Standard Deviation of Total Aliphatics (%)	Mean UCM (µg/g)	UCM of Total Aliphatics (%)	Relative Standard Deviation of % UCM (%)
SV1	124	*36.4*	66.9	53.9	*24.7*
SV3	23.0	*27.4*	16.3	70.7	*17.1*
SV4	18.2	*23.9*	12.9	70.6	*19.7*
SV5	23.5	*26.1*	17.3	73.6	*26.1*
SV7	46.4	*19.3*	29.1	62.3	*9.1*
SV8	17.4	*29.0*	14.1	81.1	*26.8*
SV8A	12.9	*6.9*	10.8	83.5	*16.1*
SV9	26.5	*25.8*	18.9	71.3	*19.3*
SV10	16.5	*12.5*	11.4	69.1	*9.5*
SV11	17.0	*14.6*	12.9	75.6	*23.2*
SV17	10.1	*13.2*	6.9	68.3	*17.9*
SV12	4.3	*12.1*	2.9	68.8	*13.6*
SV33	6.6	*1.7*	4.5	68.8	*3.2*
SV34	7.4	*14.9*	5.1	69.1	*10.9*
SV35	2.7	*6.4*	1.9	68.5	*10.1*
SV37B	1.4	*3.8*	<1.0	-	-
SV6	40.7	*18.6*	22.2	54.0	*17.7*
SV6A	84.5	*24*	47.7	56.4	*16.7*
SV6F	120	*14.2*	63.7	53.0	*15.0*
SV32	119	*6.2*	52.7	44.2	*16.1*
OV1B	5.6	*5.7*	3.1	54.6	*14.6*
OV2B	5.1	*9.0*	3.5	68.6	*12.2*
OV3B	5.4	*10.1*	3.9	72.4	*4.6*
OV4B	5.1	*13.8*	3.4	66.2	*17.6*
OV5B	5.4	*7.1*	3.6	66.6	*12.7*
GV1B	2.8	*8.6*	1.2	42.4	*11.5*
GV2	1.5	*16.2*	0.7	44.2	*20.9*
GV3	1.8	*24.8*	0.6	32.1	*24.5*
HS1A	3.3	*15.0*	1.9	59.5	*24.8*
HS2	3.5	*16.4*	1.4	39.3	*6.4*
HS3	4.5	*12.1*	1.8	39.5	*20.7*

µg/g results are expressed on a dry weight basis.
UCM – Unresolved Complex Mixture

3.3.2 GC/MS - Polycyclic Aromatic Hydrocarbons (PAHs)

3.3.2.1 Polycyclic Aromatic Hydrocarbons (PAHs)

The polycyclic aromatic hydrocarbon results (PAH) are detailed in tables 7 and 8 below. Comparison charts with previous year's data are provided for each station in section 3.4

Extracts from 9 stations were analysed for concentration of 2-6 ring PAHs and also the percentage of 4-6 ring PAHs to the total PAHs. The stations OV1B and OV5B were analysed but not assessed against historic data as their coordinates had been re-established in 2016.

As with the GC traces for the aliphatic fractions, the distribution of aromatic hydrocarbons in the total ion chromatogram (TIC) traces for the sediments are very similar to the 2014 survey. Complex mixtures of PAH were detected by gas chromatography with mass chromatography (GC-MS) including alkyl substituted compounds as well as their un-substituted (parent) homologues.

In petroleum products there are substantial amounts of alkylated PAH. Hence a relatively high proportion of these derivatives with respect to the non-alkylated parent PAH indicates a petrogenic input. Petrogenic aromatic hydrocarbon distributions in sediments differ from those of fresh crude oils, as the latter are dominated by alkylnaphthalenes and alkylphenanthrenes. These components are preferentially removed by the processes of weathering. Not only do the volatile naphthalenes evaporate during exposure to the elements but alkylnaphthalenes and alkylphenanthrenes are gradually removed by bacterially mediated aerobic degradation (Jones et al., 1983).

The 2-6 ring PAH results demonstrated little evidence of change across the seven stations analysed against the historic data. The average 2-6 ring PAH result was 1203 $ng.g^{-1}$ for all valid stations in 2021, this was 1230 $ng.g^{-1}$ in 2018, in 2016 this was 1310 $ng.g^{-1}$, the historic mean 2-6 ring PAH result for the period 2004-2016 was 1317 $\mu g.g^{-1}$ for the same stations. The average number of standard deviations from the historic mean (for period 2004-2014) across all valid stations was -0.29, this demonstrates that there has been little change in the overall PAH concentration in the Sullom Voe area.

There was one station SV1 which demonstrated some change from the historic mean. The 2-6 ring PAH concentrations at SV1, was -1.2 standard deviations from the historic mean for data period 2004-2018, this correlates with the lower concentration of Total Aliphatic Hydrocarbons observed at SV1 which is thought to be due to a change in the mud/sand contents of the sediment.

Table 7 - Concentrations of 2-6 ring aromatic hydrocarbons in selected sediments, 2021 (ng.g^{-1} dry weight sediment; ppb).

Station	SV1	SV4	SV7	SV17	SV34
Naphthalene(N)	14	4.7	5.1	8.9	1.4
C1-Naphthalenes	21	15	17	6.9	4.7
C2-Naphthalenes	89	25	75	14	6.0
C3-Naphthalenes	36	5.0	37	3.5	1.4
C4-Naphthalenes	25	2.8	26	3.0	1.1
Total Naphtalenes(N)	**186**	**53**	**160**	**37**	**15**
Phenanthrene/Anthracene(P)	19	8.5	80	37	3.7
C1-Phenanthrenes/Anthracenes	33	6.6	17	14	3.9
C2-Phenanthrenes/Anthracenes	24	10.0	25	16	4.5
C3-Phenanthrenes/Anthracenes	31	8.3	28	18	1.4
Total Phenathrenes(P)	**106**	**33**	**149**	**84**	**13**
Dibenzothiophene(D)	0.9	0.6	8.9	4.4	0.3
C1-Dibenzothiophenes	17	4.3	7.7	2.4	0.9
C2-Dibenzothiophenes	14	1.1	9.0	4.3	0.7
C3-Dibenzothiophenes	12	0.7	8.6	1.8	0.2
Total Dibenzothiophenes(D)	**44**	**6.7**	**34**	**13**	**2.2**
ΣNPD	**337**	**93**	**343**	**134**	**30**
Fluoranthene/Pyrene	182	82	496	245	19
C1-Fluoranthenes/Pyrenes	73	13	137	83	6.6
C2-Fluoranthenes/Pyrenes	7	8.9	63	37	4.1
C3-Fluoranthenes/Pyrenes	41	5.8	31	5.0	3.1
Total Fluoranthenes/Pyrenes	**303**	**109**	**726**	**380**	**33**
Benzanthracene/Chrysene	127	25	250	172	11
C1-Benzanthracenes/Chrysenes	41	8.3	42	12	3.5
C2-Benzanthracenes/Chrysenes	36	7.2	42	10.0	2.5
Total Benzanthracenes/Chrysenes	**204**	**40.6**	**334**	**194**	**17**
Benzofluorathenes/Benzopyrene	314	65	335	218	35
C1-Benzofluorathenes/Benzopyrenes	158	21	97	44	13
C2-Benzofluorathenes/Benzopyrenes	65	14	42	16	6.2
Total Benzofluorathenes/Benzpyrenes	**538**	**100**	**474**	**278**	**47**
m/z 276	212	36	122	73	20
C1-m/z276*	85	12	59	13	6.5
c2-m/z276*	64	12	43	9.0	4.8
Total m/z276*	**361**	**60**	**225**	**95**	**32**
Total 2-6 ring PAH	**1760**	**420**	**2240**	**1090**	**161**
% 4-6 ring PAHs as a % of the total PAHs	**79.7**	**73.8**	**78.6**	**86.7**	**80.1**

Table 8 - Concentrations of 2-6 ring aromatic hydrocarbons in selected sediments, 2021 (ng.g^{-1} dry weight sediment; ppb).

Station	SV6	SV6F	OV1B	OV5B
Naphthalene(N)	4.0	5.0	1.1	7.3
C1-Naphthalenes	10	3.2	2.6	2.1
C2-Naphthalenes	37	18	2.5	15
C3-Naphthalenes	12	9.3	1.3	1.5
C4-Naphthalenes	8.0	3.0	0.6	0.6
Total Naphtalenes(N)	**71**	**39**	**8.1**	**27**
Phenanthrene/Anthracene(P)	49	32	0.1	0.9
C1-Phenanthrenes/Anthracenes	22	27	0.2	1.4
C2-Phenanthrenes/Anthracenes	77	49	0.7	1.9
C3-Phenanthrenes/Anthracenes	11	52	3.0	2.1
Total Phenathrenes(P)	**160**	**160**	**4.1**	**6.2**
Dibenzothiophene(D)	1.9	8.4	<0.1	<0.1
C1-Dibenzothiophenes	1.1	4.4	<0.1	0.5
C2-Dibenzothiophenes	3.7	8.0	0.8	1.0
C3-Dibenzothiophenes	5.6	12.0	0.2	1.0
Total Dibenzothiophenes(D)	**12**	**33**	**0.9**	**2.6**
ΣNPD	**244**	**231**	**13**	**35**
Fluoranthene/Pyrene	209	305	1.2	5.9
C1-Fluoranthenes/Pyrenes	53	109	0.3	2.2
C2-Fluoranthenes/Pyrenes	32	68	0.3	1.7
C3-Fluoranthenes/Pyrenes	22	38	0.3	1.8
Total Fluoranthenes/Pyrenes	**317**	**520**	**4.0**	**12**
Benzanthracene/Chrysene	92	126	0.8	3.0
C1-Benzanthracenes/Chrysenes	25	31	0.3	1.5
C2-Benzanthracenes/Chrysenes	7.4	25	0.2	0.5
Total Benzanthracenes/Chrysenes	**124**	**183**	**1.2**	**5.0**
Benzofluorathenes/Benzopyrene	140	246	1.1	5.6
C1-Benzofluorathenes/Benzopyrenes	44	110	<0.1	4.0
C2-Benzofluorathenes/Benzopyrenes	15	42	0.8	2.9
Total Benzofluorathenes/Benzpyrenes	**199**	**398**	**1.7**	**13**
m/z 276	129	163	1.2	7.0
C1-m/z276*	38	59	0.6	4.7
c2-m/z276*	23	72	0.3	3.4
Total m/z276*	**190**	**284**	**2.1**	**15**
Total 2-6 ring PAH	**1110**	**1640**	**24.8**	**82.5**
% 4-6 ring PAHs as a % of the total PAHs	**74.9**	**84.5**	**38.0**	**56.2**

3.3.3 ICP-OES/ICP-MS – Elemental Analysis

3.3.3.1 Elemental Analysis

The elemental results are detailed in tables 9 and 10 below. The elemental results along with the historic data are detailed in tables 11 and 12, in addition comparison charts with previous year's data are provided for each station in section 3.4 . The concentrations of aluminium, and calcium are expressed as percent (%) oxides and the trace elements as mg/kg (dry weight). The standard deviation for the historic data of each station were calculated, the number of standard deviations the 2021 results were from the historic mean were calculation and tabulated in Table 13.

As no elemental analysis was included in the 2016 or 2018 surveys, the last data set for the stations was obtained in 2014. As in previous surveys, the soft shore sediments (Gluss Voe and the Houb of Scatsta) were not included in the stations for elemental analysis.

The laboratory performing the major and trace elemental analysis changed in 2021. This change originated due to uncertainty as to whether the previous laboratory was still able to perform the analysis. The analysis of the 2021 samples was performed by SGS United Kingdom Limited.

The methodology used in 2021 was the same methodology used in previous surveys as outlined in the 2014 Chemical and macrobenthic monitoring in Sullom Voe Sediments report (Appendix 2). The concentrations of a suite of major and trace elements were determined by spectrometry after total acid digestion of the sediment. The concentrations of the elements were determined by inductively-coupled plasma emission spectrometry (ICP-OES) and inductively-coupled plasma mass spectrometry (ICP-MS).

A direct comparison of the average results in mg/Kg (dry sed.) un-normalised, for all stations for each trace element to the 2014 demonstrates little change in the concentration of trace metals. See Table 11.

The absorption of metals to sediments is strongly correlated with the proportion of fine material (<65µm). To mitigate against the effects of particle size, the protocol to assess the trace elemental results to the historic data is to normalise the trace elemental results against the aluminium result at each station. The aluminium results in 2021 have shown a significant increase against the mean for the historic data set at all stations except SV12 and SV17. Where a significant change in aluminium content was observed a significant change in the particle size distribution was not observed. The change in the aluminium concentrations could originate from factors associated with the change in laboratory, such as instrumentation, applied calibration ranges and sample dilutions. Following the survey protocols, the results for the trace elements are normalised against the aluminium. The aluminium concentration has increased at the majority of sites, so the resulting observation for the trace elements in the 2021 survey is that the concentrations have decreased against the historic trend.

The most abundant trace element analysed at all of stations was strontium, ranging from 327 mg/kg (Station SV1) to 1386 mg/kg (Station SV12), compared with 465-1585 mg/kg in 2014. Barium was the second most abundant element analysed, with values ranging from 129 mg/kg (Station OV5B) to 465 mg/kg (Station SV6), compared with 291-768mg/kg in 2014.

A significant increase was observed in the mean aluminium concentration for the un-normalised concentration at 9 out of the 19 stations. Across the 19 stations there was an average relative 54% increase on the 2014 result. Across all stations, the mean 2021 aluminium result was 14.2% (m/m), in 2014 this was 9.12%(m/m) and the historic mean is 8.5% (m/m). The mean and standard deviation of the historic data set 1985-2014 were calculated and used to assess the extent of change in 2021 to the historic data set. The mean aluminium concentration in 2021 was +4.00 standard deviations from the historic mean indicating a significant change, although this was change was more evident at half the stations.

The results for SV1 demonstrated the most significant change in the major and trace elements. This station typically has very high mud content and low content of shell-based sediment. The most significant change was for the aluminium content, which was 26.3 % (m/m) in 2021, while it was 8 % (m/m) in 2014.

The 2021 the average un-normalised concentrations of all trace elements were within 25% of the 2014 values. The 2021 the average un-normalised concentration of chromium across all stations was 5.4 mg/Kg lower than the 2014 value, which is 9.2% lower as a relative percentage. The 2021 the average un-normalised concentration of copper across all stations was 1.0 mg/Kg higher than the 2014 value, which is 18% higher as a relative percentage. The 2021 the average un-normalised concentration of nickel across all stations was 1.6 mg/Kg lower than the 2014 value, which is 7.2% lower as a relative percentage. The 2021 the average un-normalised concentration of vanadium across all stations was 3.2 mg/Kg lower than the 2014 value, which is 6.3% lower as a relative percentage. The 2021 the average un-normalised concentration of zinc across all stations was 9.3 mg/Kg higher than the 2014 value, which is 21% higher as a relative percentage. The 2021 the average un-normalised concentration of lead across all stations was 4.2 mg/Kg lower than the 2014 value, which is 21% lower as a relative percentage.

The aluminium concentration is used to normalise the trace element results for trend analysis against the historic data set. At some stations there was an increase in aluminium concentration, this may account for negative biases observed in the 2021 trace elements results at these stations.

There appears to be little change in the calcium results for the un-normalised concentration at all stations. There was an average 1% increase to the 2014 result (relative 38.6% increase). The mean normalised 2021 calcium result was 1.28% (m/m), in 2014 this was 1.66% (m/m) and the historic mean is 3.13% (m/m). The mean calcium concentration in 2021 was -1.24 standard deviations from the historic mean indicating some change. The largest changes were observed at SV1 (-10.1 SD) and SV10 (-2.5 SD).

There appears to be little change in the chromium results for the un-normalised concentration at all stations. Across all stations, there was an average 5.4 mg/kg decrease to the 2014 result (relative 9.2% decrease). A decrease was also observed in the mean chromium concentration for the results normalised to aluminium at all stations (except SV17). The mean normalised 2021 chromium result was 3.54 mg/kg, in 2014 this was 5.89 mg/kg and the historic mean is 6.59 mg/kg. The mean chromium concentration in 2021 was -3.44 standard deviations from the historic mean indicating significant change overall. The largest change was observed at SV1 (-12.0 SD). It is worth noting the variation in the chromium concentration at all stations has been very low so that any changes may be observed as significant.

There appears to be little change in the copper results for the un-normalised concentration at all stations. Across all stations there was an average 1.0 mg/kg increase to the 2014 result (relative 18% increase). At some stations the concentration was increased, and others decreased, there is a high deviation in the historical data set for copper. A decrease was observed in the mean copper concentration for the results normalised to aluminium at all stations (except SV17). The mean normalised 2021 copper result was 1.07 mg/kg, in 2014 this was 1.52 mg/kg and the historic mean is 2.20 mg/kg. The mean copper concentration in 2021 was +2.49 standard deviations from the historic mean indicating there had been some change overall. The largest change was observed at SV1 (-9.1 SD).

There appears to be little change in the nickel results for the un-normalised concentration at all stations. Across all stations there was an average 1.6 mg/kg decrease to the 2014 result (relative 7.2% decrease). There is a high deviation in the historical data set for nickel. A decrease was observed in the mean nickel concentration for the results normalised to aluminium at all stations. The mean normalised 2021 nickel result was 1.67 mg/kg, in 2014 this was 2.73 mg/kg and the historic mean is 3.75 mg/kg. The mean nickel concentration in 2021 was -1.1 standard deviations from the historic mean indicating some change overall. The largest changes were observed at SV1 (-3.8 SD).

There appears to be little change in the vanadium results for the un-normalised concentration at all stations. Across all stations there was an average 3.2 mg/kg decrease to the 2014 result (relative 6.3% decrease). A decrease was observed in the mean vanadium concentration for the results normalised to aluminium at all stations. The mean normalised 2021 vanadium result was 3.41 mg/kg, in 2014 this was 5.60 mg/kg and the historic mean is 6.19 mg/kg. The mean vanadium concentration in 2021 was -2.95 standard deviations from the historic mean indicating significant change overall. The largest change were observed at SV1 (-18.0 SD).

The mean zinc concentration for the un-normalised concentration at all stations were broadly comparable to the 2014 result. Across all stations there was an average 9.3 mg/kg increase to the 2014 result (relative 21% increase). A contrasting decreasing trend was observed in the mean zinc concentration for the results normalised to aluminium at all stations (except SV5. SV8, SV17). The mean normalised 2021 zinc result was 4.59 mg/kg, in 2014 this was 5.94 mg/kg and the historic mean is 6.14 mg/kg. The mean zinc concentration in 2021 was -1.98 standard deviations from the historic mean indicating some change overall. The largest changes were observed at SV1 (-7.0 SD).

There appears to be little change in the lead results for the un-normalised concentration at all stations. Across all stations there was an average 4.2 mg/kg decrease to the 2014 result (relative 21% decrease). A decrease was observed in the mean lead concentration for the results normalised to aluminium at all stations. The mean normalised 2021 vanadium result was 1.08 mg/kg, in 2014 this was 2.06 mg/kg and the historic mean is 1.8 mg/kg. The mean lead concentration in 2021 was -1.07 standard deviations from the historic mean indicating some change overall. The largest changes were observed at SV1 (-3.3 SD).

With the exception of station SV1, there appears to be little/some change in the un-normalised trace element concentrations. At some stations the aluminium content has been observed at a significantly higher concentrations that in previous surveys, as the trace element results are normalised against the aluminium results, a negative bias trend is observed. This is most apparent at SV1 where the aluminium concentration has increased the most against the historic trend.

Table 9 - Concentrations of aluminium oxide, calcium oxide, barium and strontium.

	Units	% (m/m) (Dry Weight)	% (m/m) (Dry Weight)	mg/Kg (Dry Weight)	mg/Kg (Dry Weight)
Client Reference:	**Matrix**	**Al2O3**	**CaO**	**Barium as Ba**	**Strontium as Sr**
SV1	Sediment	26.3	8.0	186	327
SV3	Sediment	10.3	22.3	190	1232
SV4	Sediment	10.3	21.4	208	1245
SV5	Sediment	10.6	19.3	229	1184
SV7	Sediment	12.4	19.5	235	1086
SV8	Sediment	10.1	18.9	235	1198
SV8A	Sediment	15.9	13.5	367	955
SV9	Sediment	11.0	14.9	213	753
SV10	Sediment	14.6	11.7	305	804
SV11	Sediment	15.5	13.4	251	716
SV17	Sediment	7.7	25.9	200	1698
SV12	Sediment	8.1	22.3	180	1386
SV33	Sediment	13.9	17.1	211	924
SV34	Sediment	14.1	16.0	213	887
SV35	Sediment	16.4	8.3	421	840
SV6	Sediment	19.7	8.6	465	802
SV6A	Sediment	16.6	8.5	437	777
SV6F	Sediment	16.9	5.9	258	507
SV32	Sediment	18.5	5.9	324	571
OV1B	Sediment	16.0	8.1	358	653
OV2B	Sediment	14.1	10.2	280	682
OV3B	Sediment	12.7	11.1	249	699
OV4B	Sediment	11.9	14.2	244	810
OV5B	Sediment	7.8	6.8	129	408

Table 10 - Concentrations of elements in mg/Kg (dry sed.)

	Units	mg/Kg (Dry Weight)	mg/Kg (Dry Weight)	mg/Kg (Dry Weight)	mg/Kg (Dry Weight)	mg/Kg (Dry Weight)	mg/Kg (Dry Weight)	mg/Kg (Dry Weight)
Client Reference:	**Matrix**	**Chromium as Cr**	**Copper as Cu**	**Nickel as Ni**	**Vanadium as V**	**Zinc as Zn**	**Lead as Pb**	**Cadmium as Cd**
SV1	Sediment	96.6	29.9	50.5	111.2	124.5	30.7	0.29
SV3	Sediment	48.4	9.9	21.9	51.5	52.1	13.8	0.27
SV4	Sediment	43.9	8.7	20.1	45.1	57.4	15.8	0.27
SV5	Sediment	43.7	10.4	21.4	46.2	68.5	16.3	0.21
SV7	Sediment	47.2	13.8	22.4	49.4	75.3	13.5	0.17
SV8	Sediment	39.5	11.7	18.9	38.7	59.2	14.0	0.18
SV8A	Sediment	40.7	8.9	19.5	36.4	51.9	13.7	0.11
SV9	Sediment	38.7	8.9	19.2	37.2	38.4	12.7	0.12
SV10	Sediment	43.7	15.2	24.5	40.2	50.6	13.7	0.20
SV11	Sediment	61.8	11.1	24.9	45.6	65.7	14.4	0.26
SV17	Sediment	45.0	16.2	20.7	28.2	44.9	11.2	0.23
SV12	Sediment	21.0	4.4	10.2	19.9	27.3	8.6	0.07
SV33	Sediment	38.7	7.3	19.3	36.2	43.0	9.9	0.05
SV34	Sediment	37.1	6.7	19.8	36.0	43.8	9.4	0.07
SV35	Sediment	16.9	4.6	7.2	19.8	24.2	14.2	0.09
SV6	Sediment	60.0	26.4	27.9	61.0	99.9	18.0	0.08
SV6A	Sediment	68.3	39.7	30.9	71.7	102.4	12.7	0.59
SV6F	Sediment	66.3	33.1	31.1	67.7	90.9	17.4	0.29
SV32	Sediment	68.0	26.7	32.8	70.5	100.6	19.2	0.22
OV1B	Sediment	32.5	8.6	17.6	27.2	40.6	12.1	0.18
OV2B	Sediment	27.2	4.5	10.4	22.2	30.9	7.5	0.14
OV3B	Sediment	29.5	4.4	10.8	25.2	21.7	10.4	0.08
OV4B	Sediment	29.9	11.2	11.6	25.5	37.5	10.5	0.06
OV5B	Sediment	21.8	4.9	10.8	21.4	34.3	7.6	0.27

Table 11 – Comparison of sediment elemental concentrations for 2021 and 2014 (expressed as mg/Kg, un-normalised).

Station	Matrix	Al2O3		CaO		Chromium as Cr		Copper as Cu		Nickel as Ni		Vanadium as V		Zinc as Zn		Lead as Pb	
	Year	2021	2014	2021	2014	2021	2014	2021	2014	2021	2014	2021	2014	2021	2014	2021	2014
SV1	Sediment	26	8	8	10	97	92	30	30	51	43	111	101	124	112	31	36
SV3	Sediment	10	8	22	11	48	49	10	8	22	21	52	50	52	44	14	16
SV4	Sediment	10	7	21	22	44	50	9	10	20	23	45	52	57	50	16	17
SV5	Sediment	11	9	19	17	44	46	10	9	21	21	46	45	68	44	16	18
SV7	Sediment	12	10	20	11	47	69	14	16	22	30	49	66	75	71	14	23
SV8	Sediment	10	7	19	22	39	37	12	10	19	19	39	36	59	38	14	15
SV8A	Sediment	16	10	13	13	41	40	9	7	20	20	36	32	52	34	14	18
SV9	Sediment	11	9	15	16	39	51	9	9	19	26	37	47	38	45	13	16
SV10	Sediment	15	10	12	13	44	49	15	8	25	24	40	42	51	40	14	16
SV11	Sediment	16	10	13	13	62	53	11	8	25	26	46	46	66	45	14	14
SV17	Sediment	8	7	26	21	45	38	16	11	21	18	28	34	45	41	11	15
SV12	Sediment	8	8	22	20	21	28	4	4	10	14	20	24	27	23	9	12
SV33	Sediment	14	8	17	16	39	45	7	6	19	22	36	38	43	36	10	11
SV34	Sediment	14	9	16	16	37	44	7	5	20	22	36	37	44	36	9	12
SV35	Sediment	16	9	8	13	17	20	5	3	7	9	20	22	24	19	14	18
SV6	Sediment	20	11	9	7	60	70	26	36	28	29	61	65	100	94	18	26
SV6A	Sediment	17	11	9	5	68	75	40	34	31	33	72	72	102	87	13	24
SV6F	Sediment	17	11	6	4	66	88	33	34	31	38	68	82	91	99	17	26
SV32	Sediment	18	11	6	6	68	85	27	27	33	36	71	83	101	86	19	26

Table 12 – Comparison of selected sediment elemental concentration, 1985-2021 (expressed as mg/Kg, normalised against Al).

Station Al (% oxides)	1	3	4	5	7	8	8a	9	10	11	17	12	33	34	35	6	6a	6f	32
2021	26.31	10.28	10.25	10.64	12.43	10.10	15.94	11.05	14.60	15.52	7.68	8.11	13.88	14.08	16.41	19.66	16.58	16.86	18.47
2014	8.41	7.5	6.95	8.59	9.59	7.3	10.11	8.85	9.91	9.81	7.42	7.78	8.33	8.76	9.45	10.83	11.24	11.37	11.12
2008	8.35	8.32	7.5	8.68	10.34	7.21	10.12	8.47	10.48	9.67	6.39	8.16	8.69	8.49	8.73	11.66	11.4	11.41	10.74
2005																			
2004															11.19				
2003															10.35				
2002	9.35	7.06	5.6	7.31	7.55	5.8	9.47	8.83	8.39	7.51	9.89	7.01	8.17	7.97	10.85	10.76	10.93	21.55	10.89
2001															9.05				
2000															9.8				
1996	9.35	7.29	4.5	7.94	3.52	10.23	10.02	10.49	9.8	9.7	12.27	12.01	11.25	5.73	8.81	8.9	3.38	4.12	12.2
1990	9.43	6.3	6.58	6.68	10.43	9.78	8.09	4.19	9.52	6.33	9.67	10.25	10.05	8.9	8.01	7.93	1.39	1.67	5.38
1985	7.51	6.56	4.94	5.92	4	8.53	7.24	9.54	9.4	8.02	8.39	8.9	5.51	2.73	4.31	8.61			10.54

Station Ca (% oxides)	1	3	4	5	7	8	8a	9	10	11	17	12	33	34	35	6	6a	6f	32
2021	0.30	2.17	2.09	1.81	1.57	1.87	0.84	1.35	0.80	0.86	3.36	2.75	1.23	1.13	0.51	0.44	0.52	0.35	0.32
2014	1.19	2.73	3.22	2.02	1.16	3.08	1.3	1.86	1.3	1.28	2.89	2.57	1.96	1.81	1.33	0.6	0.44	0.35	0.54
2008	1.21	2.11	2.7	1.94	0.98	2.88	1.15	2.03	1.15	1.33	3.99	2.43	1.87	2.02	1.8	0.44	0.44	0.39	0.59
2005																			
2004															0.39				
2003															0.48				
2002	1.06	3.05	5.12	2.84	2.64	4.48	1.46	1.81	1.93	2.48	1.22	2.86	2.01	2.19	0.44	0.67	0.45	0.42	0.52
2001															1.36				
2000															0.8				
1996	1.1	4.71	8.2	3.04	10.57	1.49	1.81	1.43	1.87	1.68	0.47	0.86	0.64	5.56	2.41	2.04	10.97	10.22	0.53
1990	1.06	4.52	4.33	4.41	0.5	0.51	2.66	8.85	1.51	4.25	1.56	1.47	1.25	0.78	1.98	2.78	33.3	26.85	5.87
1985	1.01	3.59	6.01	3.92	8.03	2.57	3.29	1.42	1.57	2.48	2.21	1.91	5.21	14.56		3.1			0.88

Station Cr (mg/Kg)	1	3	4	5	7	8	8a	9	10	11	17	12	33	34	35	6	6a	6f	32
2021	3.67	4.71	4.28	4.11	3.80	3.91	2.55	3.50	2.99	3.98	5.85	2.59	2.79	2.64	1.03	3.05	4.12	3.93	3.68
2014	10.91	6.53	7.16	5.35	7.19	5.02	3.94	5.73	4.95	5.41	5.13	3.58	5.38	5.07	2.07	6.42	6.7	7.77	7.61
2008	12.34	7.21	8.27	6.34	7.54	5.55	5.24	6.61	5.53	6.31	5.32	4.78	5.64	5.3	2.52	6.95	7.28	8.41	8.66
2005																			
2004															1.7				
2003															1.35				
2002	11.34	7.93	7.32	6.16	7.68	4.66	4.65	5.32	6.2	6.52	4.75	5.14	5.39	5.02	1.66	7.06	7.87	8.31	8.26
2001															1.66				
2000															0.9				
1996	11.55	7.54	8.44	5.67	6.82	4.89	4.99	5.53	5.51	4.54	4.5	4.16	7.73	5.06	5.76	7.42	4.44	4.13	7.3
1990	10.54	8.57	8.21	6.44	7.77	8.69	8.03	8.59	5.88	7.27	6.2	5.95	5.07	8.76	6.74	6.43	17.27	14.97	6.69
1985	10.92	7.32	8.7	6.76	6.75	5.28	5.94	6.29	6.6	6.11	6.32	6.52	4.54	5.13		6.16			4.08

Station Cu (mg/Kg)	1	3	4	5	7	8	8a	9	10	11	17	12	33	34	35	6	6a	6f	32
2021	1.14	0.97	0.85	0.98	1.11	1.16	0.56	0.80	1.04	0.72	2.11	0.54	0.53	0.47	0.28	1.34	2.39	1.96	1.45
2014	3.6	1.11	1.47	0.99	1.66	1.31	0.66	1.04	0.76	0.81	1.54	0.46	0.71	0.62	0.3	3.36	3.06	2.98	2.39
2008	3.83	1.44	2.13	1.84	2.03	1.66	1.09	1.53	1.15	1.14	2.03	0.86	1.15	1.06	0.69	2.06	3.25	3.16	2.98
2005																			
2004															0.54				
2003															0.29				
2002	3.53	1.84	1.96	1.64	2.25	2.07	0.95	0.91	1.19	1.2	0.91	0.71	0.98	0.75	0.37	3.25	3.75	3.29	2.39
2001															0.66				
2000															0.6				
1996	3.64	1.65	2.44	1.26	2.84	0.98	1.1	1.05	1.02	0.93	3.26	2.5	2.93	1.05	1.02	2.36	1.48	1.46	2.38
1990	3.5	2.54	2.43	1.8	3.26	3.89	2.6	5.73	1.47	3	1.15	1.56	1.49	3.93	1.87	2.77	8.63	7.78	2.42
1985	4.26	2.9	3.85	3.72	4.25	2.11	2.49	1.89	2.13	2.24	2.15	2.02	3.09	6.23		3.14			1.23

Station Ni (mg/Kg)	1	3	4	5	7	8	8a	9	10	11	17	12	33	34	35	6	6a	6f	32
2021	1.92	2.13	1.96	2.01	1.80	1.87	1.23	1.74	1.68	1.61	2.69	1.26	1.39	1.40	0.44	1.42	1.86	1.85	1.78
2014	5.08	2.8	3.35	2.47	3.14	2.54	2.01	2.9	2.45	2.67	2.43	1.76	2.64	2.45	0.94	2.71	2.97	3.31	3.21
2008	5.15	2.76	3.33	2.53	2.9	2.08	1.98	2.6	2.19	2.48	2.03	1.84	2.3	2.36	0.92	1.94	2.81	3.24	3.35
2005																			
2004															0.8				
2003															0.87				
2002	5.13	3.54	3.57	3.01	3.58	2.41	2.11	2.49	2.98	3.06	2.22	2.57	2.57	2.63	0.92	2.97	3.39	3.62	3.58
2001															1.33				
2000															0.7				
1996	5.99	2.61	3.11	2.52	1.7	2.4	2.4	3.05	2.55	2.47	3.42	2.08	3.91	1.4	2.84	3.82	1.18	0.49	3.85
1990	6.68	4.76	4.86	4.49	5.27	5.32	5.32	6.44	4.52	5.37	4.34	4.68	4.38	6.29	5.12	4.04	9.35	11.98	5.39
1985	7.72	6.71	8.7	6.93	9.75	6.08	6.08	4.61	5	5.36	5.01	4.83	5.63	12.09		6.16			2.28

Station V (mg/Kg)	1	3	4	5	7	8	8a	9	10	11	17	12	33	34	35	6	6a	6f	32
2021	4.23	5.01	4.40	4.34	3.97	3.83	2.28	3.37	2.75	2.94	3.66	2.45	2.61	2.55	1.20	3.10	4.32	4.02	3.82
2014	12.06	6.66	7.47	5.25	6.86	4.88	3.17	5.30	4.27	4.68	4.60	3.11	4.60	4.25	2.30	5.99	6.37	7.19	7.44
2008	11.86	6.61	7.60	5.53	6.48	4.58	3.95	5.31	4.20	4.76	4.23	3.68	4.37	4.12	2.29	5.83	6.32	7.1	7.82
2005																			
2004															1.70				
2003															1.35				
2002	11.02	6.94	6.43	5.34	6.36	4.14	3.59	4.19	4.53	4.93	3.84	3.85	4.04	4.02	1.38	6.32	7.14	7.47	7.16
2001															1.99				
2000															1.30				
1996	11.44	7.54	8.67	5.54	7.95	4.3	4.29	4.77	4.59	3.81	7.17	3.66	7.56	4.54	4.99	7.08	5.03	6.07	7.05
1990	11.13	9.37	8.21	6.14	7.96	9.3	7.91	8.83	5.46	6.95	5.69	5.56	4.78	9.33	5.87	6.18	20.14	16.77	5.95
1985	11.58	7.47	8.50	6.76	7.25	4.34	5.66	4.61	5.32	4.86	4.53	4.72	3.81	7.33		7.2			1.8

Station Zn (mg/Kg)	1	3	4	5	7	8	8a	9	10	11	17	12	33	34	35	6	6a	6f	32
2021	4.73	5.07	5.60	6.44	6.06	5.86	3.26	3.48	3.46	4.23	5.84	3.37	3.10	3.11	1.47	5.08	6.18	5.39	5.45
2014	13.29	5.89	7.15	5.11	7.39	5.17	3.33	5.07	4.06	4.56	5.53	3.01	4.27	4.07	2.06	8.65	7.75	8.71	7.71
2008	13.17	5.77	8.13	5.76	7.54	5.83	4.25	5.43	4.2	4.76	6.1	3.92	4.26	4.24	2.86	6.52	8.51	9.11	8.38
2005																			
2004															1.88				
2003															1.64				
2002	14.33	7.79	9.46	6.02	7.95	6.03	4.01	4.3	4.41	5.06	3.94	3.71	3.92	3.89	1.47	9.11	9.61	9.23	7.53
2001															1.99				
2000															1.5				
1996	11.44	6.58	8.89	5.29	8.24	3.91	4.19	4.39	4.08	3.71	8.07	6.16	7.91	3.84	4.31	8.2	4.44	4.61	6.97

Station Pb (mg/Kg)	1	3	4	5	7	8	8a	9	10	11	17	12	33	34	35	6	6a	6f	32
2021	1.17	1.34	1.55	1.53	1.09	1.39	0.86	1.15	0.94	0.93	1.46	1.06	0.72	0.67	0.86	0.91	0.77	1.03	1.04
2014	4.24	2.07	2.49	2.12	2.39	2.05	1.76	1.78	1.59	1.38	1.98	1.54	1.34	1.37	1.87	2.44	2.1	2.32	2.33
2008	4.29	1.56	2.44	1.47	2.19	2.06	1.65	1.24	1.58	1.14	1.28	0.28	0.64	1.1	1.6	2.08	2.35	2.45	2.64
2005																			
2004															1.85				
2003															2.03				
2002	4.2	2.78	3.98	2.61	2.62	1.81	1.4	2.06	1.29	1.72	1.35	1.51	1.25	0.77	1.61	2.4	2.79	0.61	2.01
2001															2.32				
2000															1.6				
1996	2.35	0.96	1.33	0.88	1.14	0.78	0.8	0.76	0.61	0.82	0.81	0.83	1.07	0.87	0.57	1.12	1.18	0.97	0.74
1990	4.77	2.38	1.67	1.5	1.82	2.04	1.98	2.39	1.37	1.9	1.24	1.37	1.69	2.81	1.12	1.51	6.47	4.79	1.49
1985	4.66	2.29	2.43	2.36	3	1.64	1.24	1.26	1.17	1	1.07	0.9	2	3.3		2.21			1.61

Table 13 – Number of standard deviations the 2021 result is relative to the historic mean for the station.

		Normalised as Aluminium Oxide						
Station	Al	Ca	Cr	Cu	Ni	V	Zn	Pb
Units	% oxides	% oxides	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg
SV1	22.7	-10.1	-12.0	-9.1	-3.8	-18.0	-7.0	-3.3
SV3	4.3	-1.3	-4.1	-1.4	-1.1	-2.4	-1.6	-1.0
SV4	3.6	-1.4	-6.0	-1.9	-1.2	-4.1	-2.8	-0.9
SV5	2.9	-1.2	-3.9	-0.9	-0.9	-2.4	2.1	-0.5
SV7	1.6	-0.6	-7.9	-1.7	-0.9	-4.5	-4.4	-1.7
SV8	1.2	-0.5	-1.2	-0.8	-0.9	-0.7	0.6	-0.7
SV8A	5.5	-1.3	-2.1	-1.1	-1.1	-1.4	-1.6	-1.5
SV9	1.2	-0.5	-2.4	-0.7	-1.3	-1.3	-2.4	-0.7
SV10	7.2	-2.5	-4.8	-0.5	-1.4	-3.7	-4.5	-0.9
SV11	4.9	-1.2	-2.2	-1.0	-1.4	-2.0	-0.5	-0.9
SV17	-0.6	1.0	0.6	0.3	-0.4	-1.1	0.0	0.4
SV12	-0.5	1.0	-2.2	-1.0	-1.2	-1.9	-0.6	0.0
SV33	2.7	-0.6	-2.6	-1.2	-1.7	-1.6	-1.1	-1.3
SV34	2.9	-0.6	-2.1	-0.8	-0.8	-1.4	-4.9	-1.0
SV35	3.8	-1.0	-0.8	-0.9	-0.8	-0.8	-0.8	-1.5
SV6	6.6	-1.0	-7.7	-2.8	-1.5	-5.8	-2.7	-2.0
SV6A	1.8	-0.6	-0.9	-0.6	-0.7	-0.7	-0.6	-1.1
SV6F	0.9	-0.6	-1.2	-0.7	-0.6	-1.1	-1.1	-0.7
SV32	3.5	-0.5	-2.1	-1.5	-1.8	-1.1	-3.8	-1.1

3.4 SULLOM VOE STATIONS - 2021 DATA VIEWED AGAINST HISTORIC DATA

3.4.1 INNER BASIN AND SOUTHERN SULLOM VOE (STATIONS 1, 3, 4 AND 5)

3.4.1.1 Inner Basin Station SV1

For station SV1, the mud content in 2021 was 40.1%, which 42.9% lower than in 2018. The organic content for station SV1 in 2018 was 13.2%, which was -9.3% lower than the 2018 result.

The mean concentration of total aliphatic hydrocarbons (TAH) at station SV1 was 124 µg/g (dry matter). The relative standard deviation between the 3 TAH replicates was 36.4% indicating high variation in the sediment composition for TAH, the relative standard deviation between the 3 replicates in 2018 was 40%. The 2021 mean TAH result was -1.8 standard deviations of the historic mean for the results from 2004-2018. This suggests some change in the overall TAH concentration at station SV1 which correlates with the higher sand content and lower mud content observed at this station. The percentage of UCM in the TAH was similar to the historic mean result 2004-2018, indicating there has been little change in the composition of oil.

The concentration of 2-6 ring PAH concentration at station SV1, was lower in 2021 than historic mean for the results from 2004-2018. The 2021 2-6 ring PAH result was -1.2 standard deviations of the historic mean for the results from 2004-2018. This suggests some change in the overall PAH concentration at station SV1, which correlates with the higher sand content and lower mud content observed at this station. The percentage of 4-6 ring PAHs to the total PAHs was within 1 standard deviations from the historic mean indicating there has been little change.

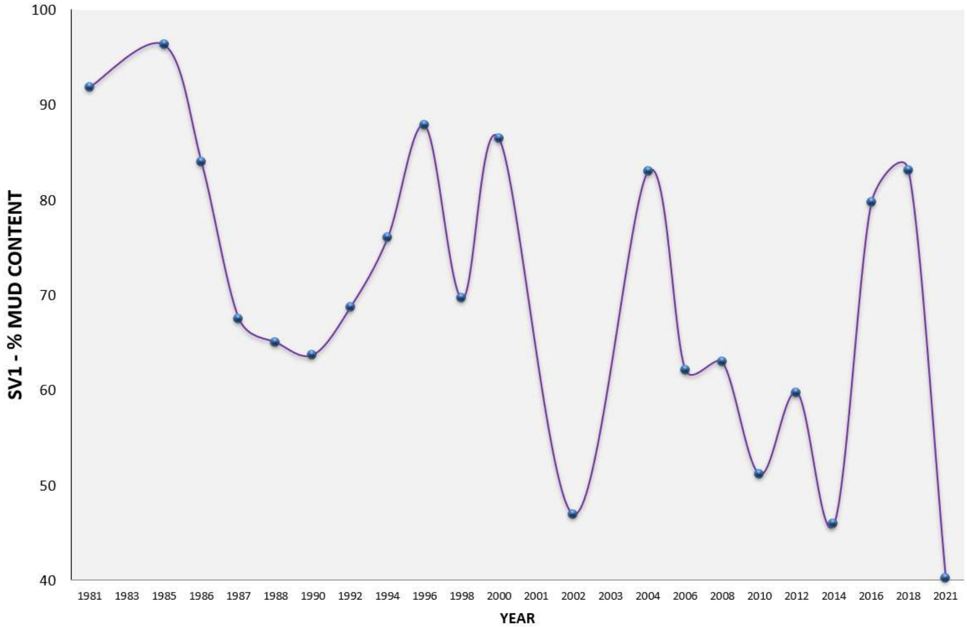

Figure 3 - SV1 Percentage Mud content

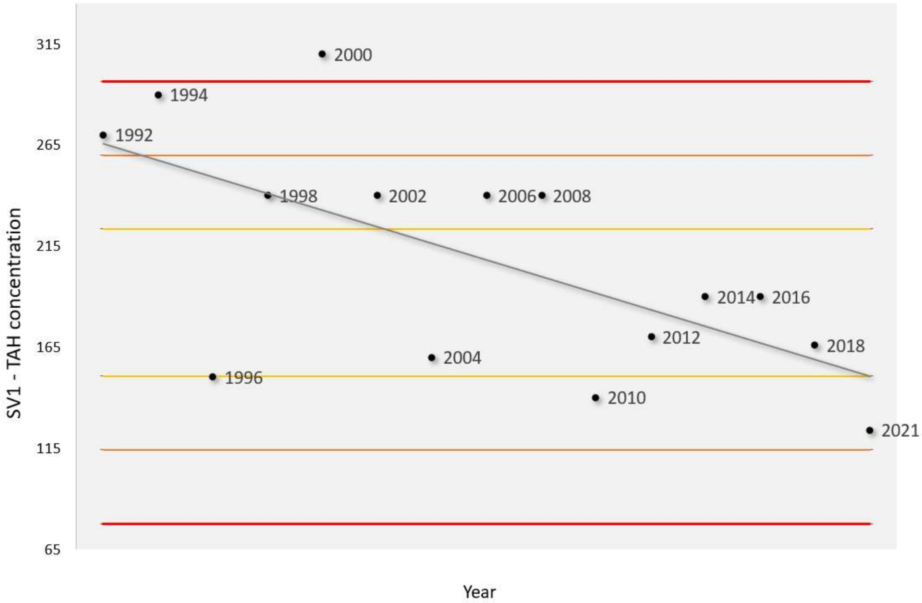

Figure 4 - SV1 Total Aliphatic Hydrocarbon concentration (µg.g^{-1} dry wt. sed.)

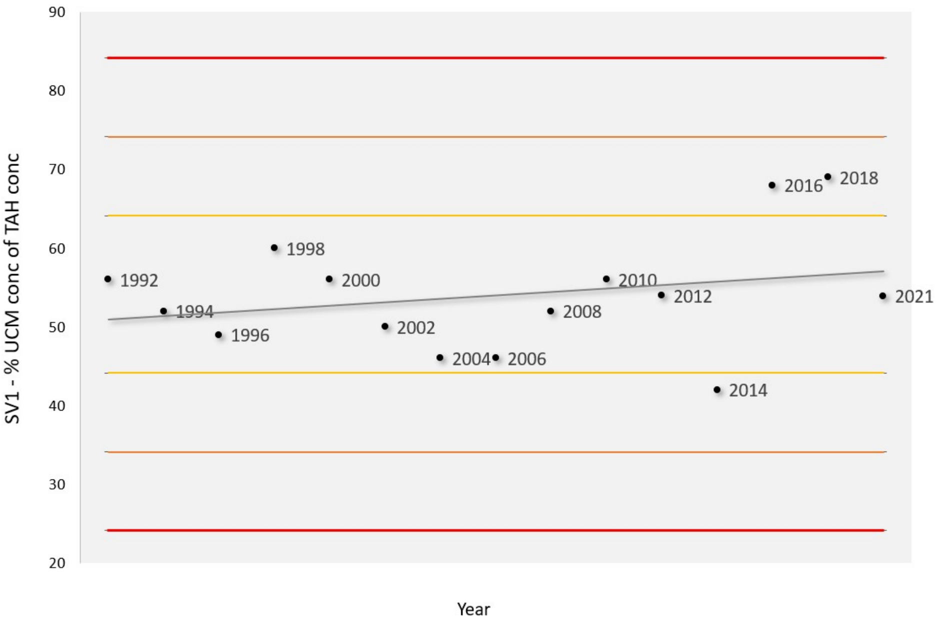

Figure 5 – SV1 Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

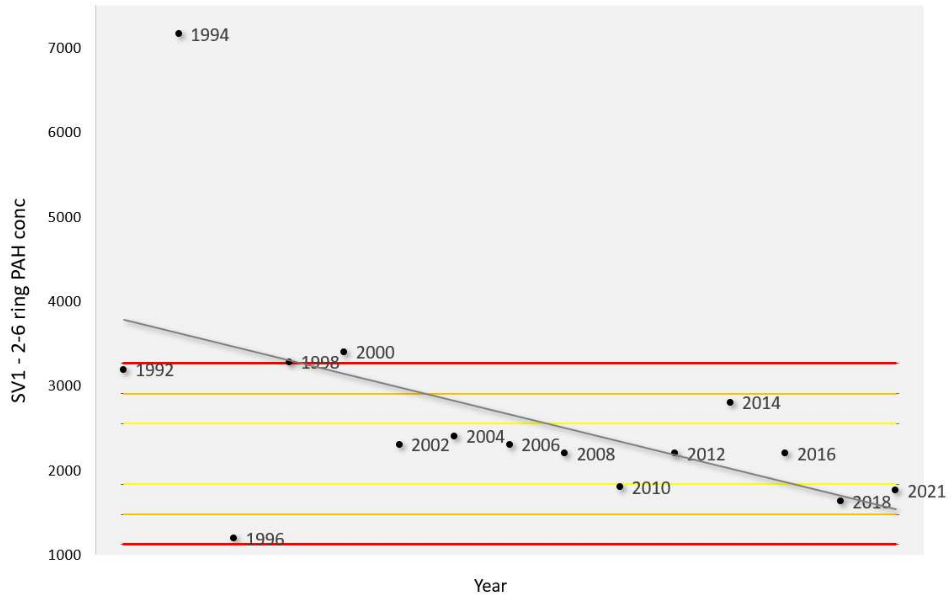

Figure 6 - SV1 2-6 ring PAH concentration (ng.g^{-1} dry sed.)

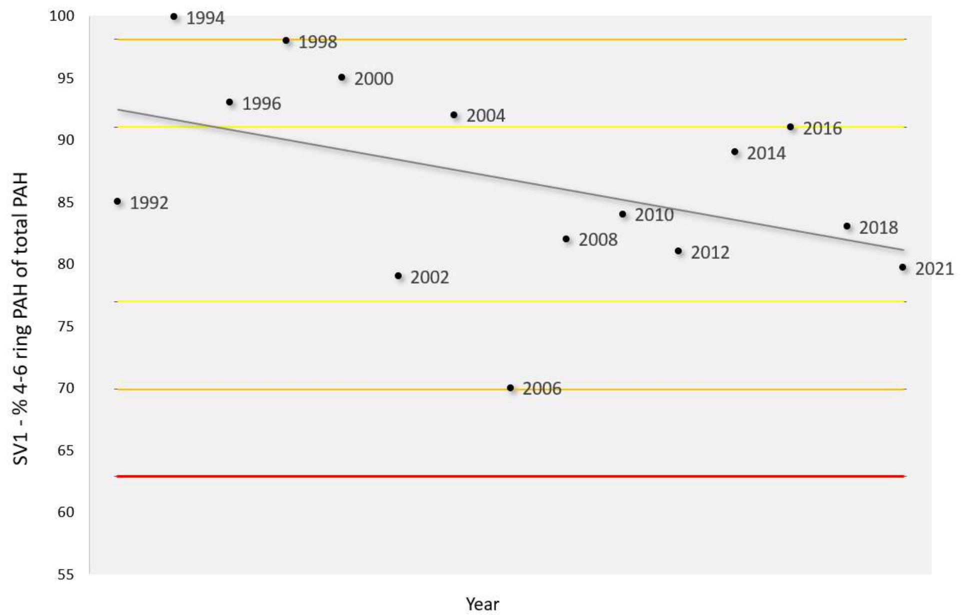

Figure 7 - SV1 4-6 ring PAHs as a percentage of the total PAHs (%)

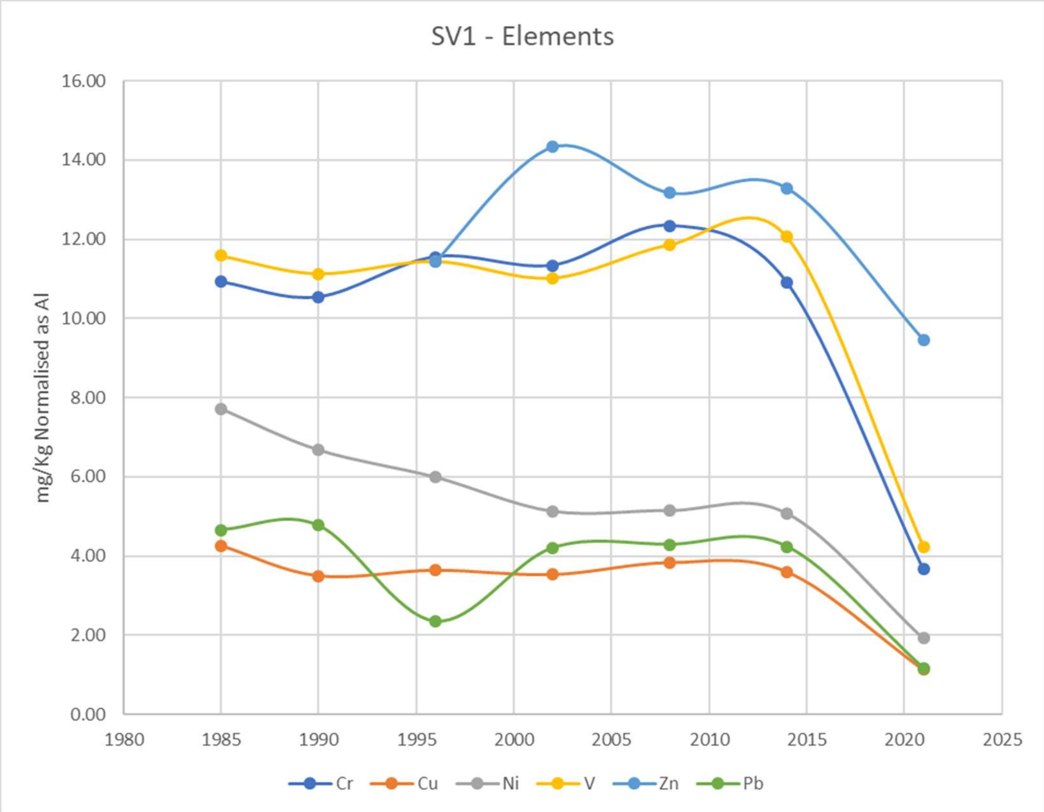

Figure 8 - SV1 Elements in mg/Kg (dry basis) normalised as Aluminium.

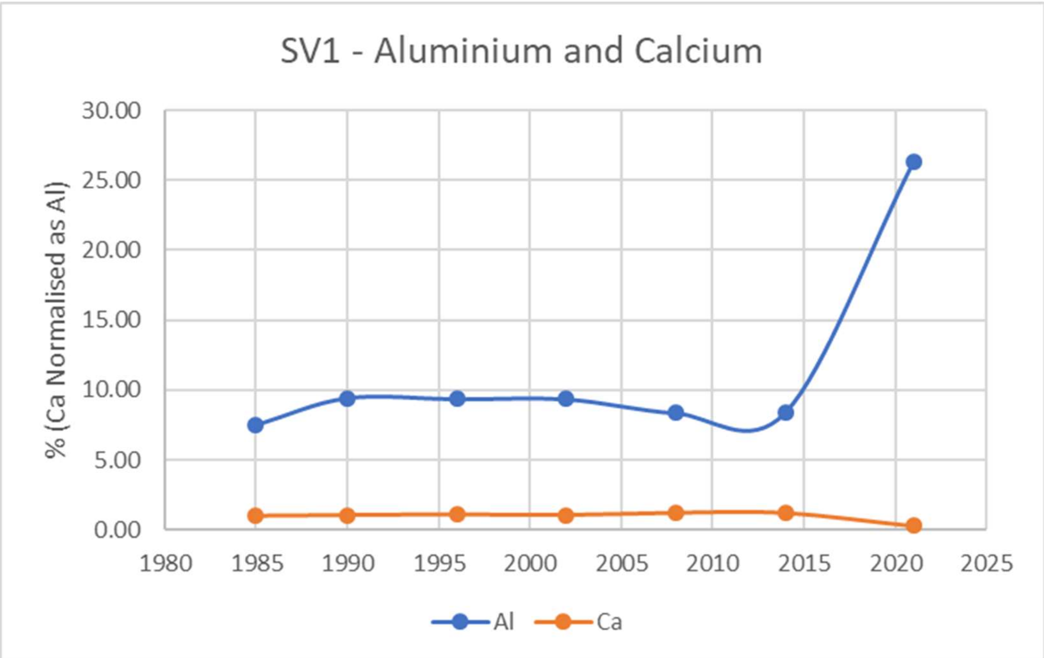

Figure 9 - SV1 Aluminium and Calcium in % (m/m - dry basis) Calcium normalised as Aluminium.

3.4.1.2 Southern Sullom Voe SV3

For station SV3, the mud content in 2021 was 38.3%, which 10.3% lower than in 2018. The organic content for station SV3 in 2021 was 6.88%, which was 1.4% higher than the 2018 result.

The mean concentration of total aliphatic hydrocarbons (TAH) at station SV3 was 23.0 µg/g (dry matter). The relative standard deviation between the 3 TAH replicates was 27.4% indicating moderate variation in the sediment composition for TAH. The 2021 mean TAH result was within 1 standard deviation of the historic mean for the results from 2004-2018. This suggests little change in the overall TAH concentration at station SV3. The percentage of UCM in the TAH was similar to the 2018 result which was higher than the historic mean result 2004-2018, indicating there continues to be some change to the composition of oil.

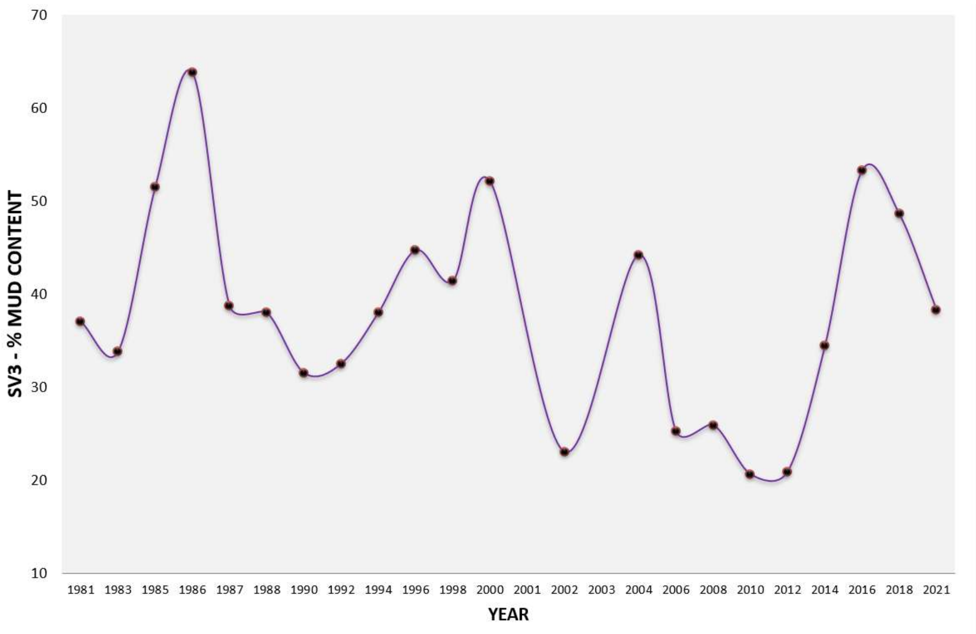

Figure 10 – SV3 Percentage Mud content

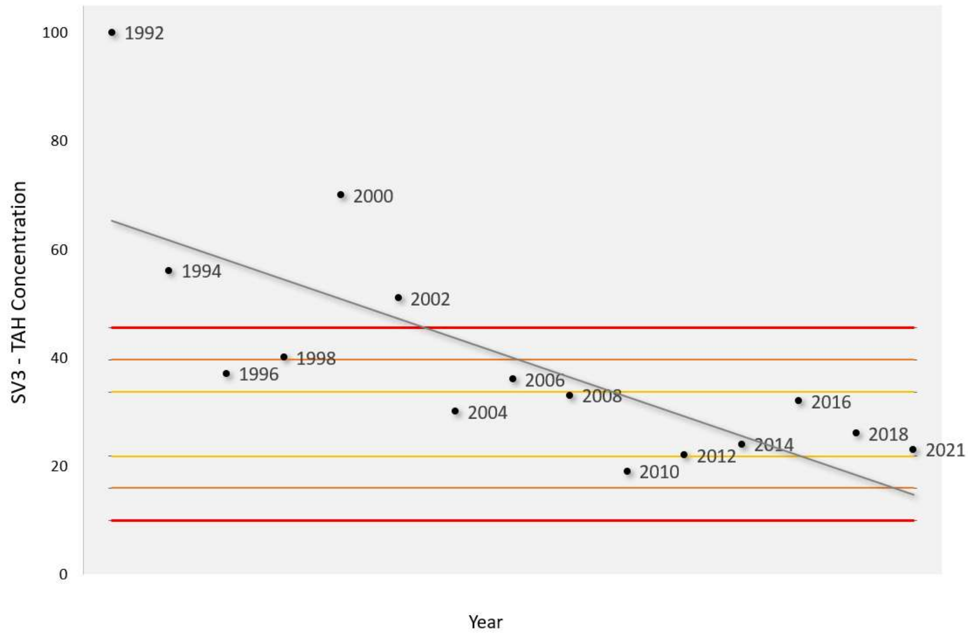

Figure 11 – SV3 Total Aliphatic Hydrocarbon concentration (µg.g^{-1} dry wt. sed.)

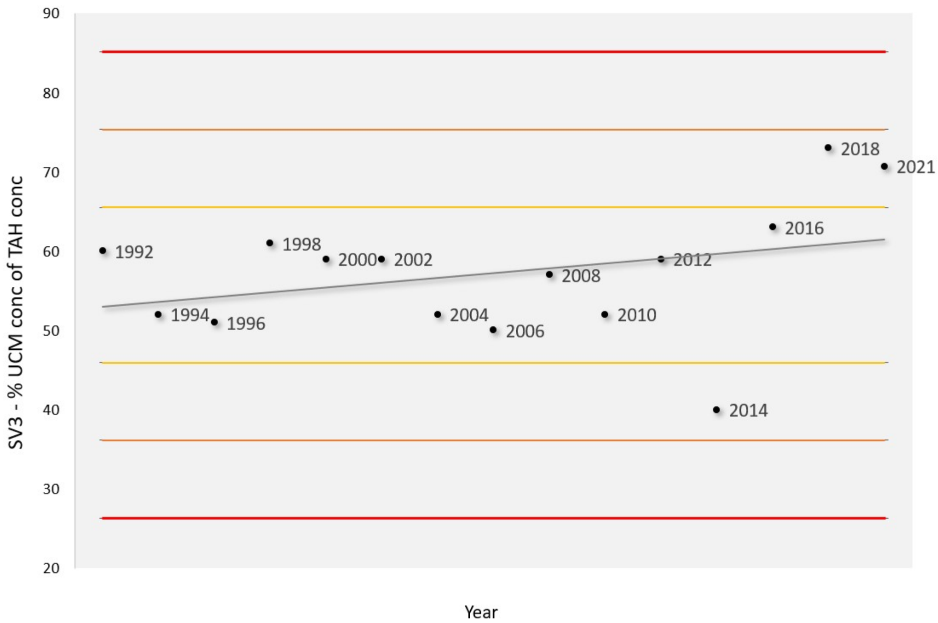

Figure 12 – SV3 Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

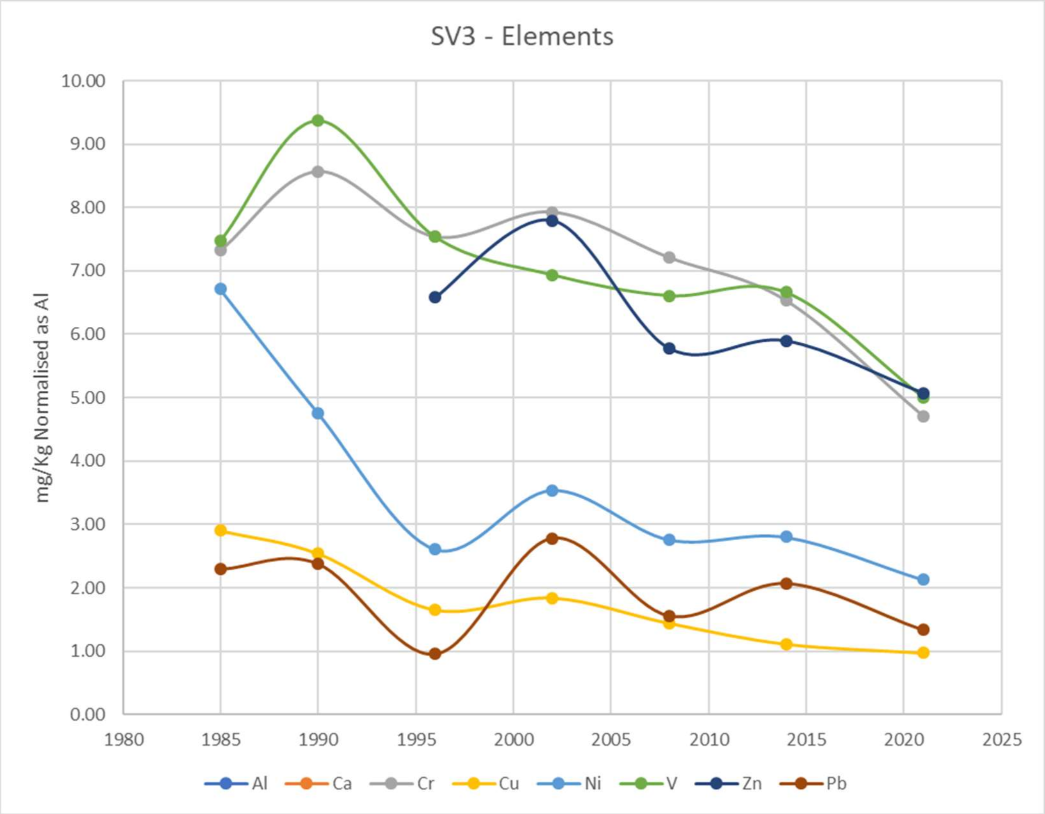

Figure 13 – SV3 Elements in mg/Kg (dry basis) normalised as Aluminium.

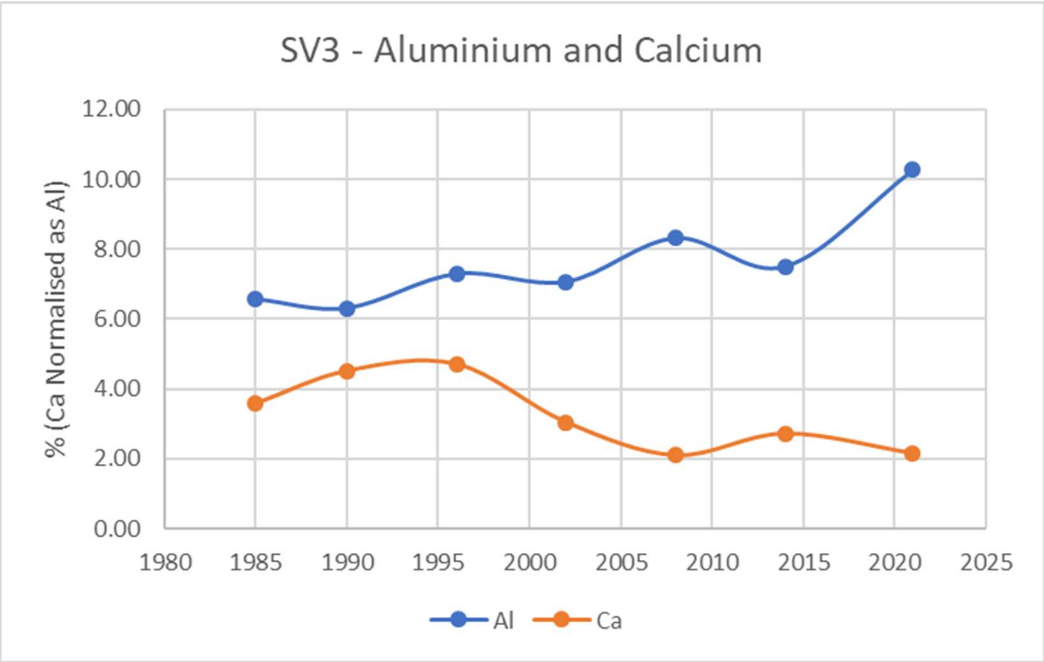

Figure 14 – SV3 Aluminium and Calcium in % (m/m - dry basis) Calcium normalised as Aluminium.

3.4.1.3 Southern Sullom Voe SV4

For station SV4, the mud content in 2021 was 42.6%, which was 9.5% lower than in 2018. The organic content for station SV4 in 2021 was 4.47%, which was a -1.3% to the 2018 result.

The concentration of total aliphatic hydrocarbons (TAH) at station SV4 in 2021 was similar to the 2018 result. The 2021 result was within 1 standard deviation from the historic mean for results 2004-2018. The relative standard deviation between the 3 TAH grab replicates was 23.9% indicating moderate variation in the sediment composition for TAH. The percentage of UCM in the TAH in 2021 was similar to the 2018 result which was higher than the historic mean result 2004-2018, indicating there continues to be some change to the composition of oil.

The concentration of 2-6 ring PAH concentration at station SV4 in 2021 was higher than the 2018 result. The 2021 result was within1 standard deviations from the historic mean, indicating there was little change against the historic mean. The percentage of 4-6 ring PAHs of the total PAHs has increased, the 2021 result was -1.1 standard deviations from the historic mean. This indicates a continuation of some change from the historic mean.

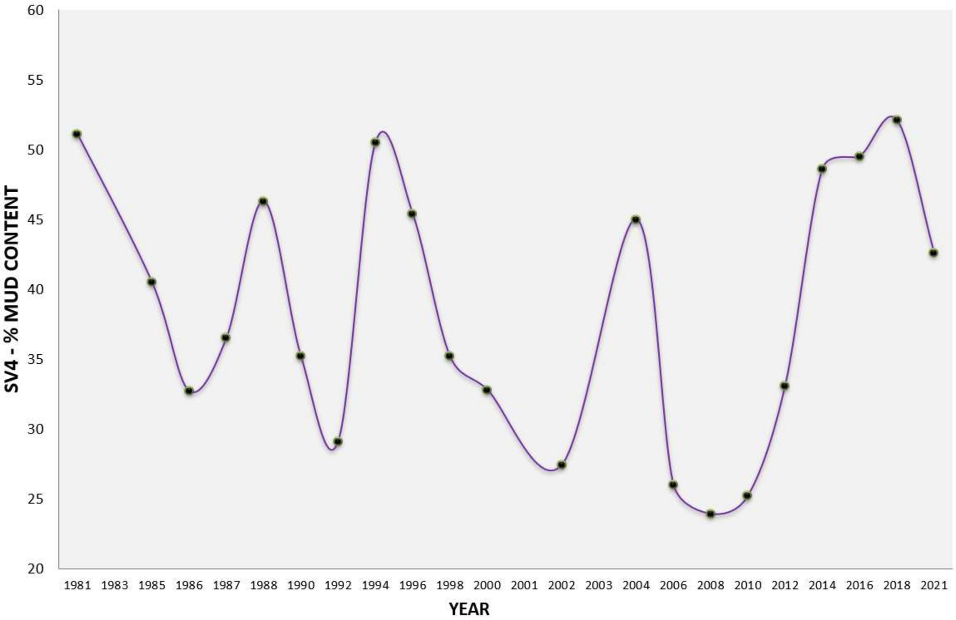

Figure 15 – SV4 Percentage Mud content

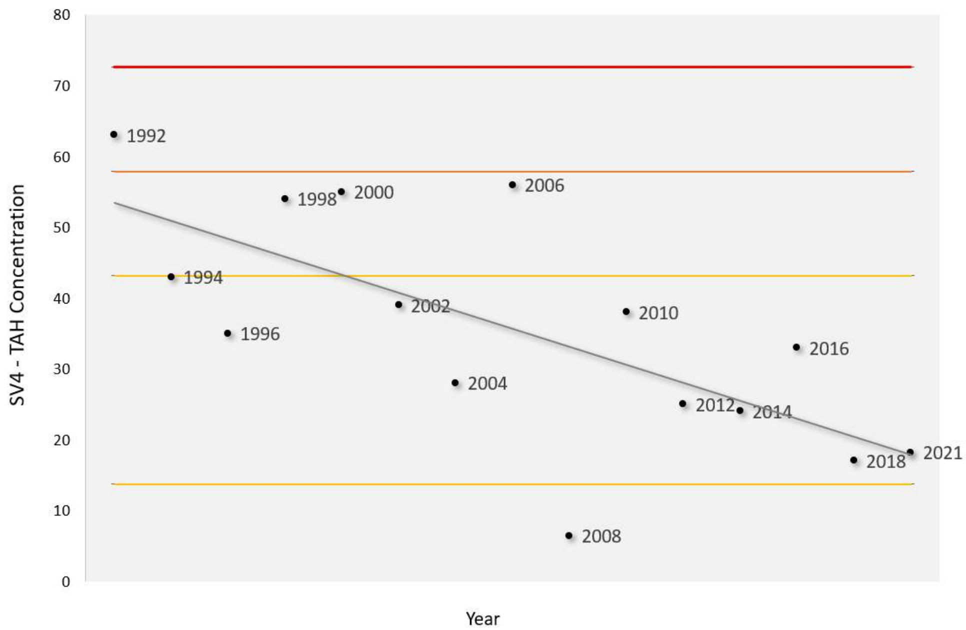

Figure 16 – SV4 Total Aliphatic Hydrocarbon concentration (µg.g^{-1} dry wt. sed.)

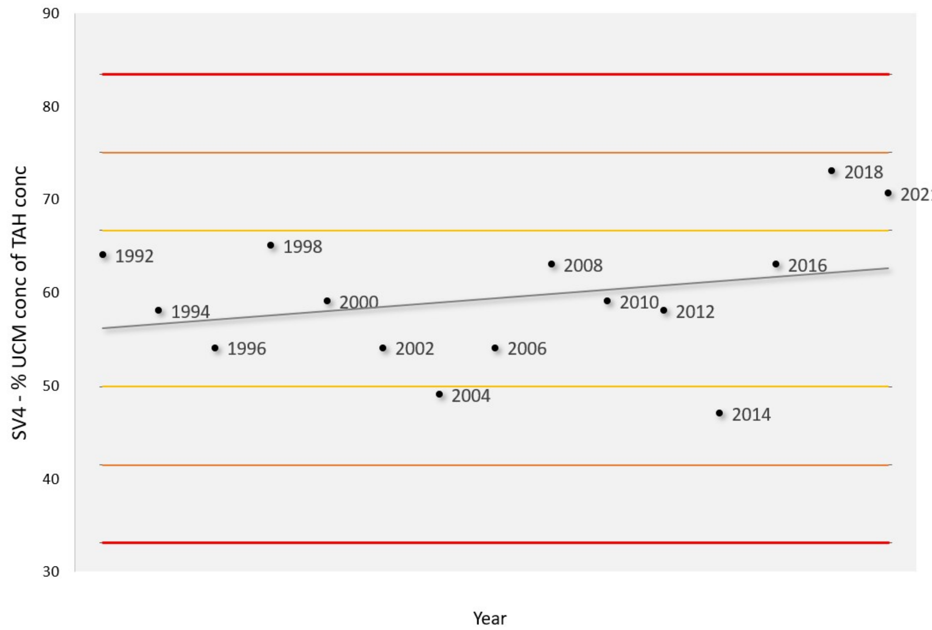

Figure 17 – SV4 Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

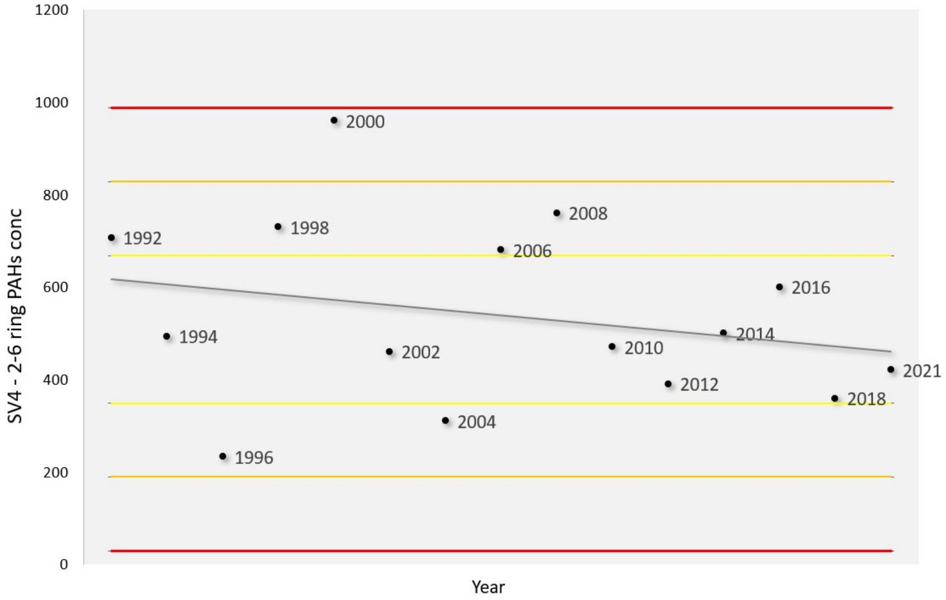

Figure 18 – SV4 2-6 ring PAH concentration (ng.g^{-1} dry sed.)

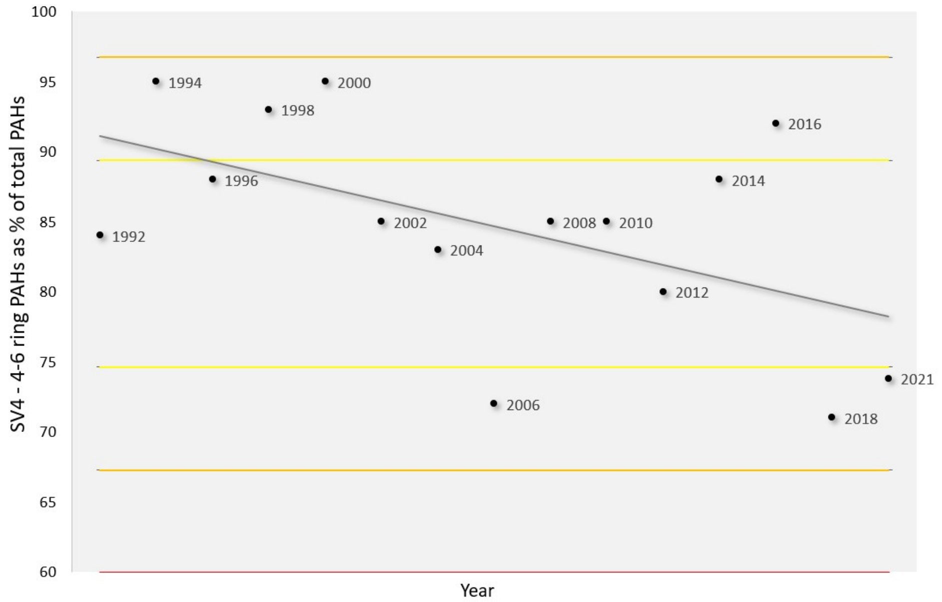

Figure 19 – SV4 4-6 ring PAHs as a percentage of the total PAHs (%)

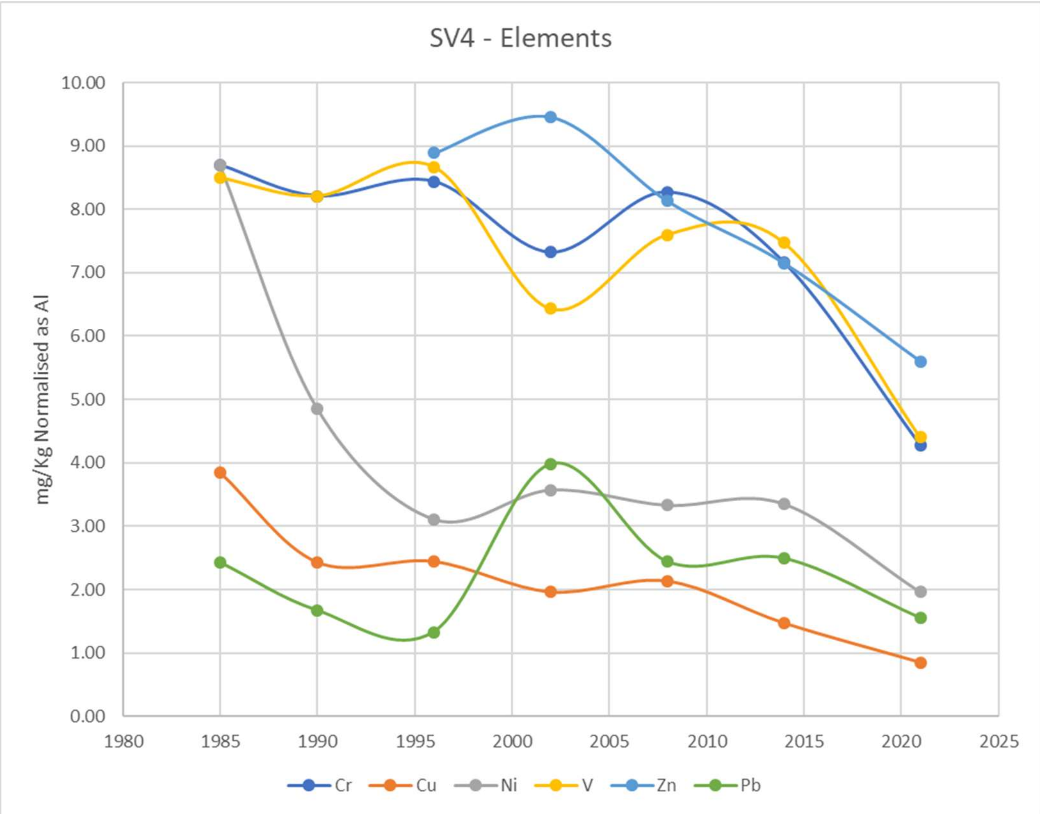

Figure 20 – SV4 Elements in mg/Kg (dry basis) normalised as Aluminium.

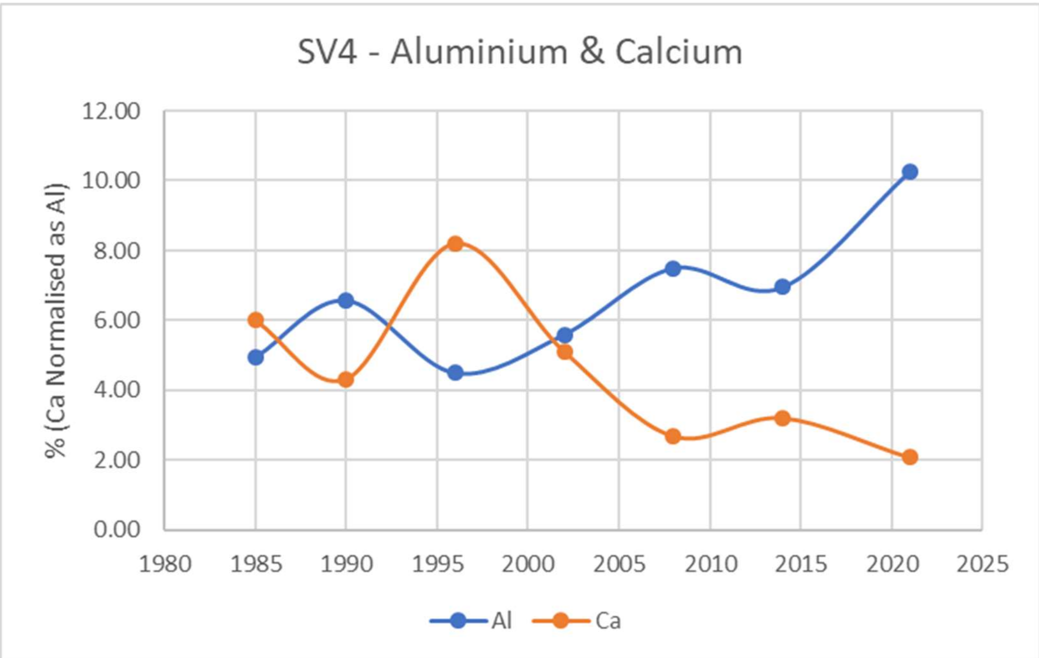

Figure 21 – SV4 Aluminium and Calcium in % (m/m - dry basis) Calcium normalised as Aluminium.

3.4.1.4 Fluga Ness SV5

For station SV5, the mud content in 2021 was 40.5%, which 14.7% lower than in 2018. The organic content for station SV5 in 2021 was 4.85%, which was 2.6% lower than the 2018 result.

The concentration of total aliphatic hydrocarbons (TAH) at station SV5 in 2021 was 23.5 µg/g (dry matter). The 2021 result was -1.3 standard deviations from the historic mean. The relative standard deviation between the 3 TAH grab replicates was 26.1% indicating moderate variation in the sediment composition for TAH. The percentage of UCM in the TAH was similar to the 2018 result which was higher than the historic mean result 2004-2018, indicating there continues to be some change to the composition of oil.

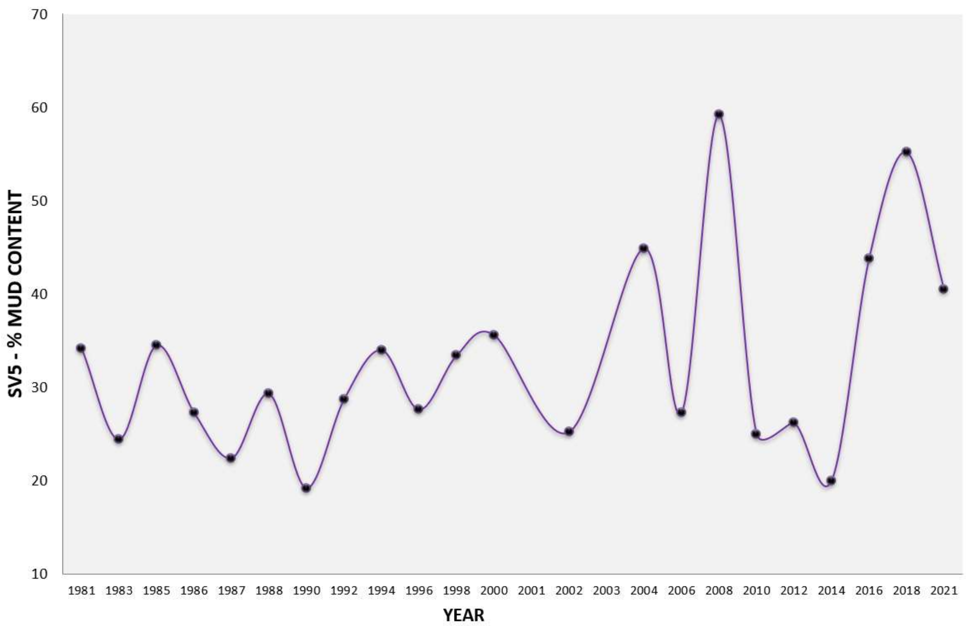

Figure 22 – SV5 Percentage Mud content

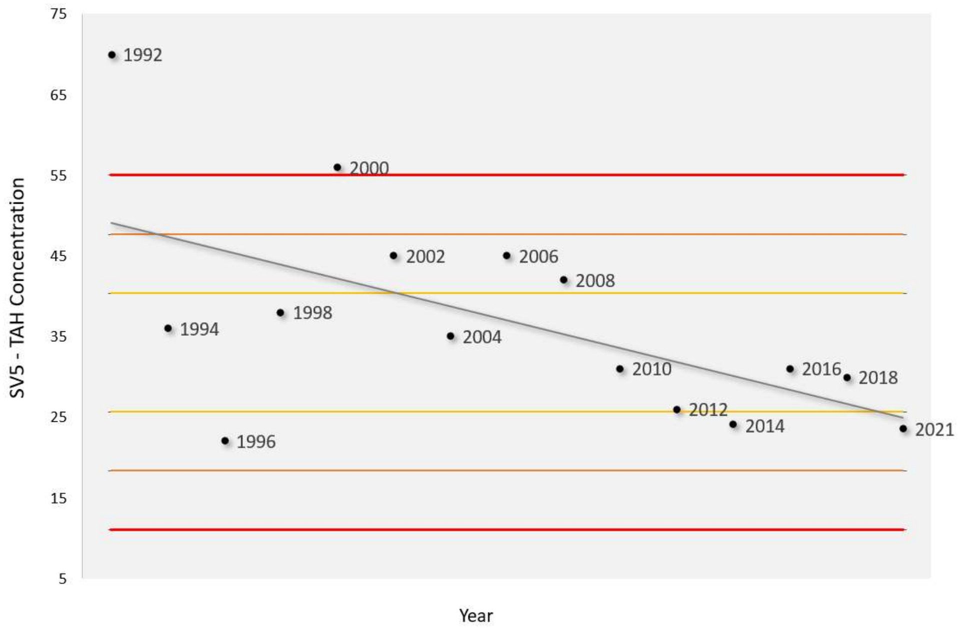

Figure 23 – SV5 Total Aliphatic Hydrocarbon concentration (µg.g-1 dry wt. sed.)

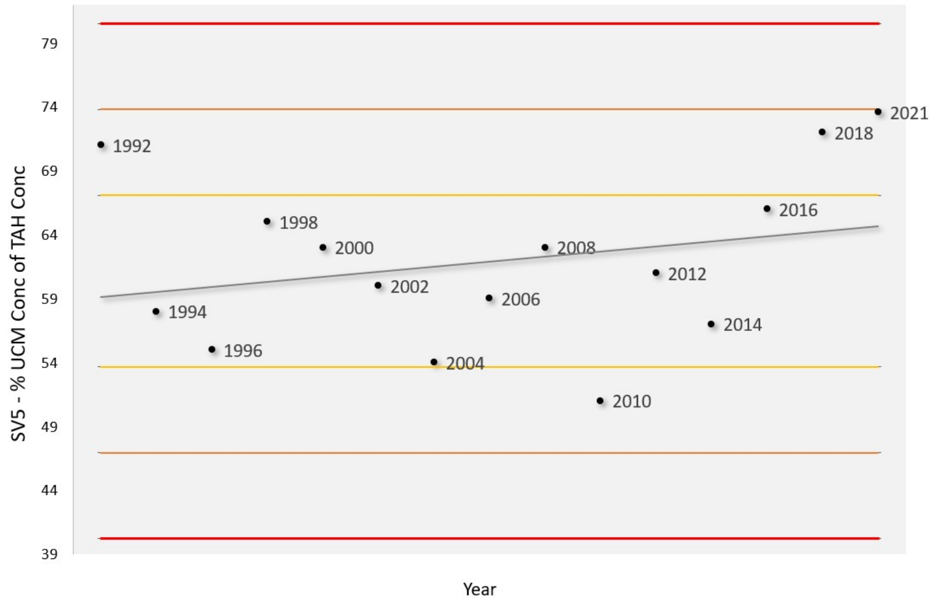

Figure 24 – SV5 Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

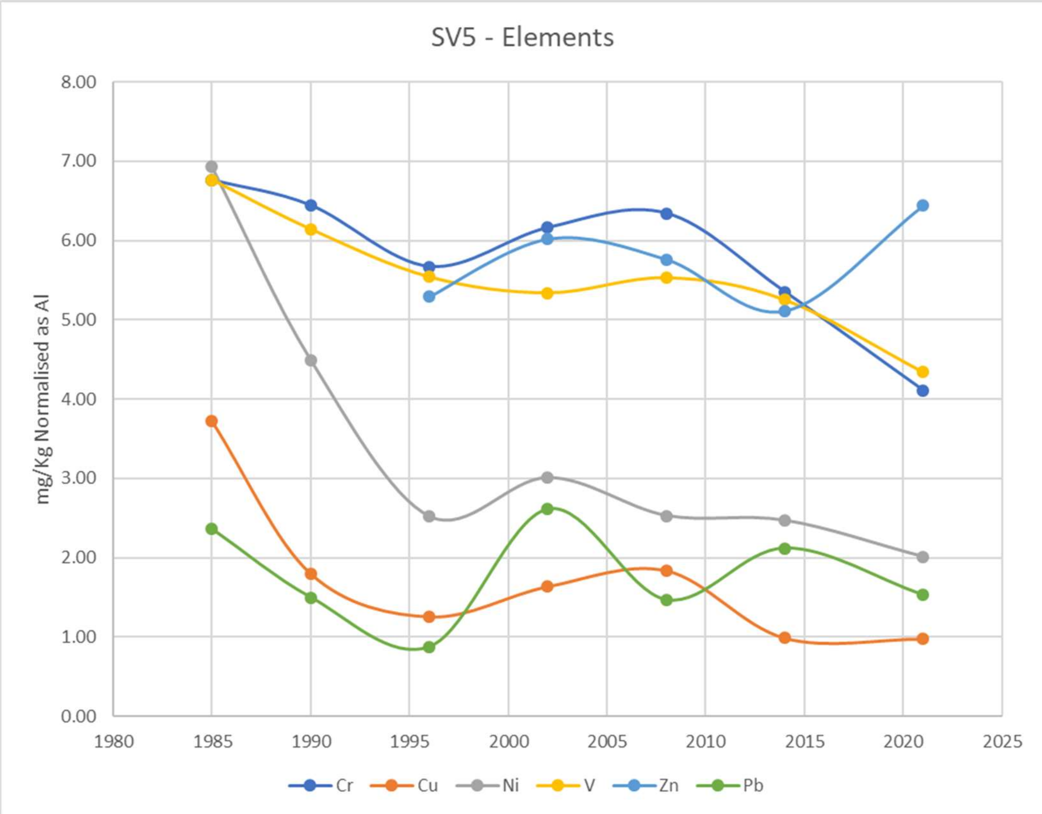

Figure 25 – SV5 Elements in mg/Kg (dry basis) normalised as Aluminium.

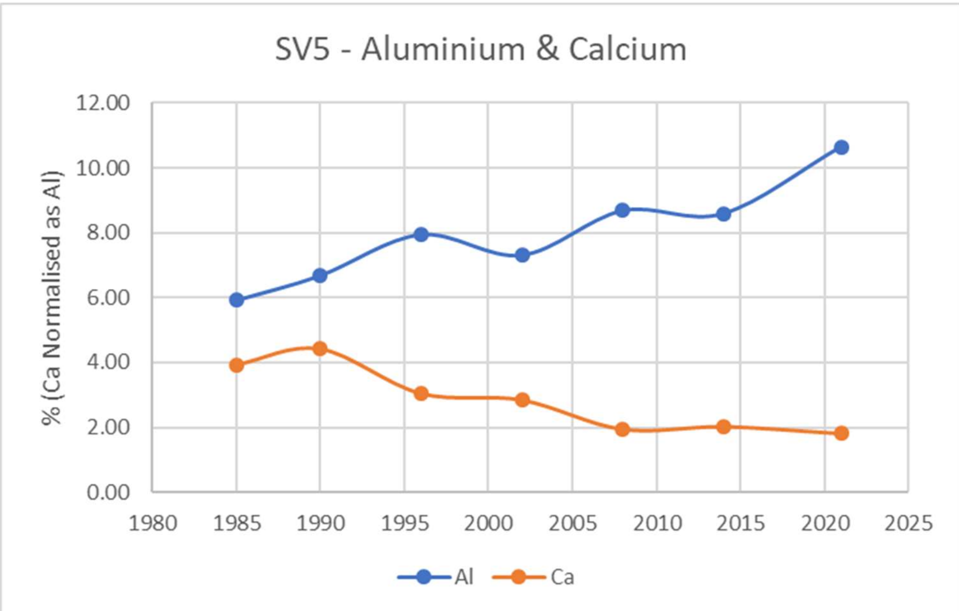

Figure 26 – SV5 Aluminium and Calcium in % (m/m - dry basis) Calcium normalised as Aluminium.

3.4.2 JETTY AREA AND WEST OF CALBECK NESS (STATIONS 7-11 AND 17)

3.4.2.1 Jetty Grid SV7

For station SV7, the mud content in 2021 was 40.7% and 4.7% lower than in 2018. The variation in mud concentration at this site is historically high. The organic content in 2021 was 6.23% which was a similar level to the 2018 result of 8.8%.

The concentration of total aliphatic hydrocarbons (TAH) at station SV7 in 2021 was higher than in 2018. The 2021 result was within 1 standard deviation from the historic mean which indicates little change from the historic data set 2004-2018. The relative standard deviation between the 3 TAH grab replicates was 19.3% indicating moderate variation in the sediment composition for TAH. The percentage of UCM in the TAH was a lower level than the percentage in 2016-2018 but continues to be higher than the historic mean.

The concentration of 2-6 ring PAH concentration at station SV7 in 2021 was also higher than the concentration in 2018. The 2021 result was within 1 standard deviation from the historic mean which indicates little change from the historic data set 2004-2018. The percentage of 4-6 ring PAHs of the total PAHs has demonstrated little change against the 2016-2018 results. The 2021 result was within 1 standard deviation from the historic data set mean 2004-2018, indicating that there has been little change.

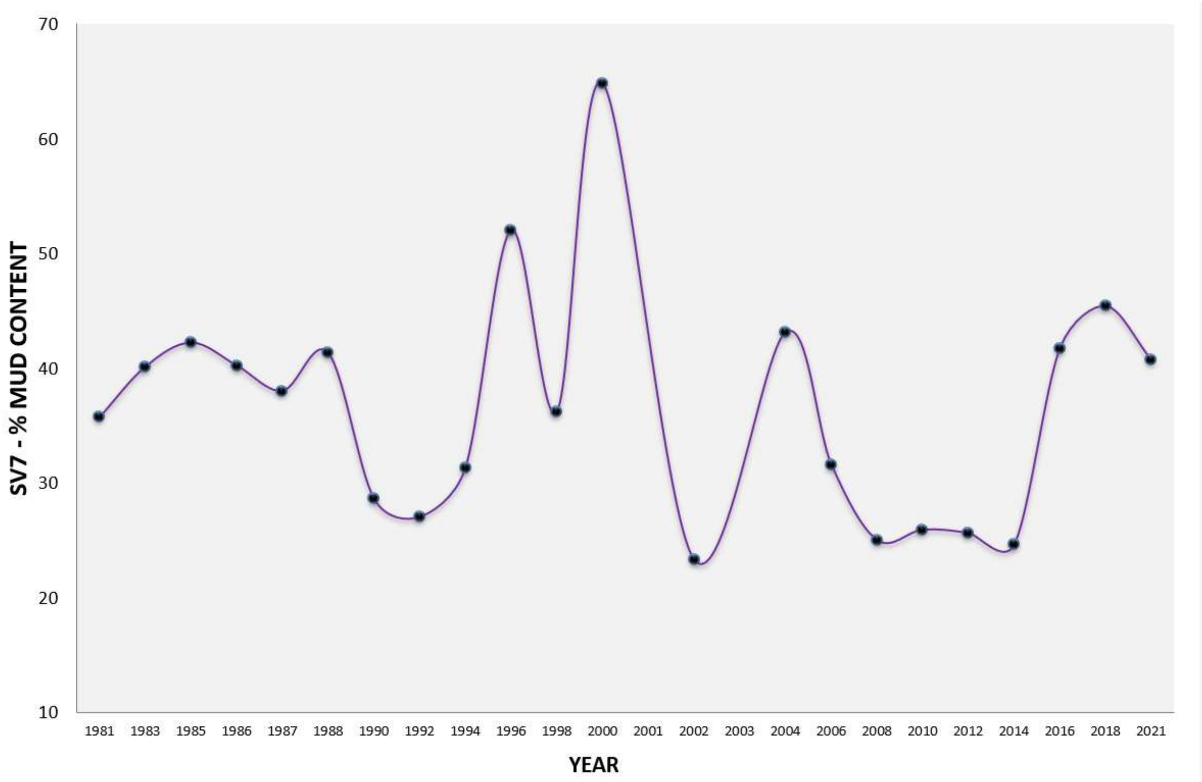

Figure 27 – SV7 Percentage Mud content

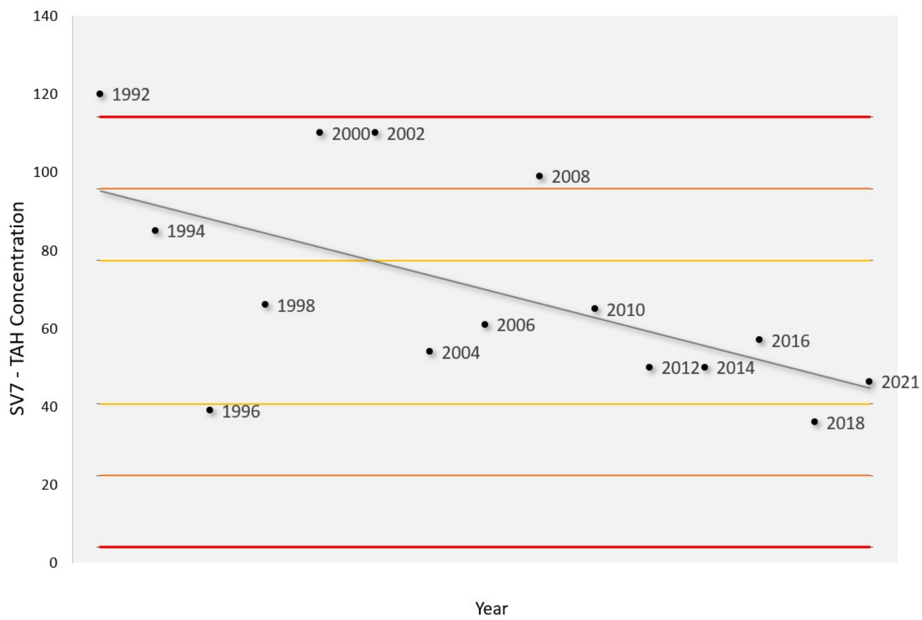

Figure 28 – SV7 Total Aliphatic Hydrocarbon concentration (µg.g^{-1} dry wt. sed.)

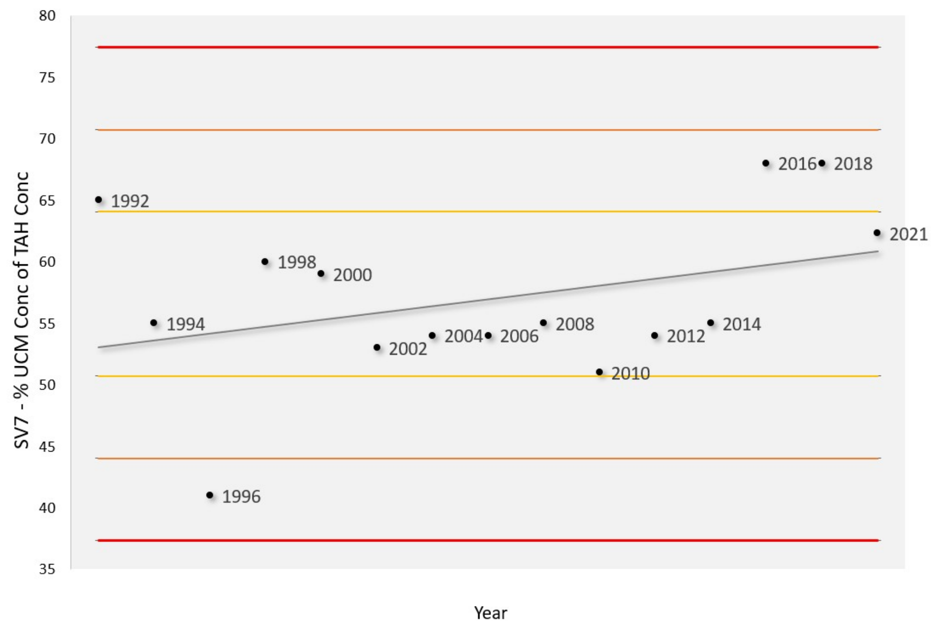

Figure 29 – SV7 Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

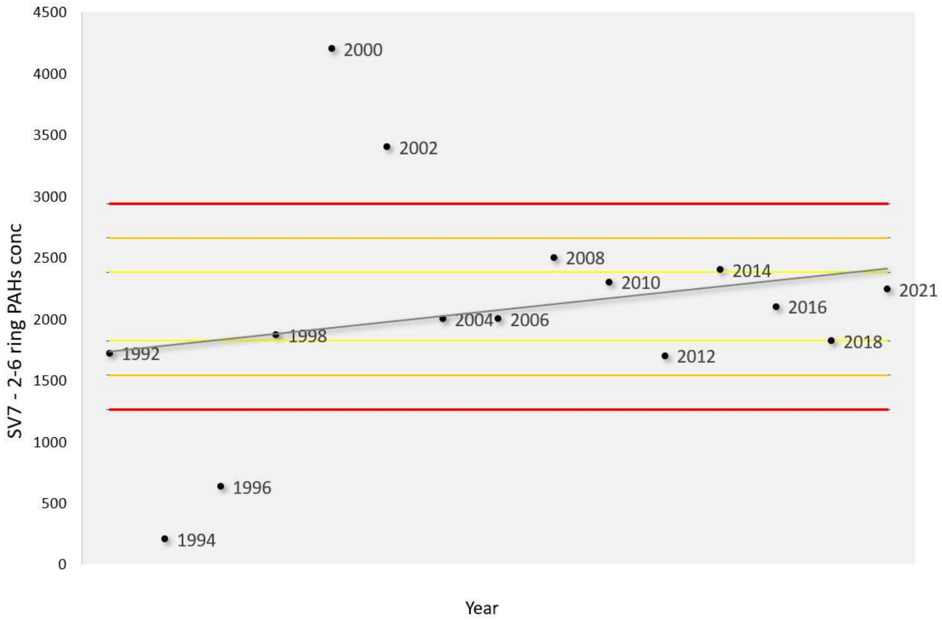

Figure 30 – SV7 2-6 ring PAH concentration (ng.g^{-1} dry sed.)

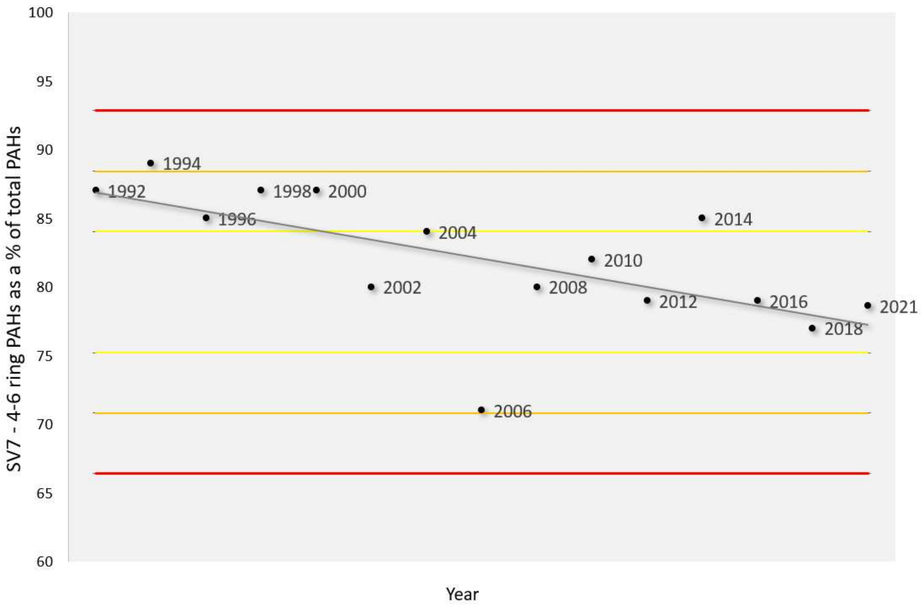

Figure 31 – SV7 4-6 ring PAHs as a percentage of the total PAHs (%)

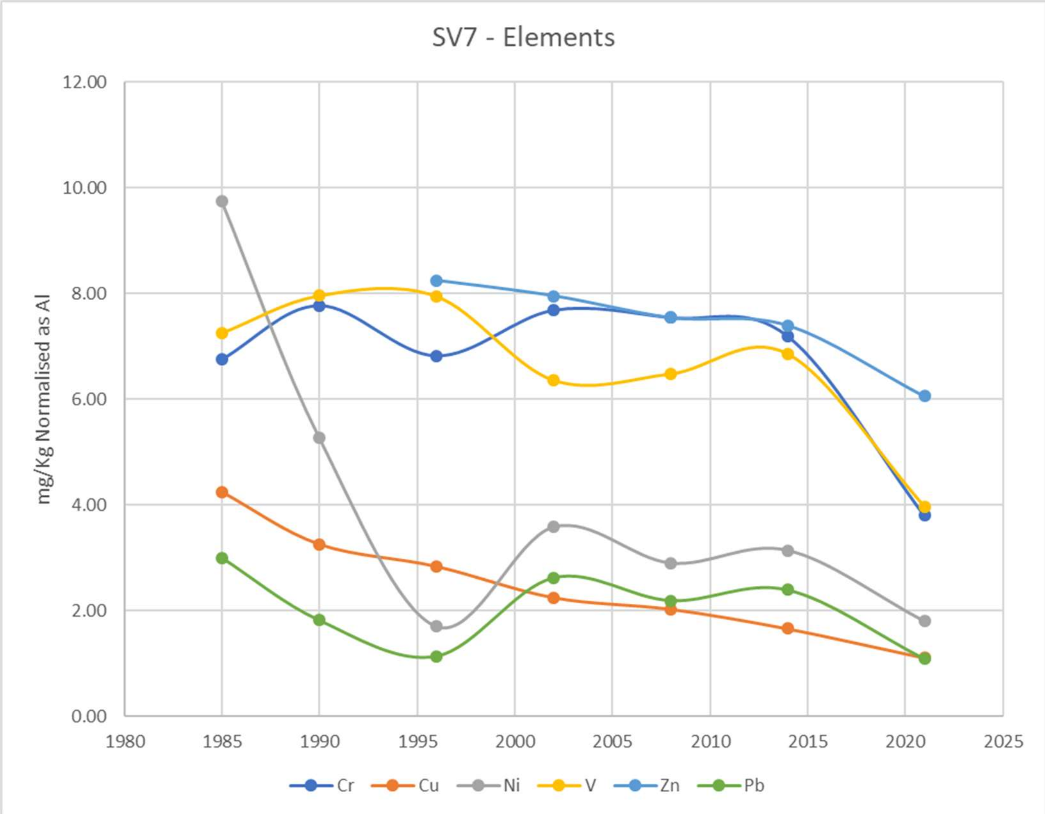

Figure 32 – SV7 Elements in mg/Kg (dry sed. normalised as Aluminium).

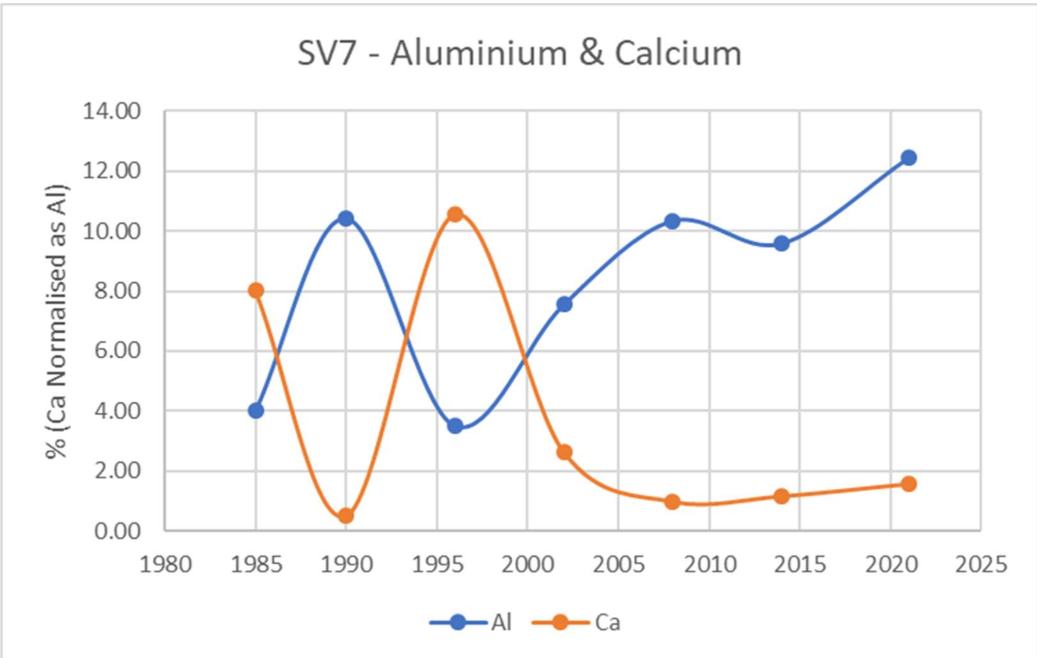

Figure 33 – SV7 Aluminium and Calcium in % (m/m - dry sed.) Calcium normalised as Aluminium.

3.4.2.2 Jetty Grid SV8

For station SV8, the mud content in 2021 was 35.8% which was 3.0% lower than the 2018 result. The organic content in 2021 was 4.24% which was lower than the 2018 result of 4.60%.

The concentration of total aliphatic hydrocarbons (TAH) at station SV8 in 2021 was lower than the 2018 result. The 2021 result was within 1 standard deviation from the historic mean 2004-2018, indicating there has been little change. The relative standard deviation between the 3 TAH grab replicates was 29% indicating moderate variation in the sediment composition for TAH. The percentage of UCM in the TAH is higher than the mean and is +2.1 standard deviations from the historic mean 2004-2018.

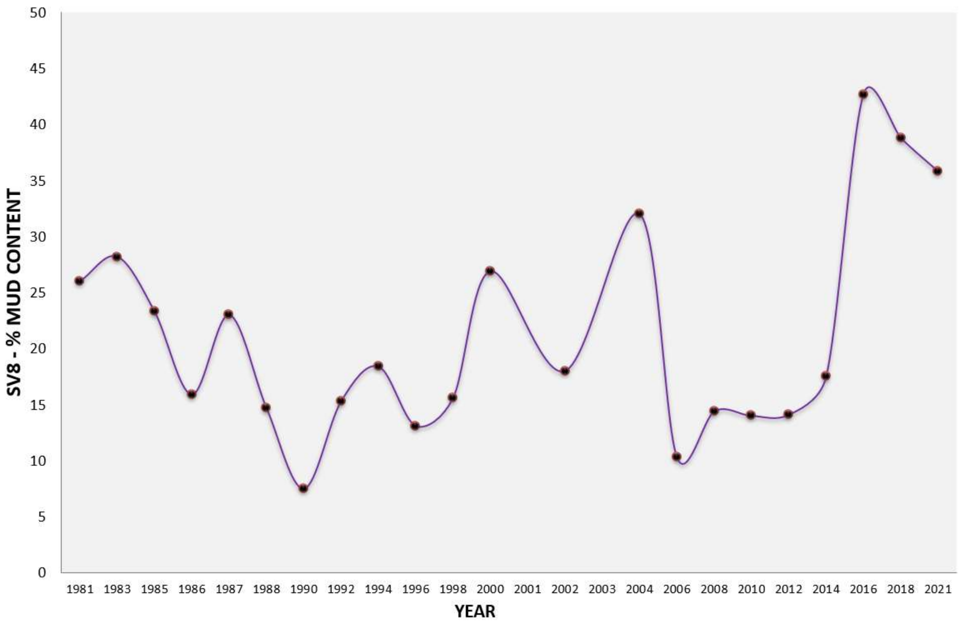

Figure 34 – SV8 Percentage Mud content

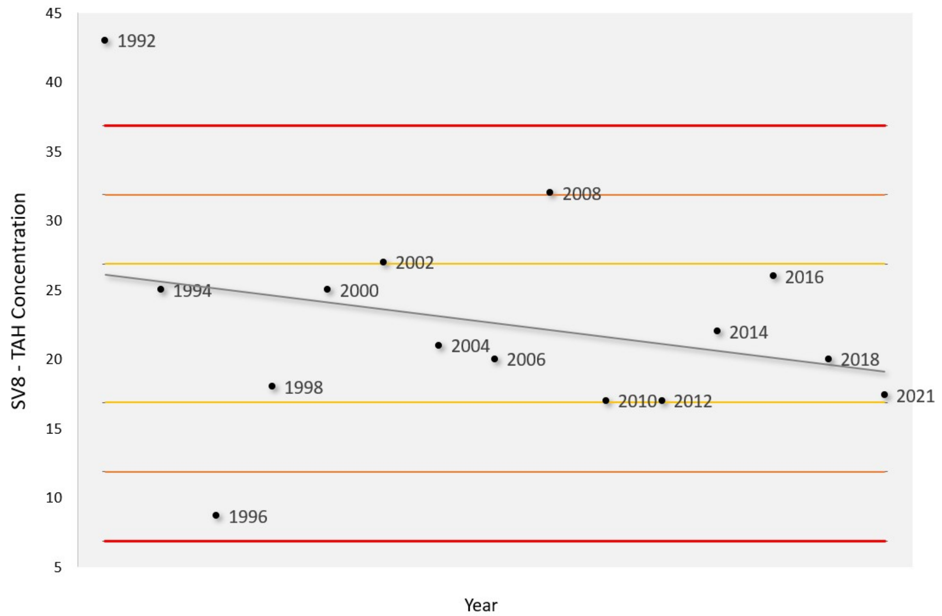

Figure 35 – SV8 Total Aliphatic Hydrocarbon concentration (µg.g^{-1} dry wt. sed.)

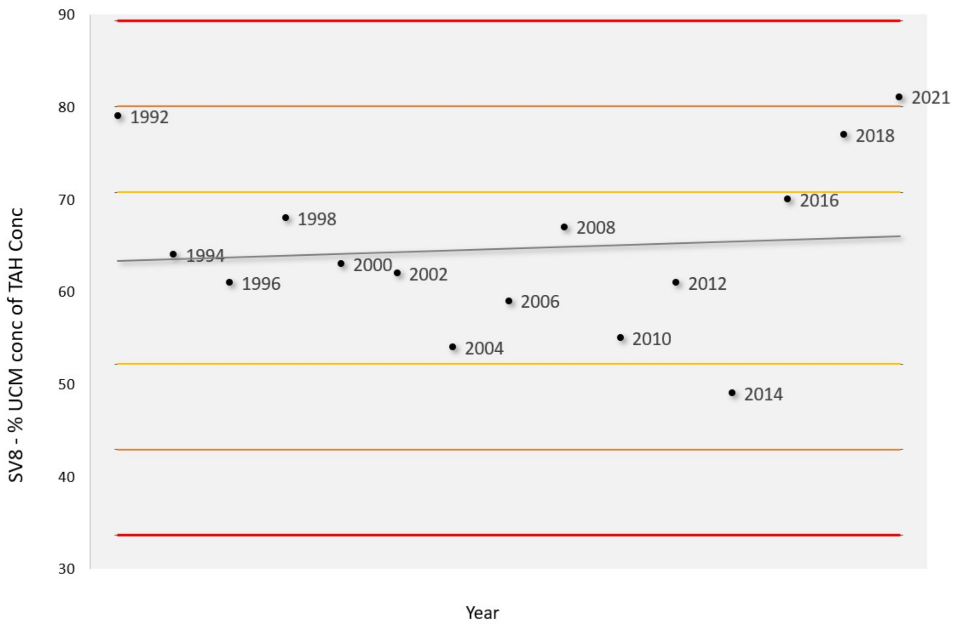

Figure 36 – SV8 Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

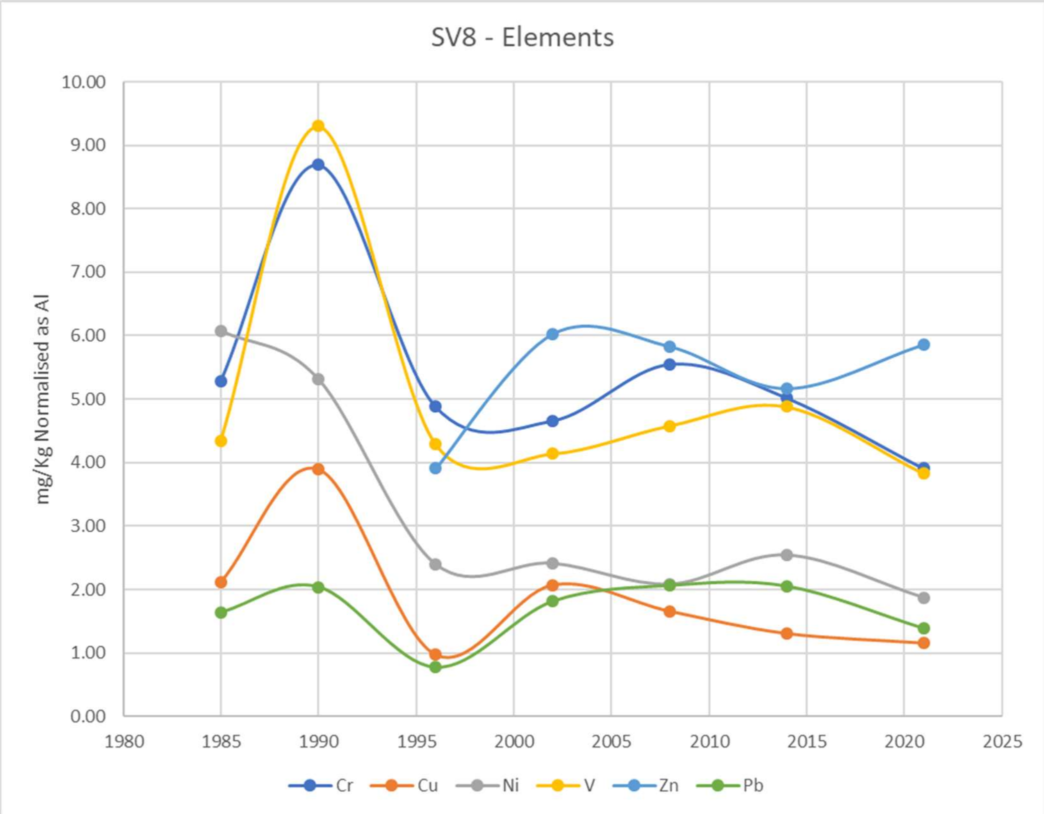

Figure 37 – SV8 Elements in mg/Kg (dry sed. normalised as Aluminium).

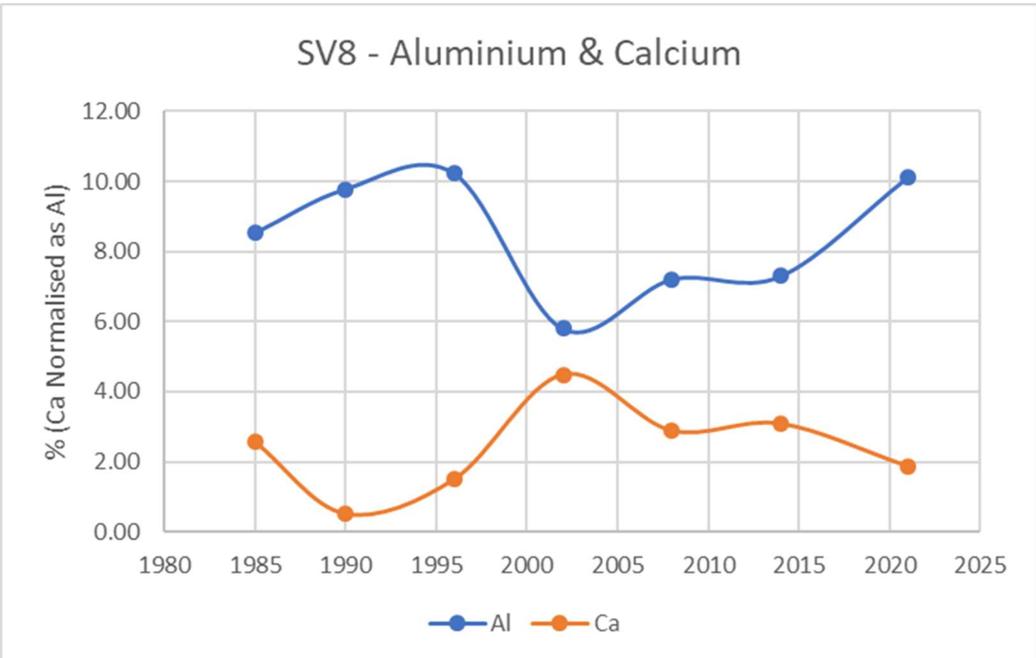

Figure 38 – SV8 Aluminium and Calcium in % (m/m - dry sed.) Calcium normalised as Aluminium.

3.4.2.3 Jetty Grid SV8A

For station SV8A, the mud content in 2021 was 34.8% which is 8.8% lower than in 2018. The organic content in 2021 was 3.64% which was the very similar to the 2018 result.

The concentration of total aliphatic hydrocarbons (TAH) at station SV8A in 2021 was lower than the 2018 result but in line with the historic mean. The 2021 result was within 1 standard deviation from the historic mean for data 2004-2018, this indicates there has been little change. The relative standard deviation between the 3 TAH grab replicates was 6.9% indicating low variation in the sediment composition for TAH. The percentage of UCM in the TAH was higher than the 2018 result but +2.93 standard deviations of the historic mean for data set 2004-2018, indicating significant change.

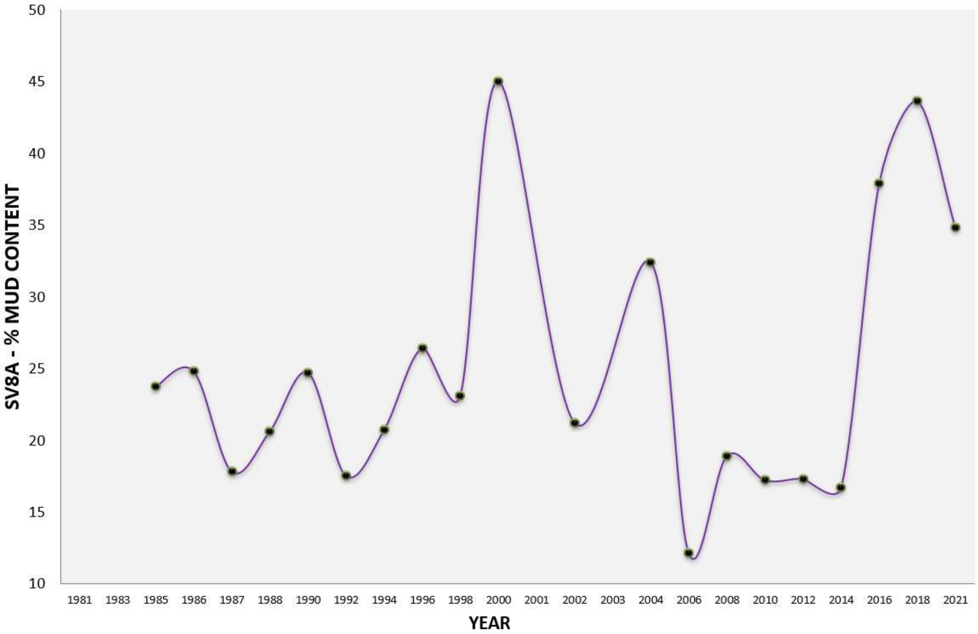

Figure 39 – SV8A Percentage Mud content

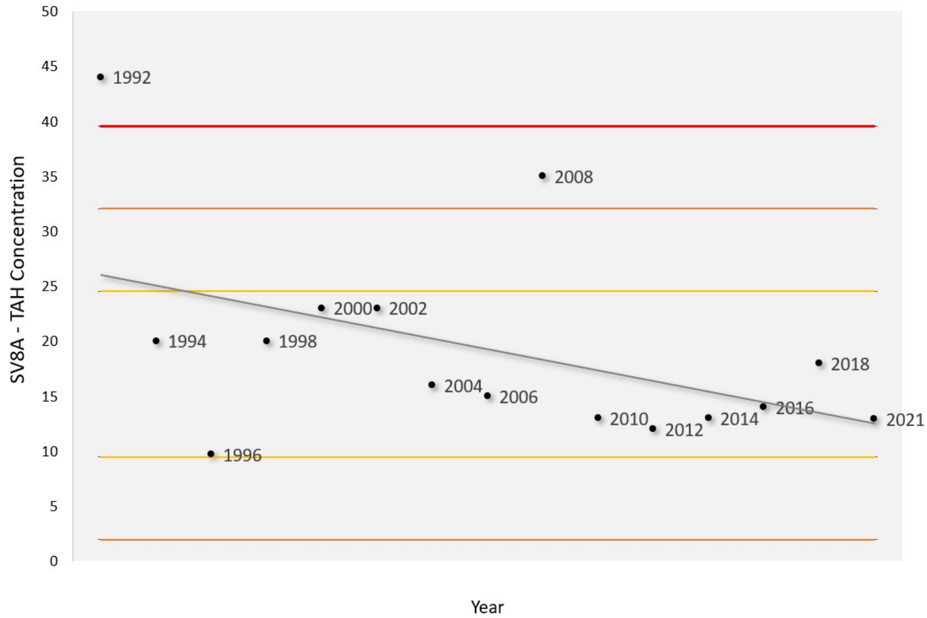

Figure 40 – SV8A Total Aliphatic Hydrocarbon concentration (µg.g^{-1} dry wt. sed.)

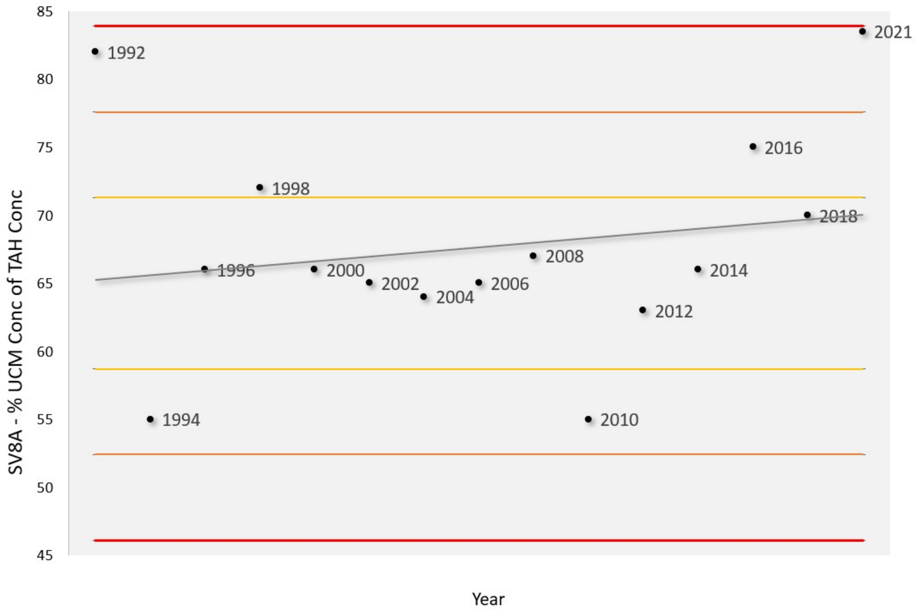

Figure 41 – SV8A Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

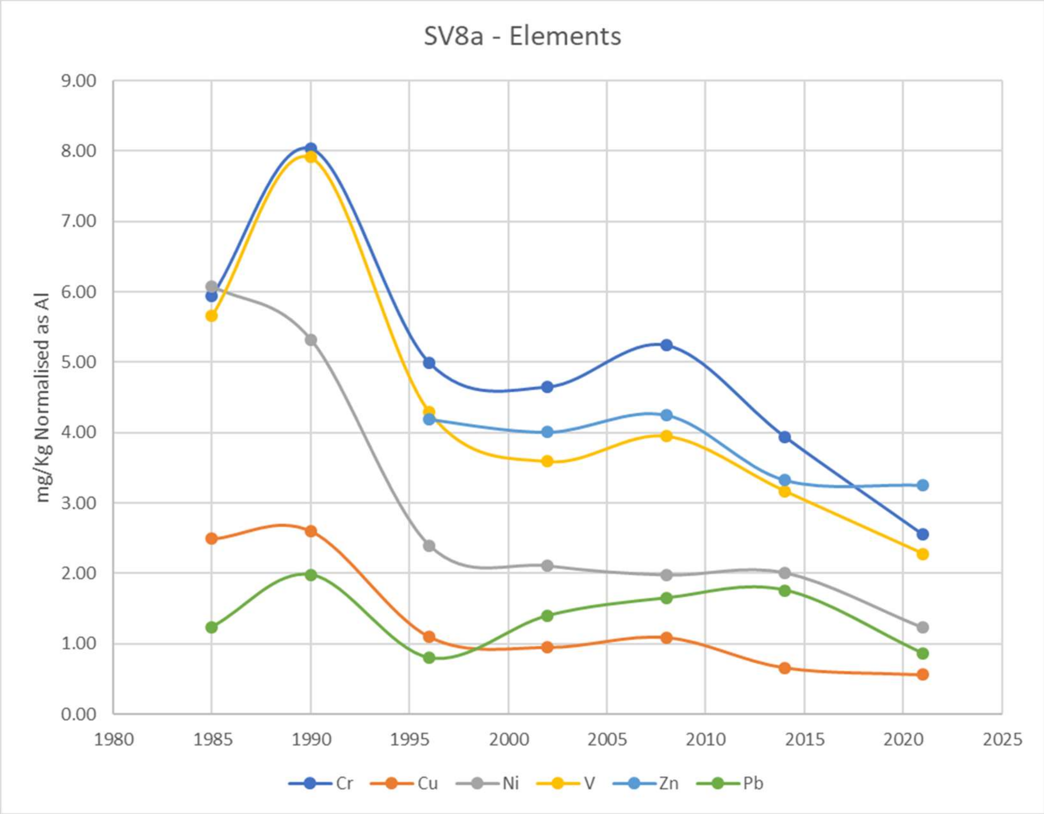

Figure 42 – SV8a Elements in mg/Kg (dry sed. normalised as Aluminium).

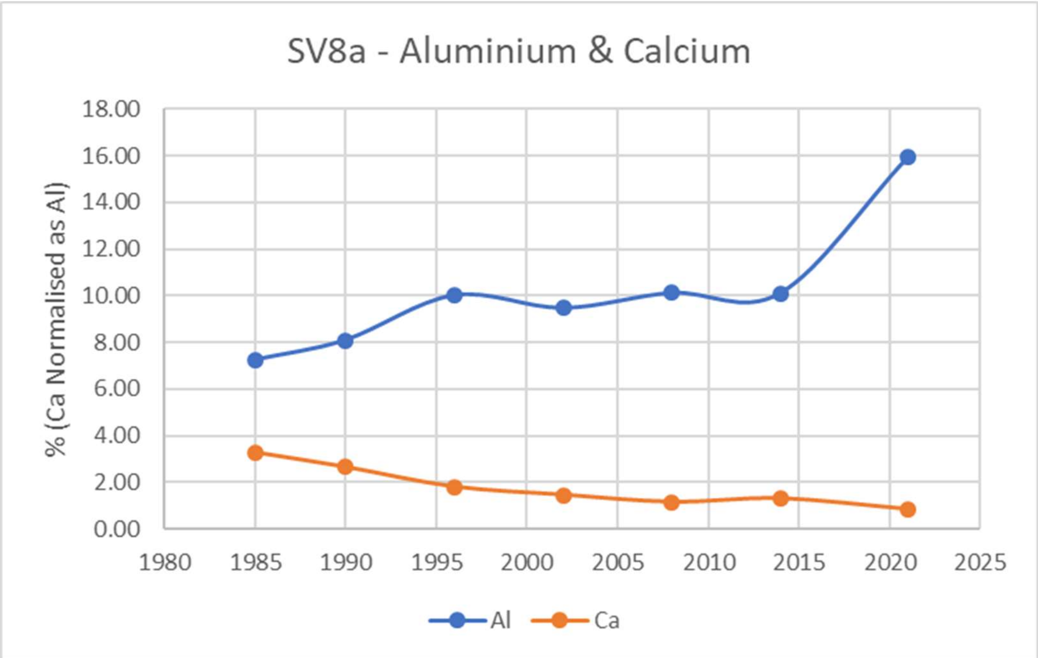

Figure 43 – SV8a Aluminium and Calcium in % (m/m - dry sed.) Calcium normalised as Aluminium.

3.4.2.4 Outer Voe SV9

For station SV9, the mud content in 2021 was 47.8% and 3.0% higher than the 2018 result. The organic content in 2021 was 6.3% which was higher than the 2018 result of 5.74%.

The concentration of total aliphatic hydrocarbons (TAH) at station SV9 in 2021 was lower than the 2018 concentration but was within 1 standard deviation from the historic mean for the data set 2004-2018. The relative standard deviation between the 3 TAH grab replicates was 25.8% indicating moderate variation in the sediment composition for TAH. The percentage of UCM in the TAH was lower than in 2018 but still higher than the historic mean. The 2021 UCM result was +1.2 standard deviations from the mean for the historic data set 2004-2018, indicating there has been some change.

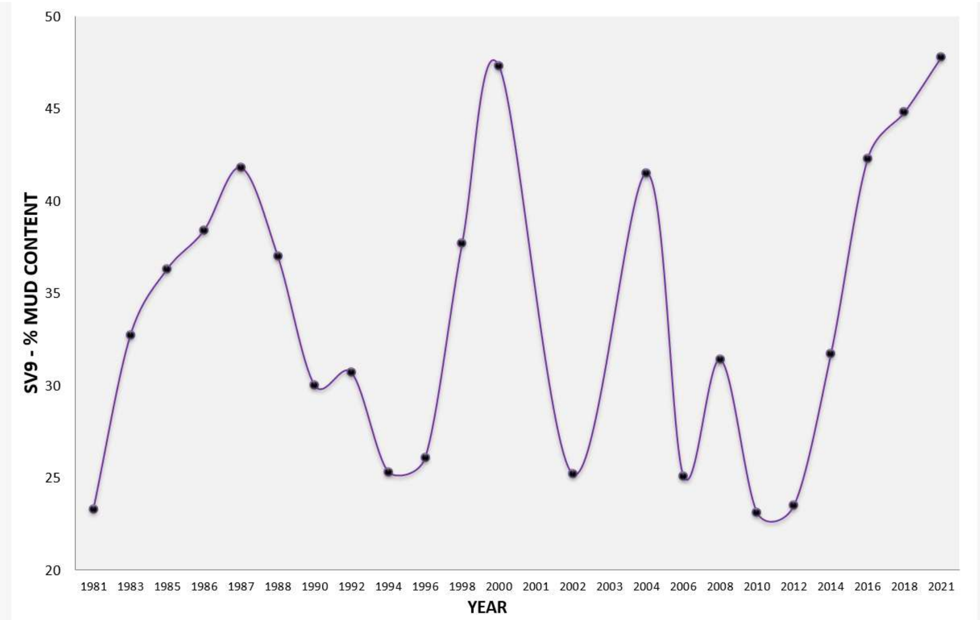

Figure 44 – SV9 Percentage Mud content

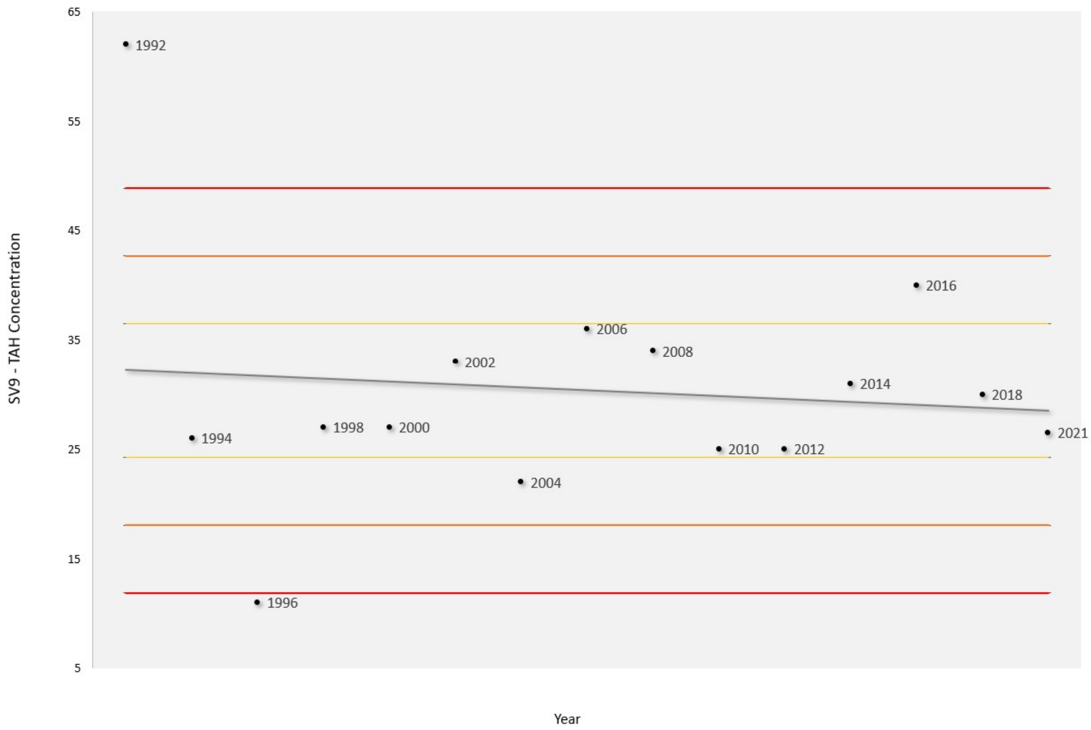

Figure 45 – SV9 Total Aliphatic Hydrocarbon concentration (µg.g^{-1} dry wt. sed.)

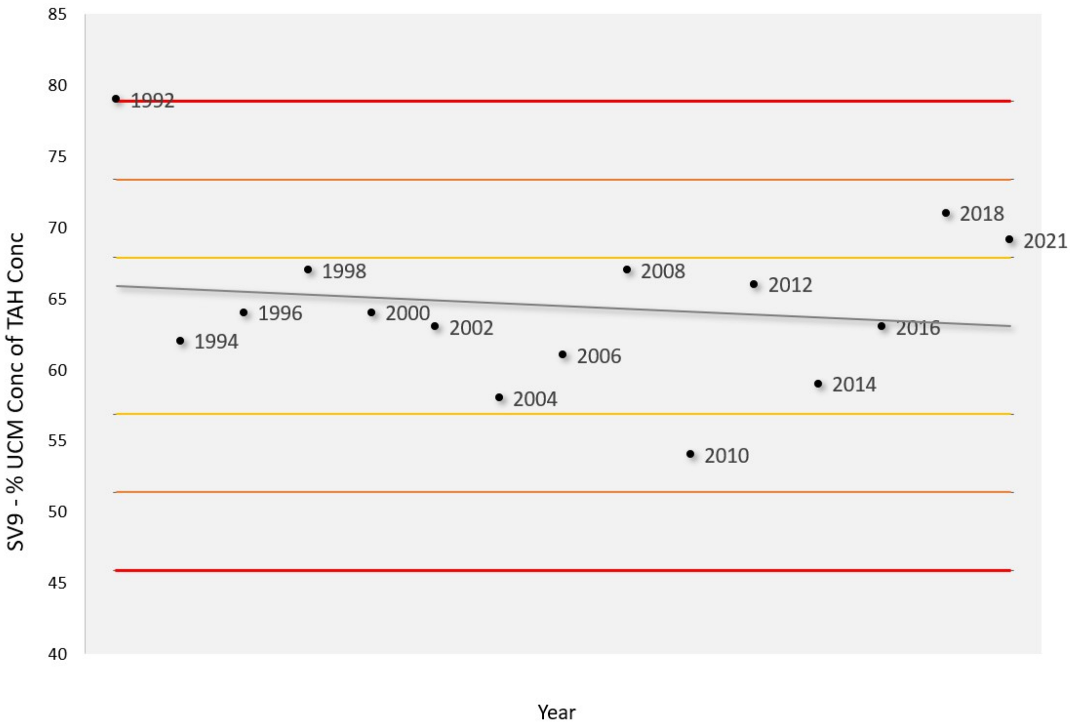

Figure 46 – SV9 Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

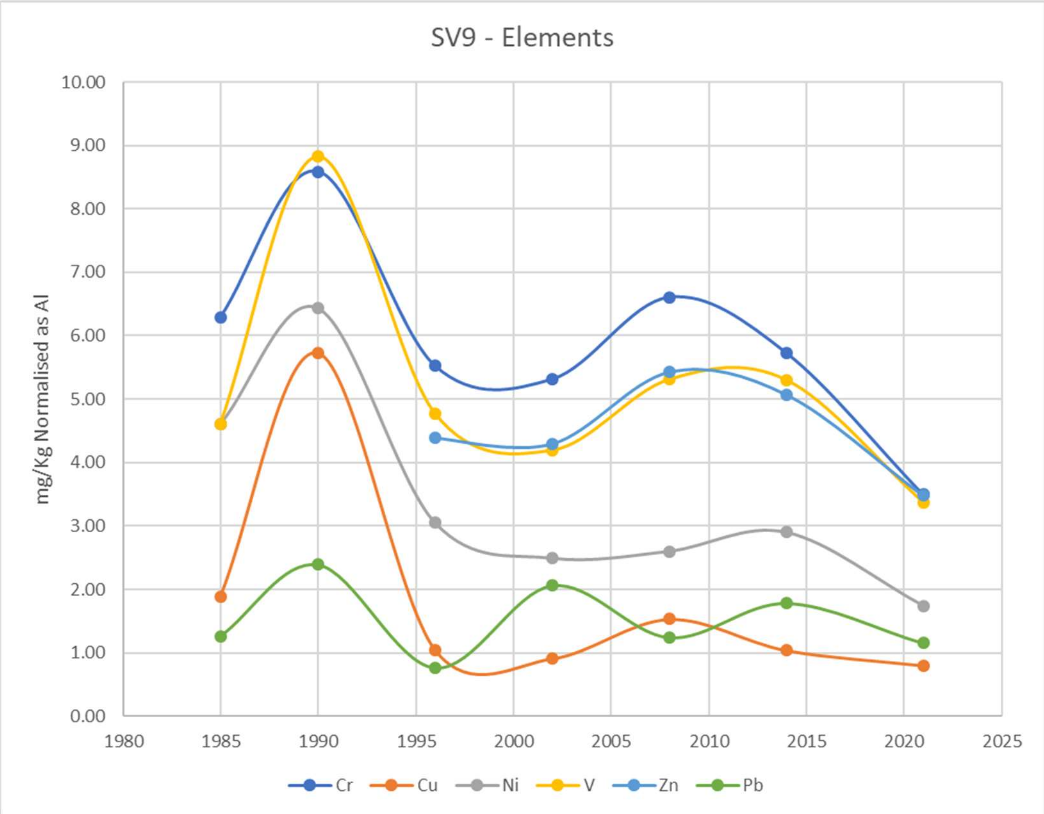

Figure 47 – SV9 Elements in mg/Kg (dry sed. normalised as Aluminium).

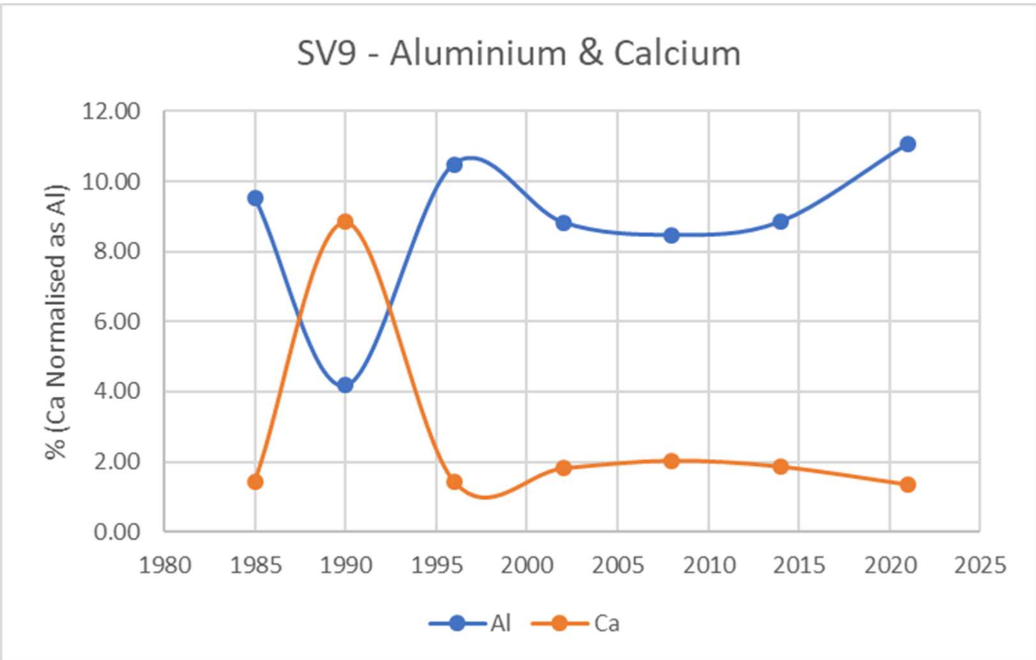

Figure 48 – SV9 Aluminium and Calcium in % (m/m - dry sed.) Calcium normalised as Aluminium.

3.4.2.5 Outer Voe SV10

For station SV10, the mud content in 2021 was 52.8% and 5.2% higher than in 2018. The organic content in 2021 was 5.22% which was similar to the 2018 result of 5.2%.

The concentration of total aliphatic hydrocarbons (TAH) at station SV10 in 2021 was similar to the 2018 result. The 20121 result was within 1 standard deviation from the historic mean for data set 2004-2018. The relative standard deviation between the 3 grab samples for TAH was 12.5%, indicating low variation in the sediment composition for TAH. The percentage of UCM in the TAH was lower than in 2018 but higher than the historic mean, and was +1.1 standard deviations from the historic mean for data 2004-2018.

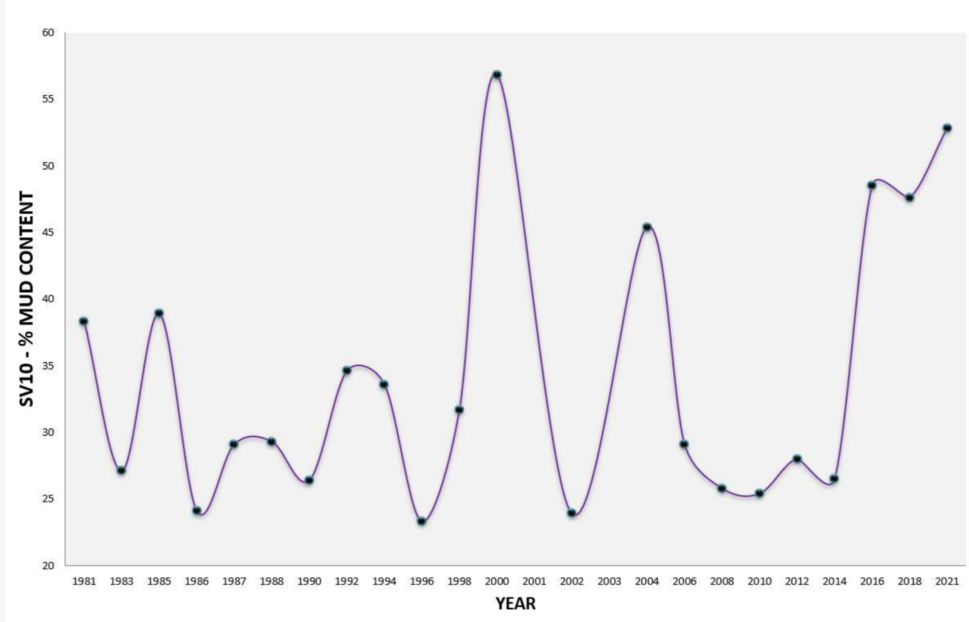

Figure 49 – SV10 Percentage Mud content

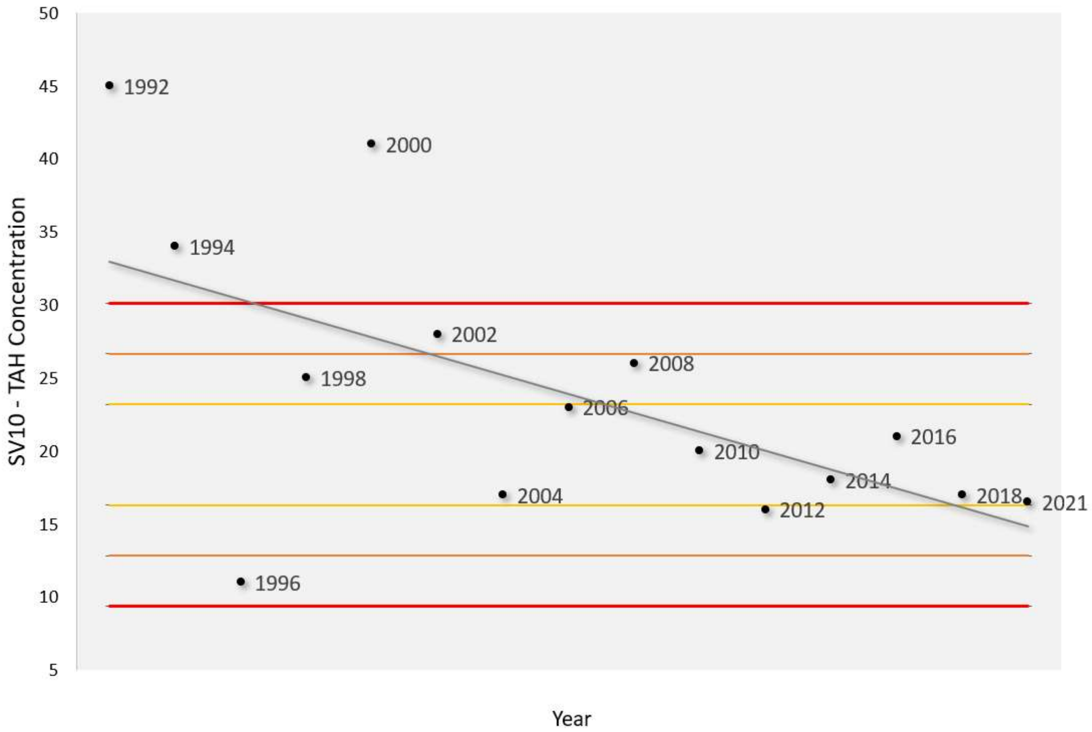

Figure 50 – SV10 Total Aliphatic Hydrocarbon concentration (µg.g-1 dry wt. sed.)

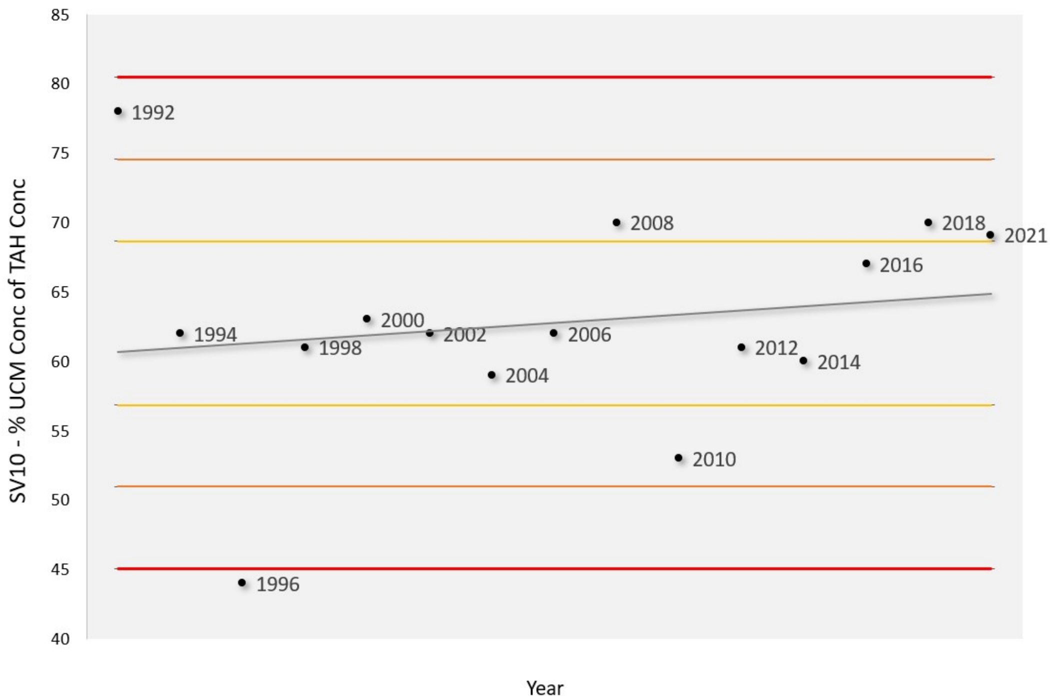

Figure 51 – SV10 Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

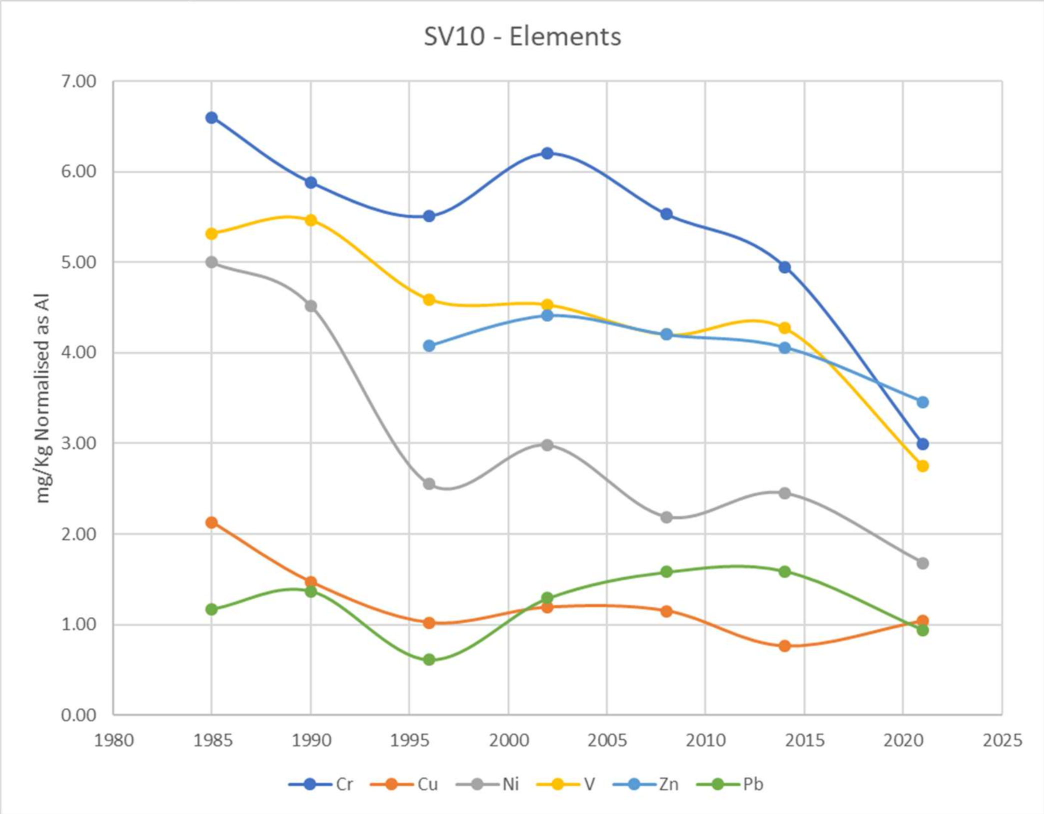

Figure 52 – SV10 Elements in mg/Kg (dry sed. normalised as Aluminium).

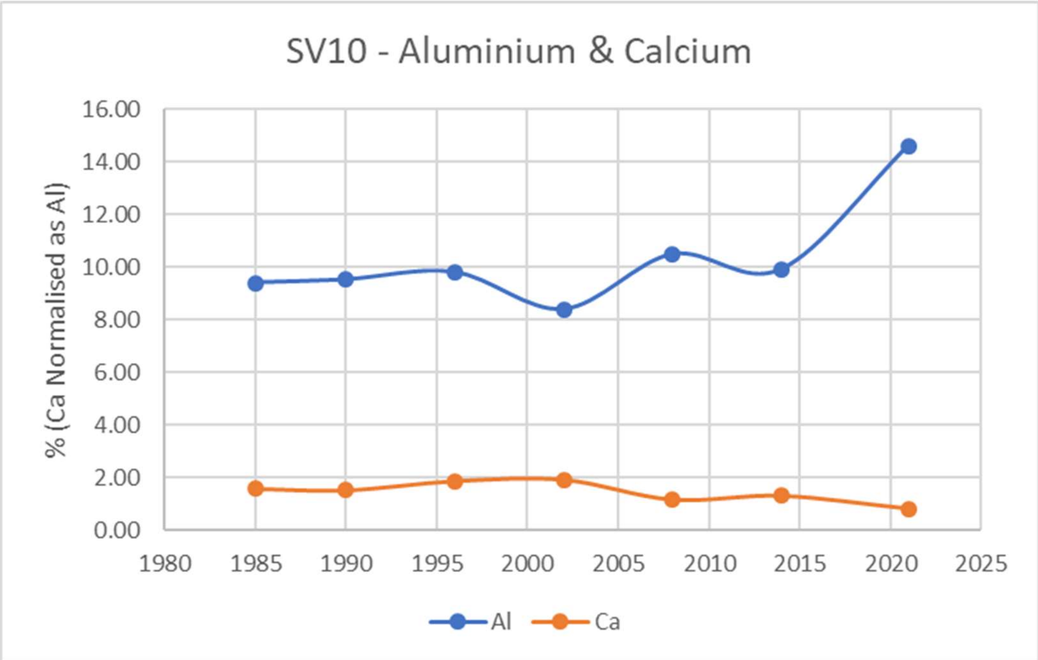

Figure 53 – SV10 Aluminium and Calcium in % (m/m - dry sed.) Calcium normalised as Aluminium.

3.4.2.6 Outer Voe SV11

For station SV11, the mud content in 2021 was 51.8% which was 2.8% higher than the 2018 result. The organic content in 2021 was 5.94% which was 0.8% higher than in 2018.

The concentration of total aliphatic hydrocarbons (TAH) at station SV11 in 2021 was lower than in 2018. The 2021 result was within 1 standard deviation from the historic mean and indicates there has been little change. The relative standard deviation between the 3 TAH grab replicates was 14.6% indicating low variation in the sediment composition for TAH. The percentage of UCM in the TAH was higher than in 2018, but similar to 2016 result. The 2021 UCM result was +1.7 standard deviations from the historic mean for data 2004-2018 which indicates there has been some change.

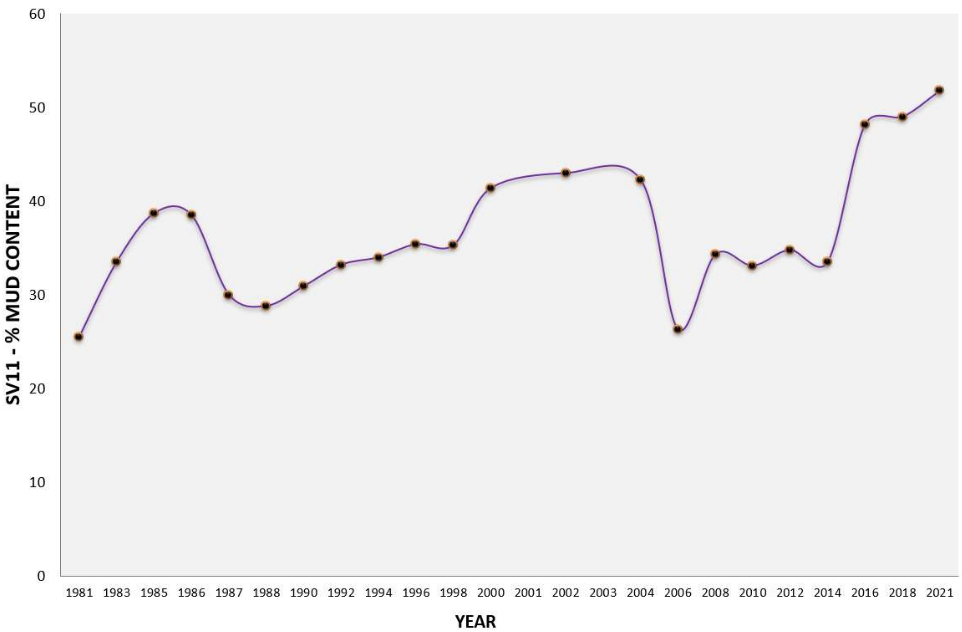

Figure 54 – SV11 Percentage Mud content

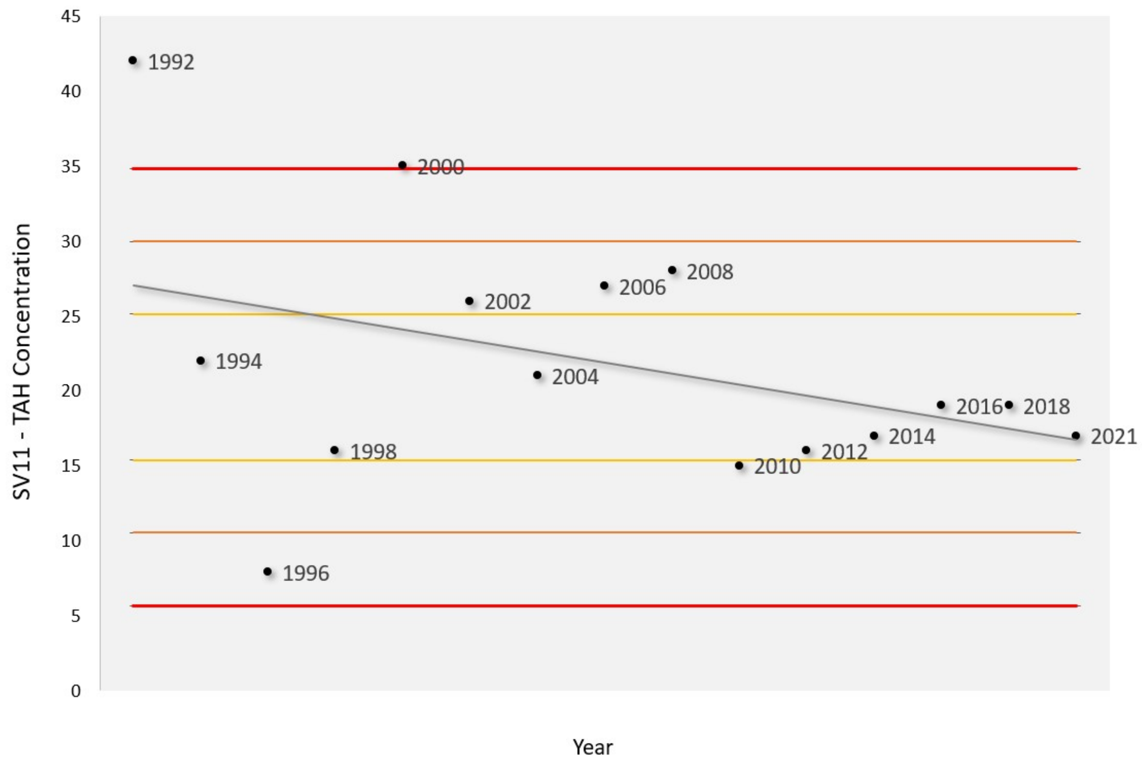

Figure 55 – SV11 Total Aliphatic Hydrocarbon concentration (µg.g^{-1} dry wt. sed.)

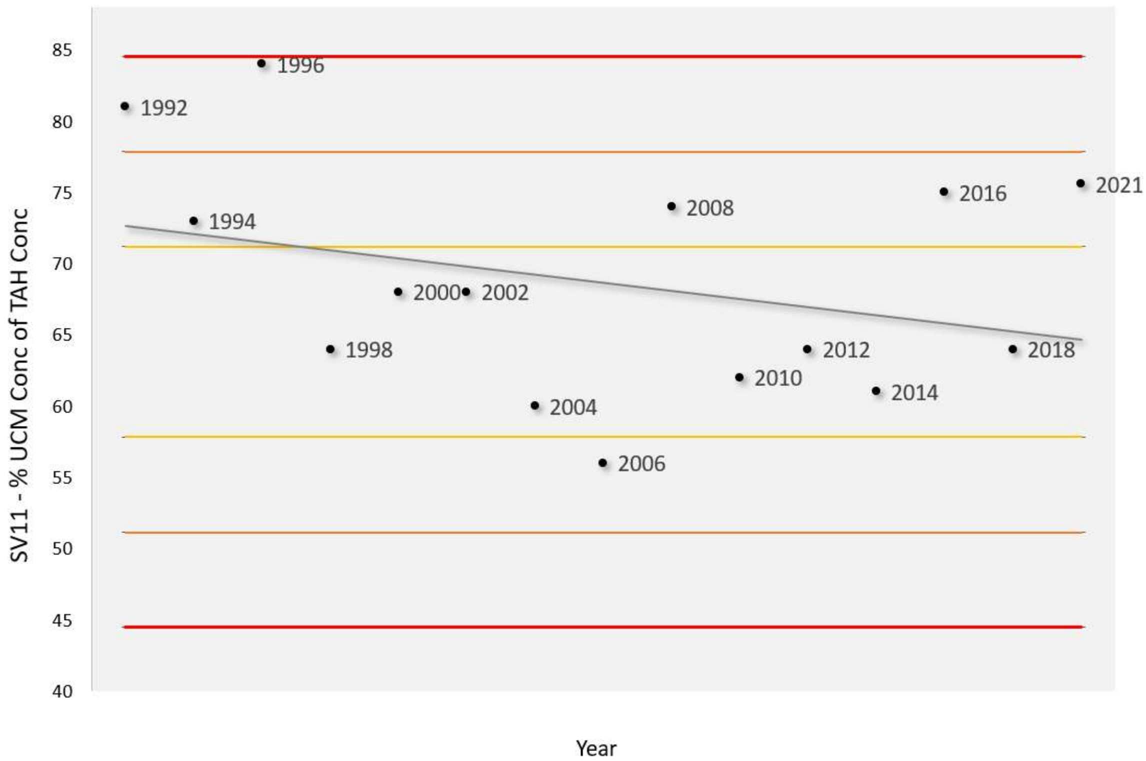

Figure 56 – SV11 Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

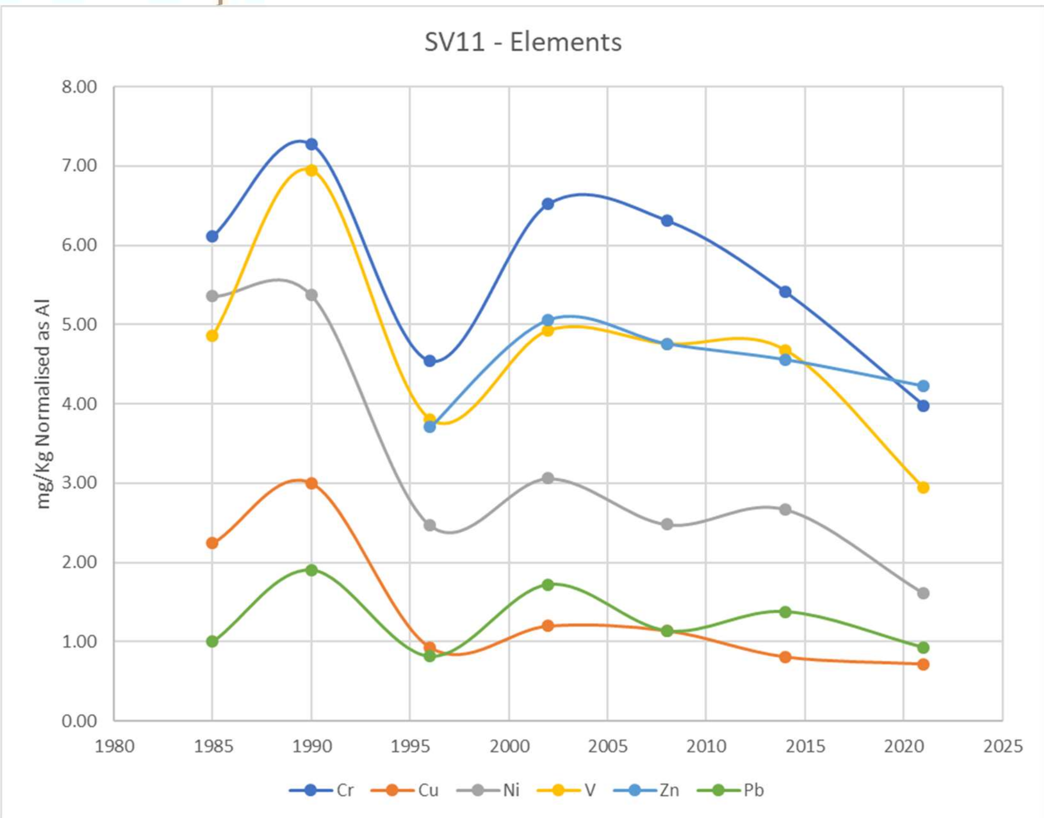

Figure 57 – SV11 Elements in mg/Kg (dry sed. normalised as Aluminium).

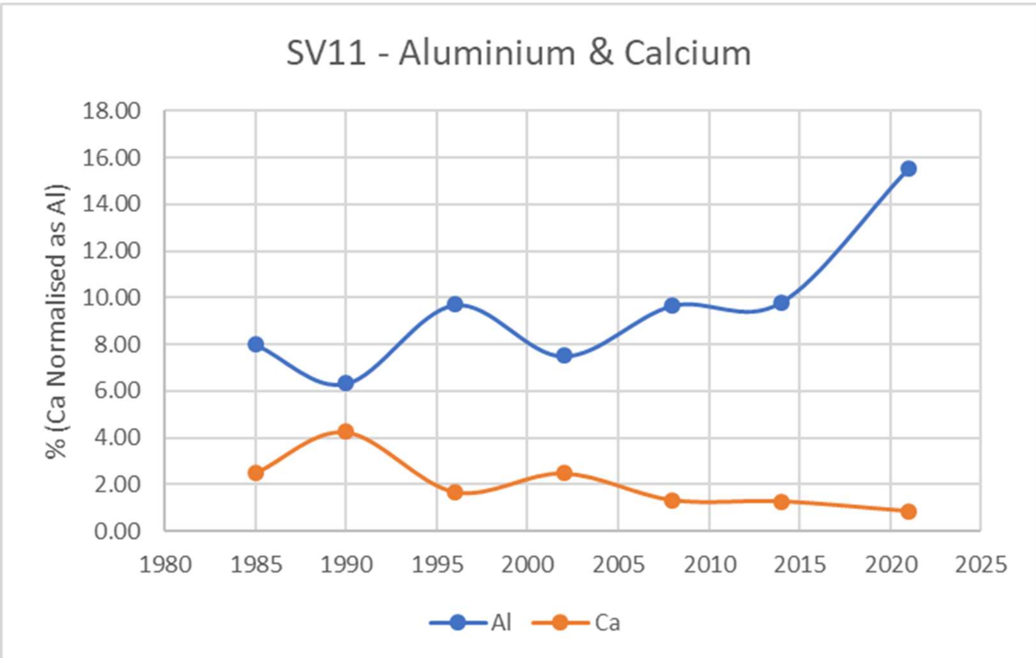

Figure 58 – SV11 Aluminium and Calcium in % (m/m - dry sed.) Calcium normalised as Aluminium.

3.4.2.7 Jetty Grid SV17

For station SV17, the mud content in 2021 was 34.3%, which was 18.8% higher than the result in 2018 but in-line with the results from 2016, 2004 and 1996. The organic content in 2021 was 3.39% which was 2.3% lower than in 2018.

The concentration of total aliphatic hydrocarbons (TAH) at station SV17 in 2021 was lower than in 2018. The 2021 result was within 1 standard deviation from the historic mean for data 2004-2018, indicating that there has been little change. The relative standard deviation between the 3 TAH grab replicates was 13.2% indicating low variation in the sediment composition for TAH. The percentage of UCM in the TAH was higher than the 2018 result. The 2021 result was within 1 standard deviation from the historic mean for data 2004-2018, indicating there has been little change.

The concentration of 2-6 ring PAH concentration at station SV17 in 2021 was within 1 standard deviation of the historic mean for data 2004-2018, which indicates there has been little change. The percentage of 4-6 ring PAHs of the total PAHs was +1.5 standard deviations of the historic mean for data 2004-2018, which indicates there has been some change

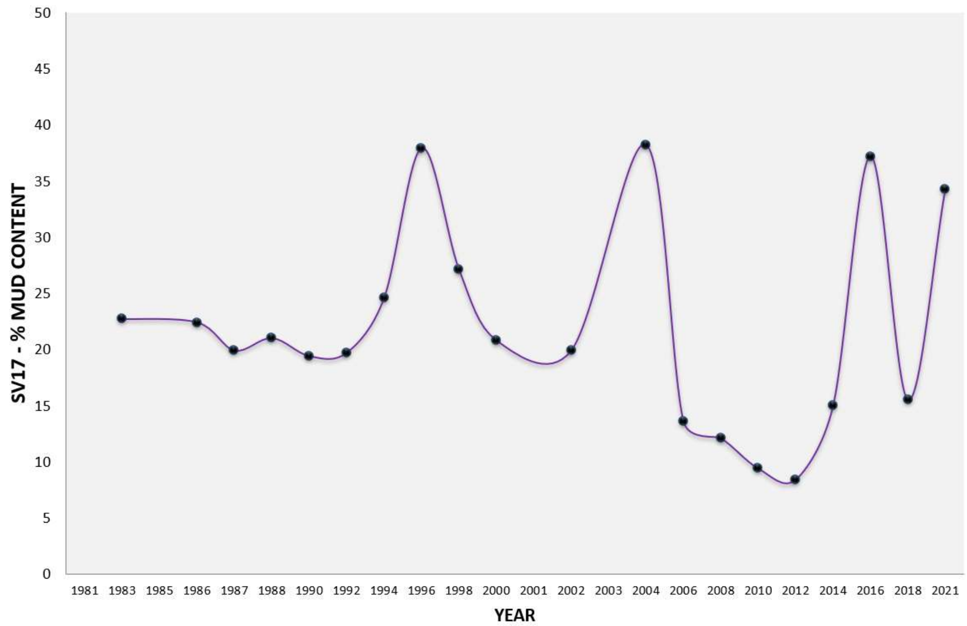

Figure 59 – SV17 Percentage Mud content

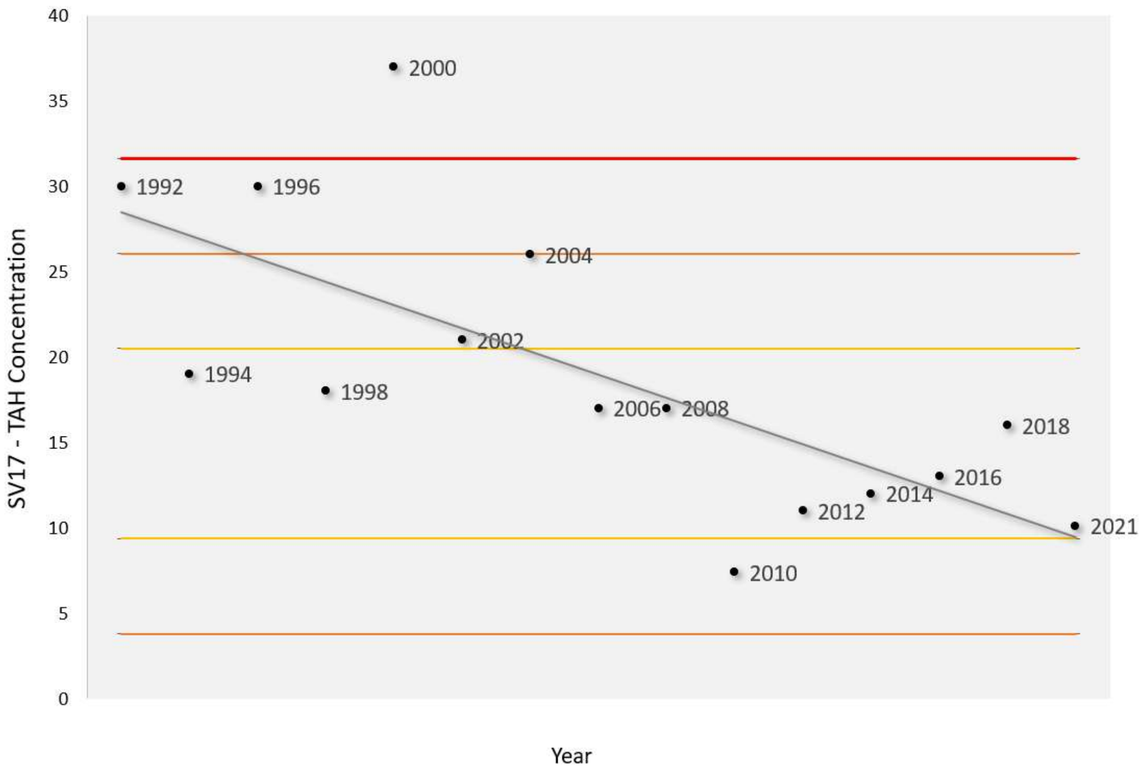

Figure 60 – SV17 Total Aliphatic Hydrocarbon concentration (µg.g^{-1} dry wt. sed.)

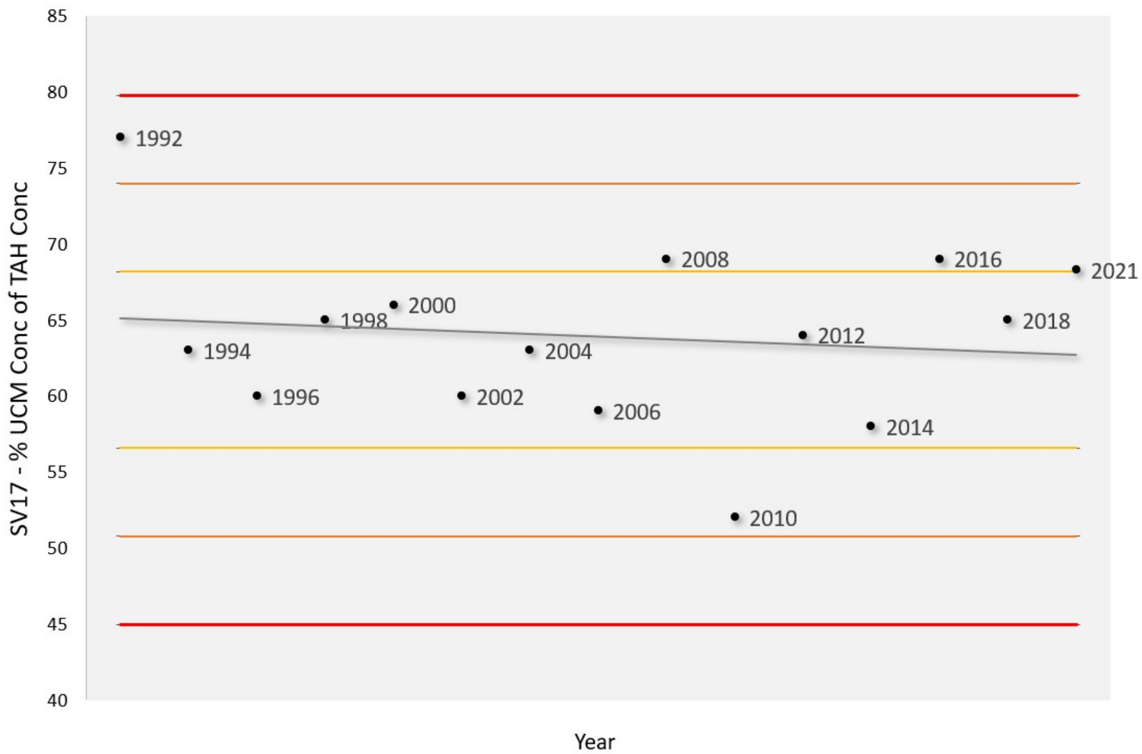

Figure 61 – SV17 Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

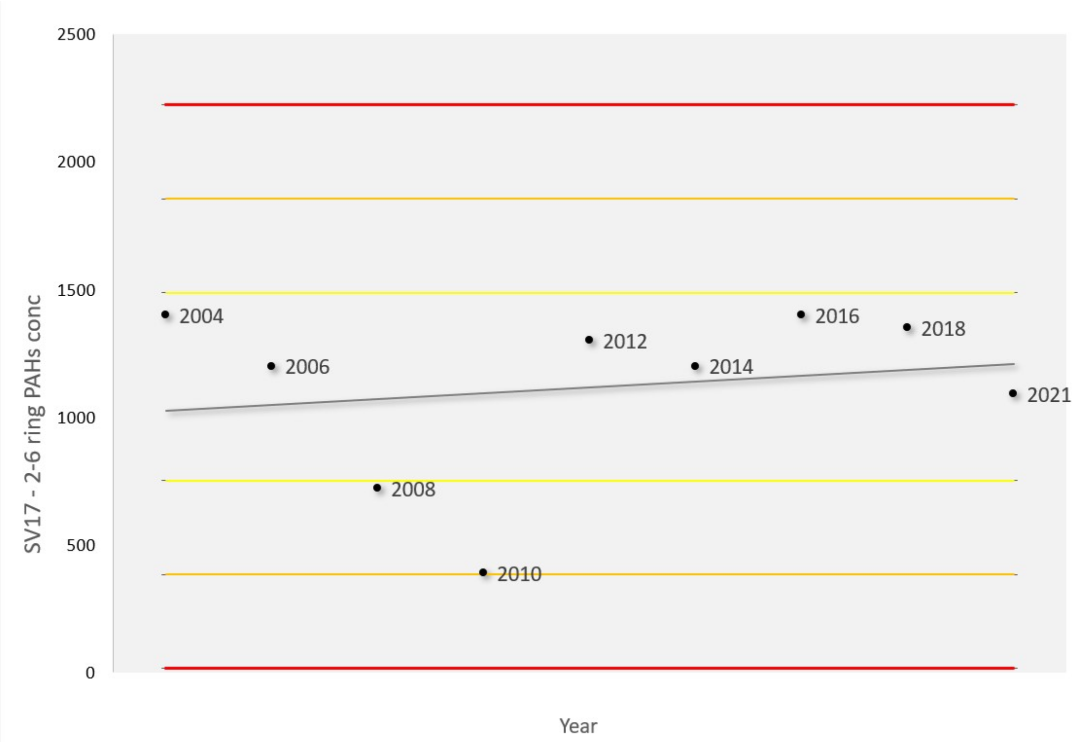

Figure 62 – SV17 2-6 ring PAH concentration (ng.g^{-1} dry sed.)

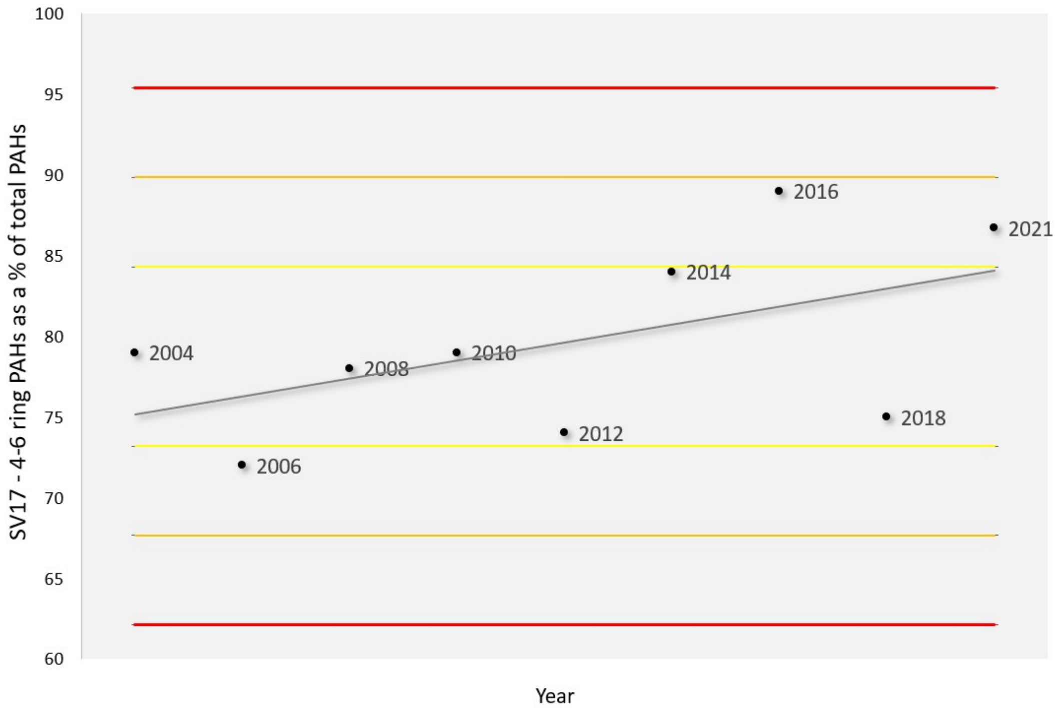

Figure 63 – SV17 4-6 ring PAHs as a percentage of the total PAHs (%)

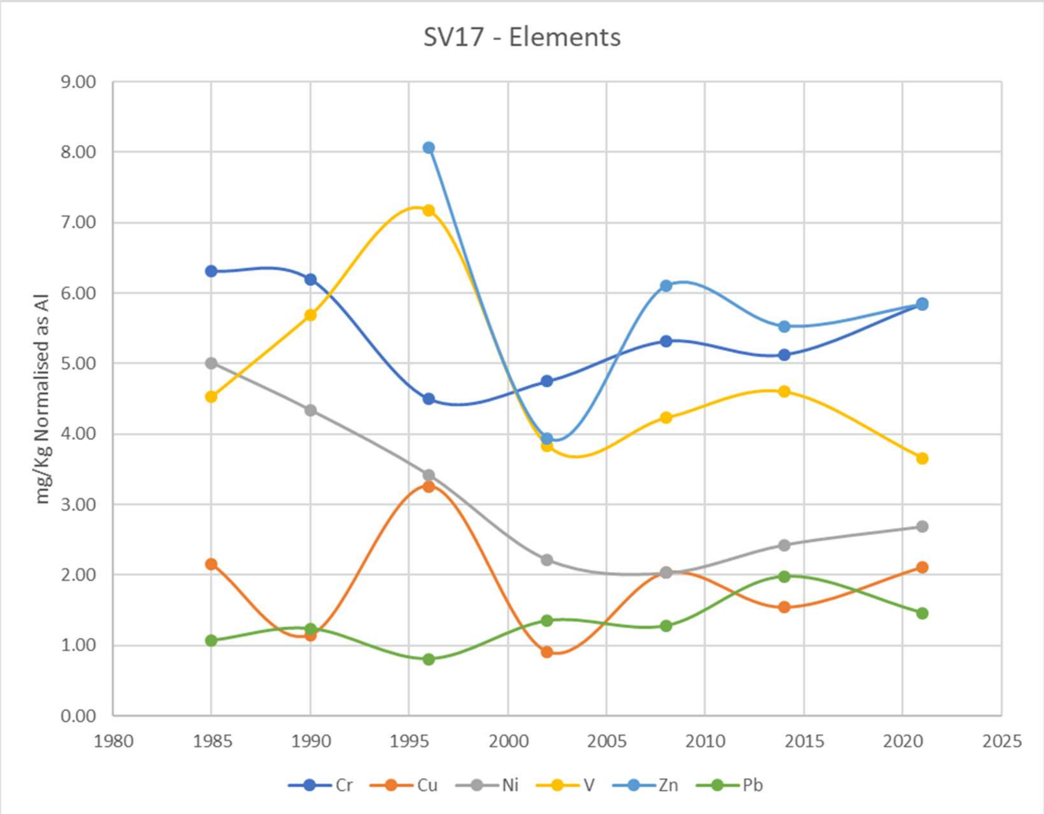

Figure 64 – SV17 Elements in mg/Kg (dry sed. normalised as Aluminium).

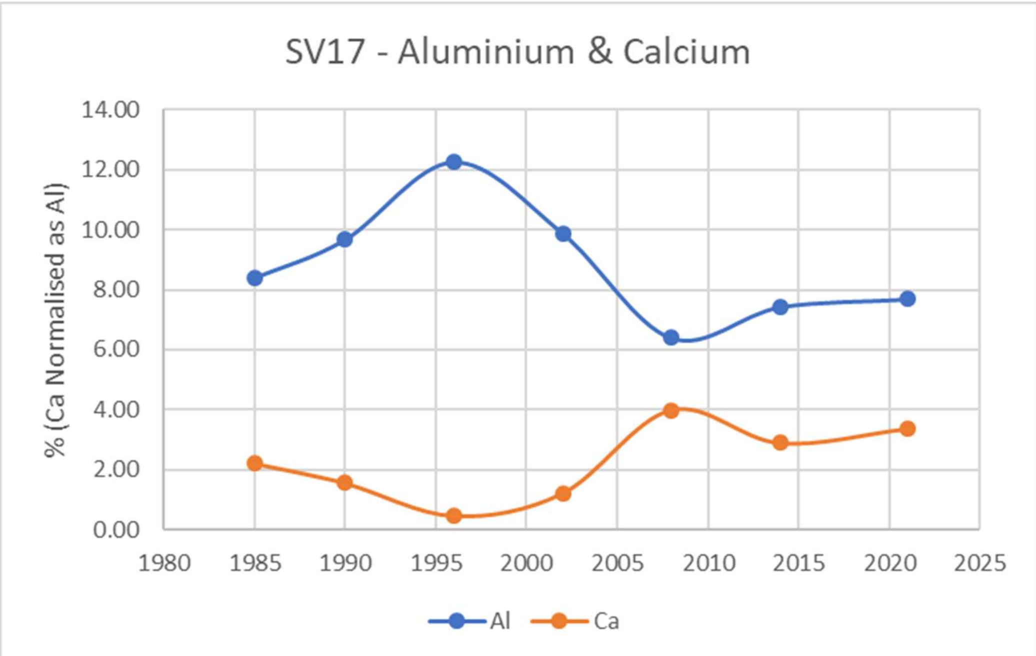

Figure 65 – SV17 Aluminium and Calcium in % (m/m - dry sed.) Calcium normalised as Aluminium.

3.4.3 YELL SOUND AND NORTH OF CALBECK NESS (STATIONS 33 TO 37)

3.4.3.1 Calbeck Ness SV12

For station SV12, the mud content in 2021 was 7.8% which was 3.7% lower than in 2018. The organic content in 2021 was 3.39% which is 1.0% higher than in 2018.

The concentration of total aliphatic hydrocarbons (TAH) at station SV12 is generally low (<10µg.g^{-1}) and in 2021 the level was similar to the historic mean 2004-2018. The 2021 result was within 1 standard deviation from the historic mean for data 2004-2018, indicating there had been little change. The relative standard deviation between the 3 TAH grab replicates was 12.1% indicating low variation in the sediment composition for TAH. The percentage of UCM in the TAH was lower than 2016-2018 but shows little change from the historic mean for data 2004-2018.

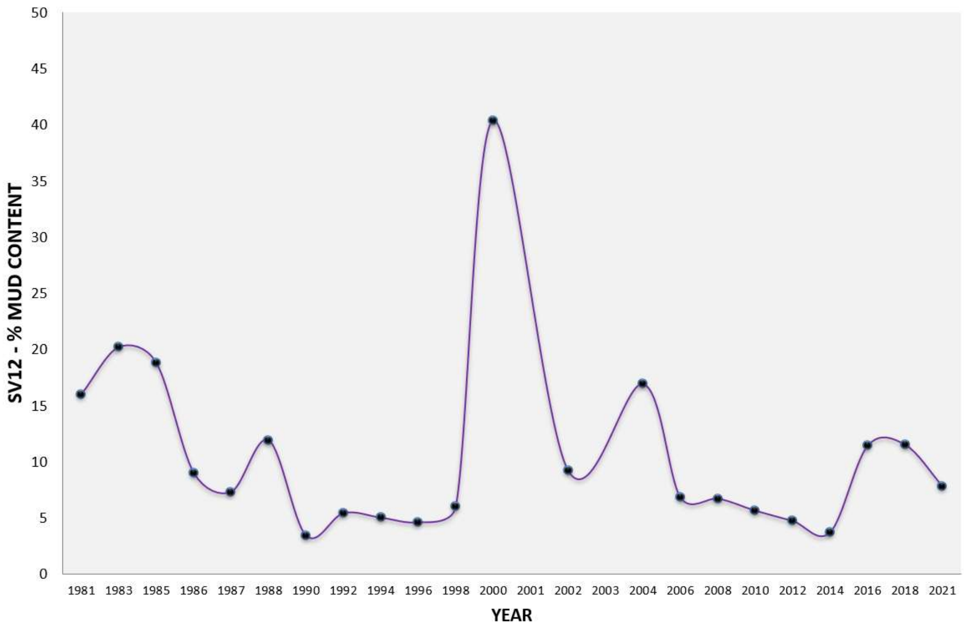

Figure 66 – SV12 Percentage Mud content

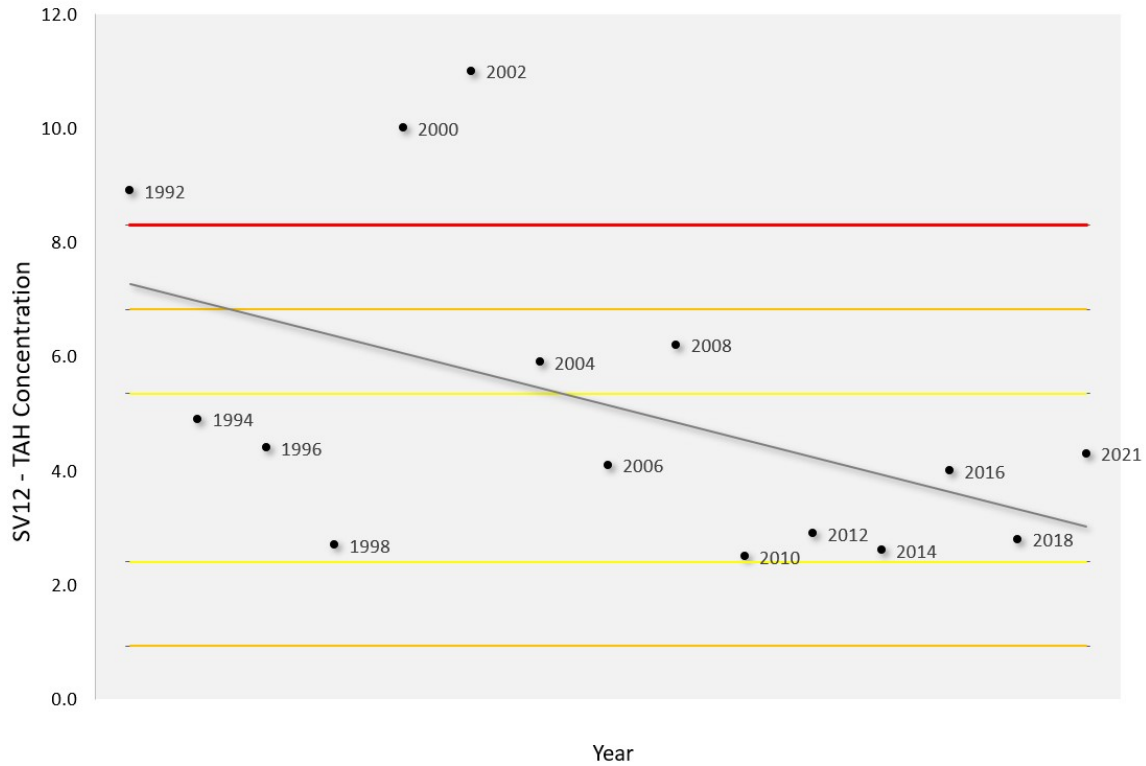

Figure 67 – SV12 Total Aliphatic Hydrocarbon concentration (µg.g^{-1} dry wt. sed.)

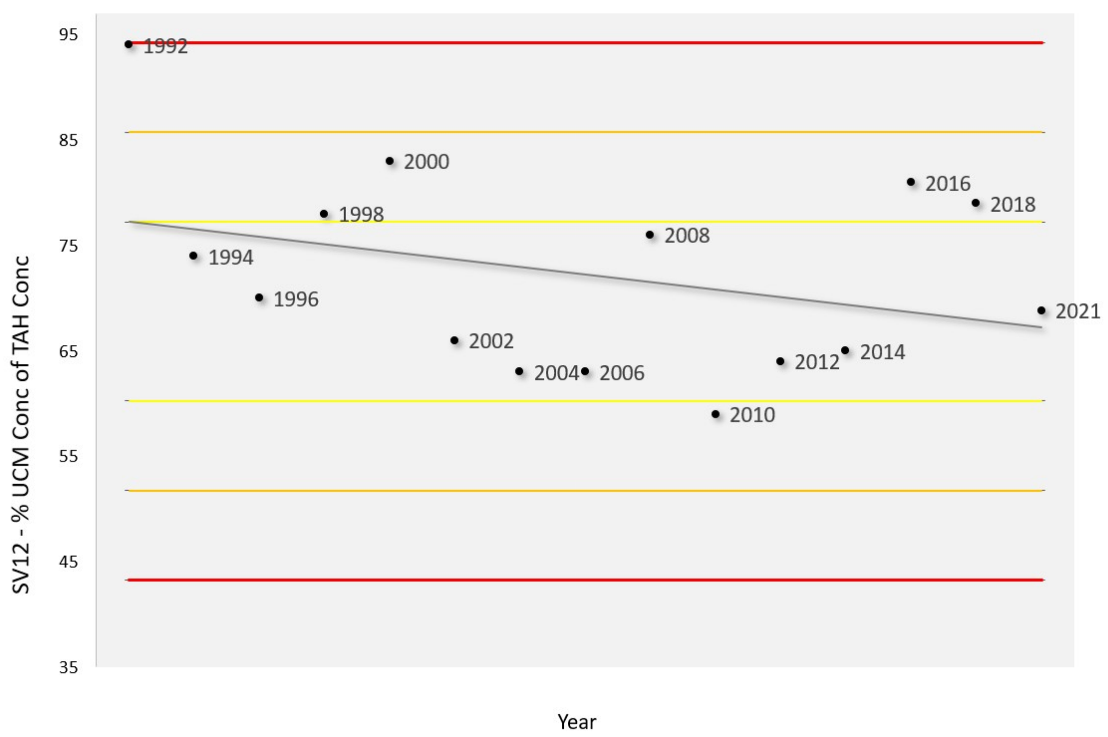

Figure 68 – SV12 Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

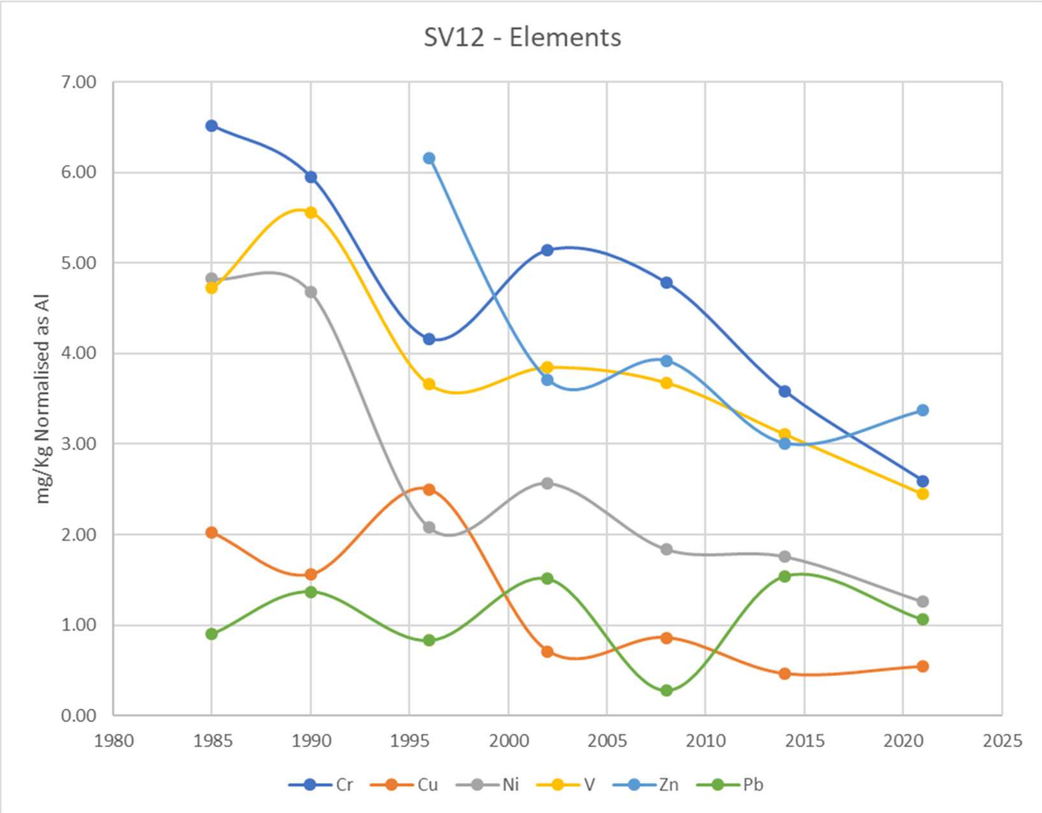

Figure 69 – SV12 Elements in mg/Kg (dry sed. normalised as Aluminium).

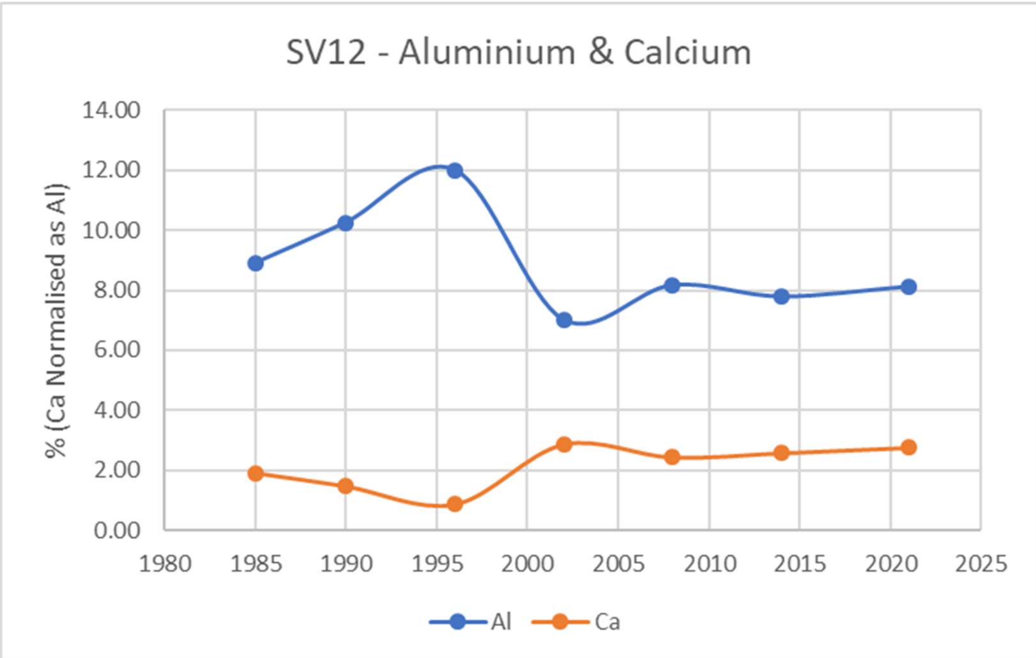

Figure 70 – SV12 Aluminium and Calcium in % (m/m - dry sed.) Calcium normalised as Aluminium.

3.4.3.2 Calbeck Ness SV33

For station SV33, the mud content in 2021 was 32.6% and was 2.9% lower than in 2018. The organic content in 2021 was 3.9% which was 0.1% higher than 2018 result.

The concentration of total aliphatic hydrocarbons (TAH) at station SV33 was higher than in 2018 and is more comparable with the results from 2010 to 2014, 2018. The 2021 result was within 1 standard deviation from the historic mean for data 2004-2018, indicating there had been little change. The relative standard deviation between the 3 TAH grab replicates was 1.7% indicating low variation in the sediment composition for TAH. The percentage of UCM in the TAH was comparable to the level in 2016-2018 and higher than the historic mean for 2004-2018.

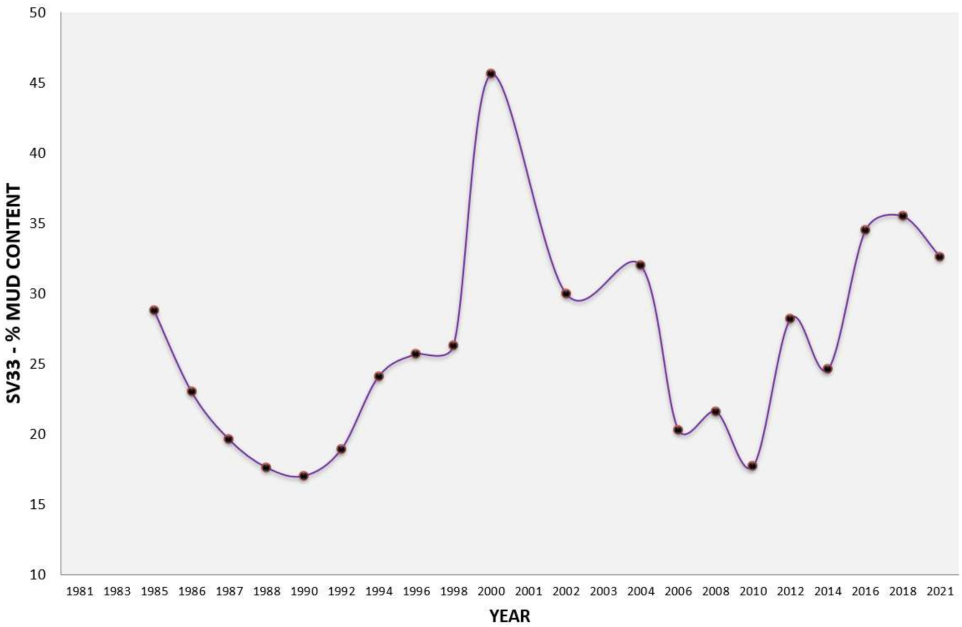

Figure 71 – SV33 Percentage Mud content

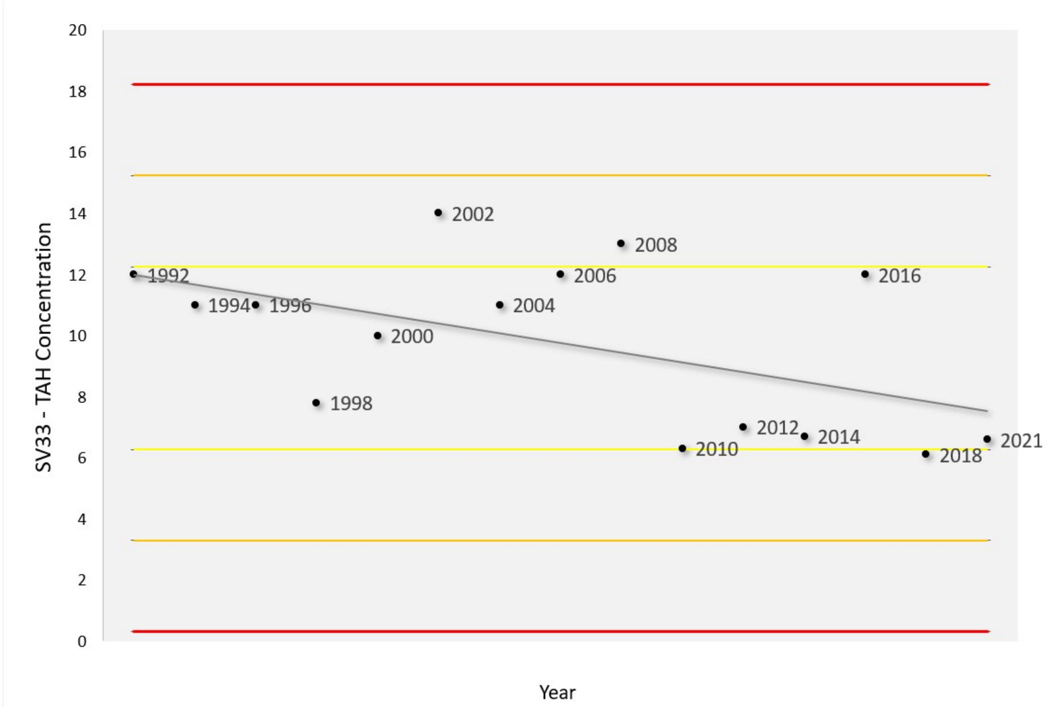

Figure 72 – SV33 Total Aliphatic Hydrocarbon concentration (µg.g^{-1} dry wt. sed.)

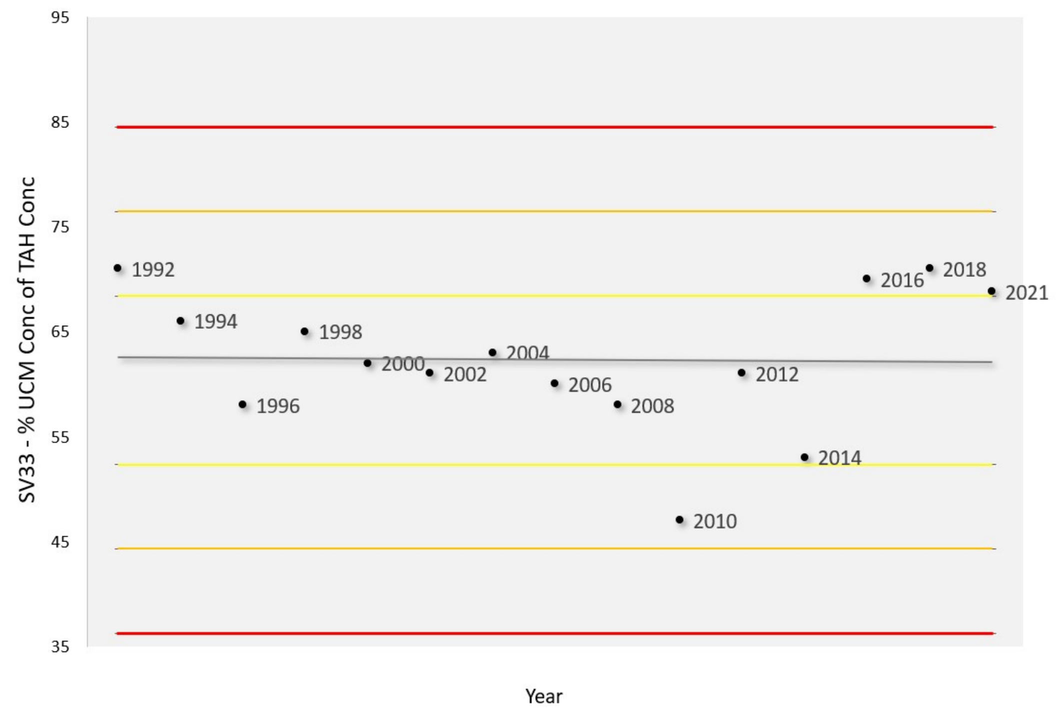

Figure 73 – SV33 Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

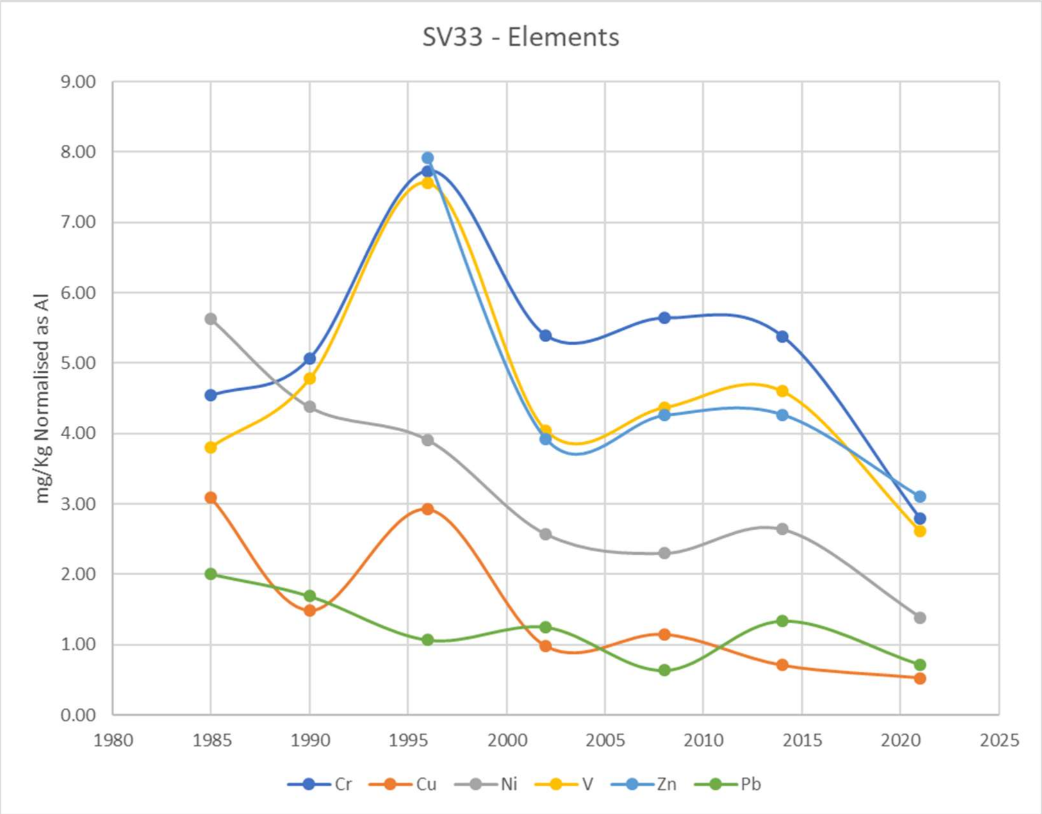

Figure 74 – SV33 Elements in mg/Kg (dry sed. normalised as Aluminium).

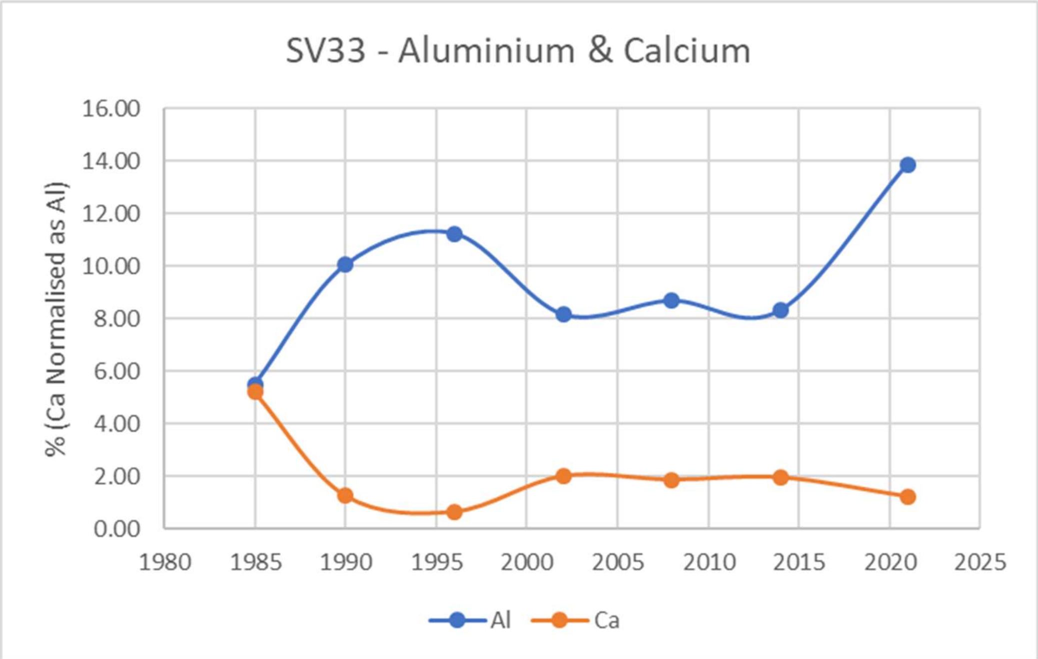

Figure 75 – SV33 Aluminium and Calcium in % (m/m - dry sed.) Calcium normalised as Aluminium.

3.4.3.3 Calbeck Ness SV34

For station SV34, the mud content in 2021 was 31.3% and 2.8% lower than the 2018 result. The organic content in 2021 was 4.21% which was 0.3% higher than the 2018 result.

The concentration of total aliphatic hydrocarbons (TAH) at station SV34 is generally low (<10µg.g^{-1}) and has not changed significantly. The 2021 result was higher than the 2018 result and within 1 standard deviation from the historic mean for 2004-2018 indicating little change. The relative standard deviation between the 3 TAH grab replicates was 14.9 % indicating low variation in the sediment composition for TAH. The percentage of UCM in the TAH was higher than the 2018 result and within 1 standard deviations of the historic mean for 2004-2018, indicating little change.

The concentration of 2-6 ring PAH concentration at station SV34 in 2021 was lower than in 2018. The 2021 result was within 1 standard deviation from the historic mean for 2004-2018 and indicates little change. The percentage of 4-6 ring PAHs of the total PAHs has demonstrated little change against the historic mean for 2004-2018.

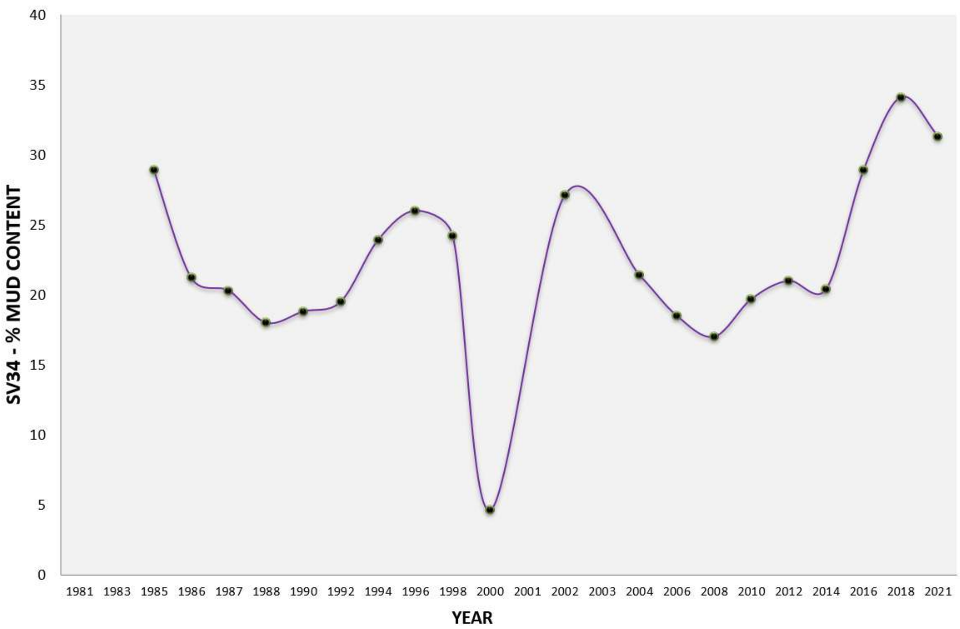

Figure 76 – SV34 Percentage Mud content

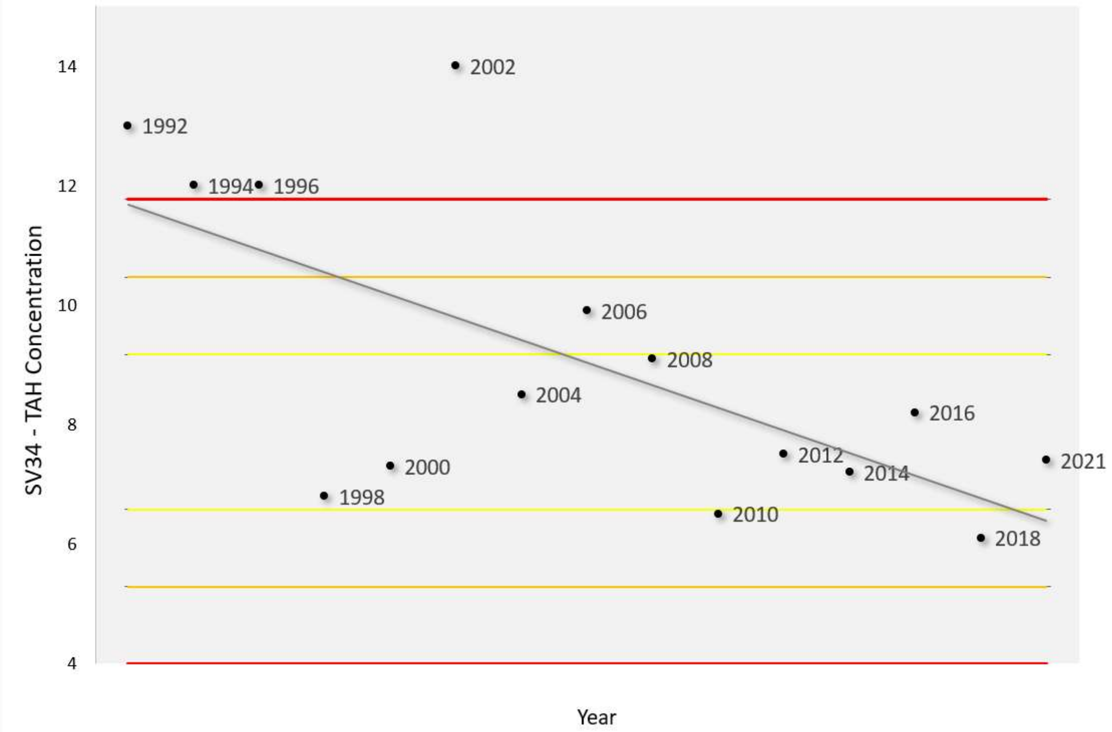

Figure 77 – SV34 Total Aliphatic Hydrocarbon concentration (µg.g^{-1} dry wt. sed.)

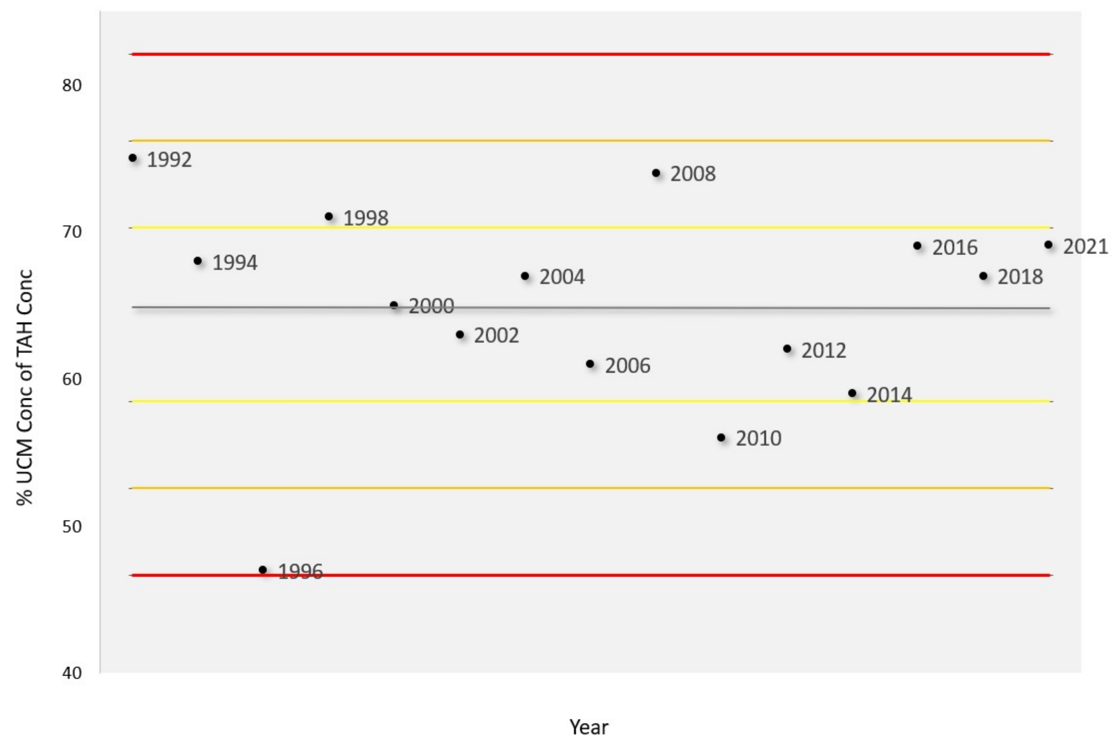

Figure 78 – SV34 Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

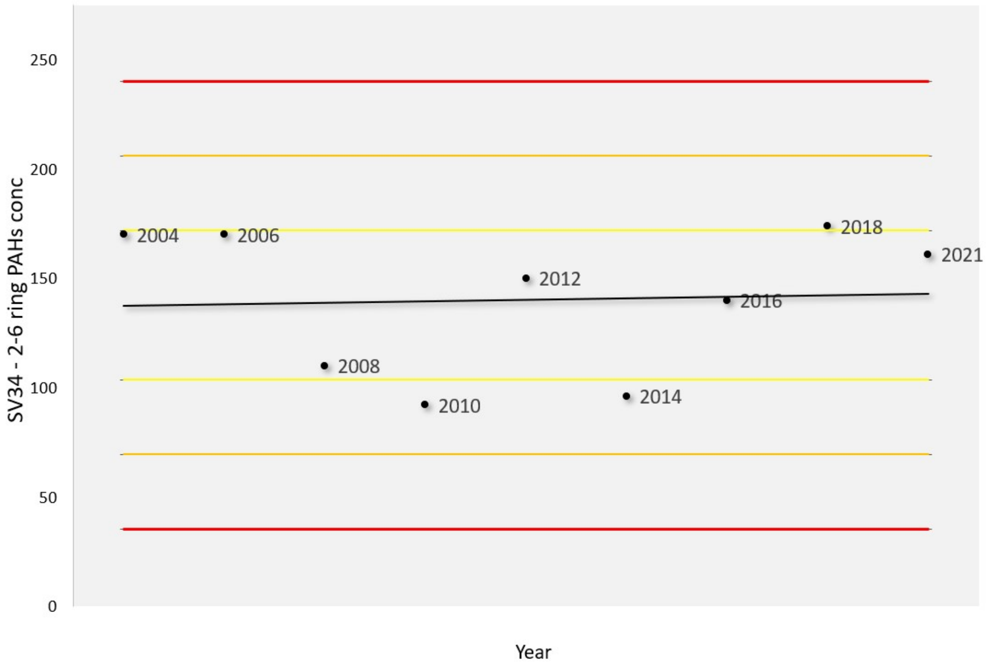

Figure 79 – SV34 2-6 ring PAH concentration (ng.g^{-1} dry sed.)

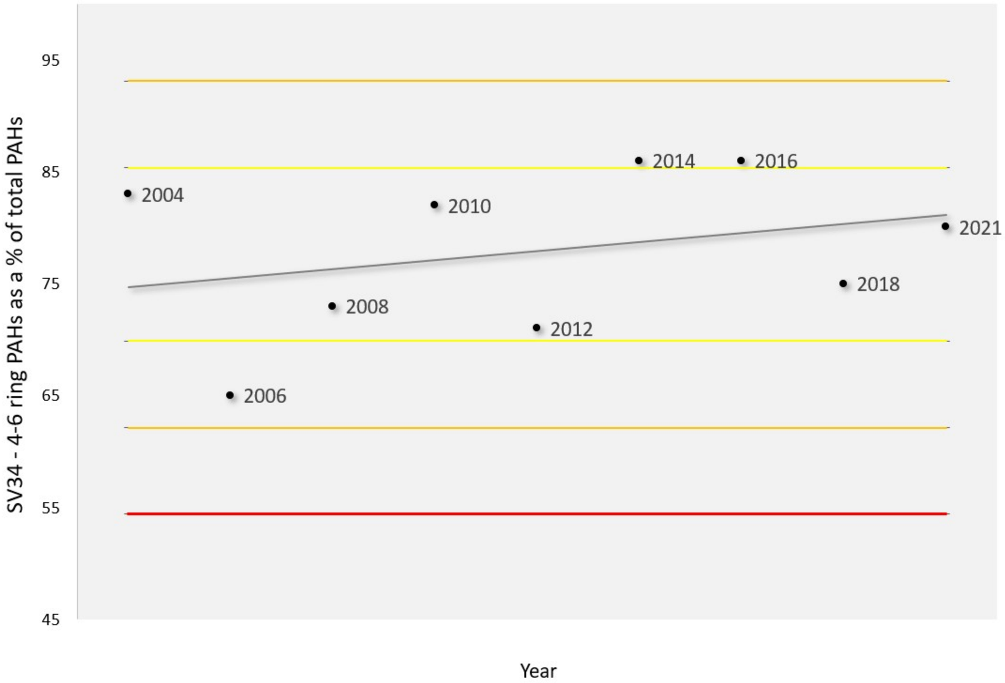

Figure 80 – SV34 4-6 ring PAHs as a percentage of the total PAHs (%)

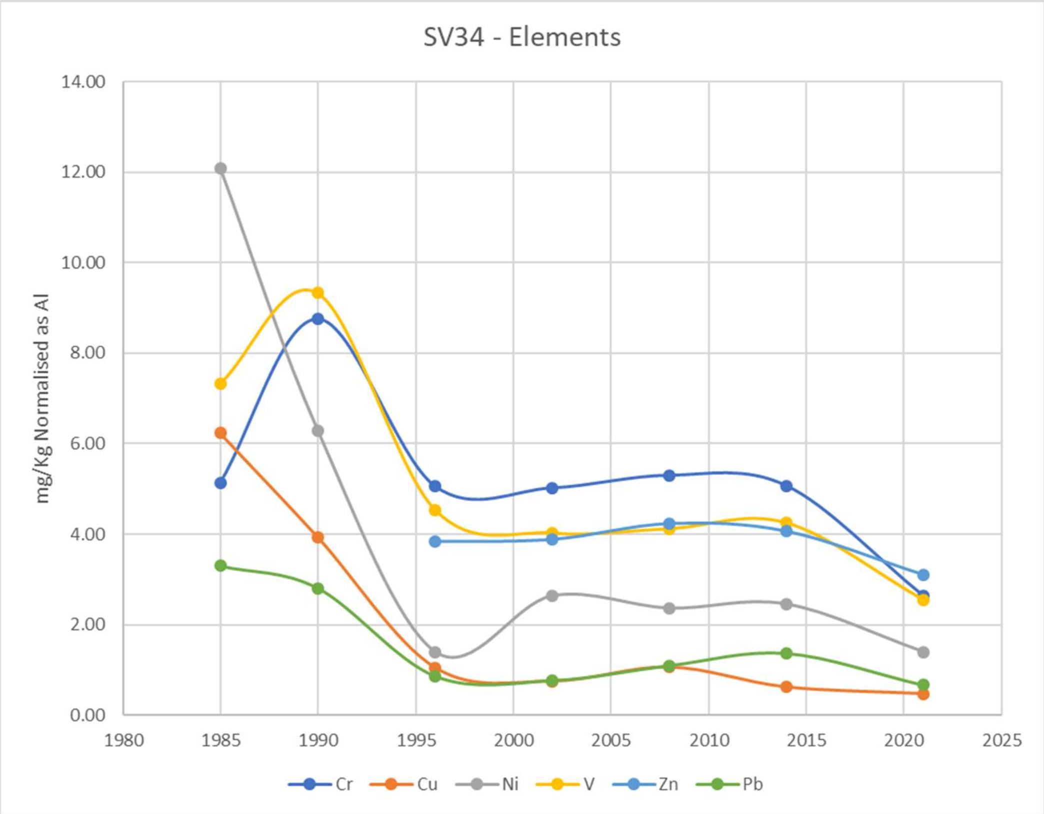

Figure 81 – SV34 Elements in mg/Kg (dry sed. normalised as Aluminium).

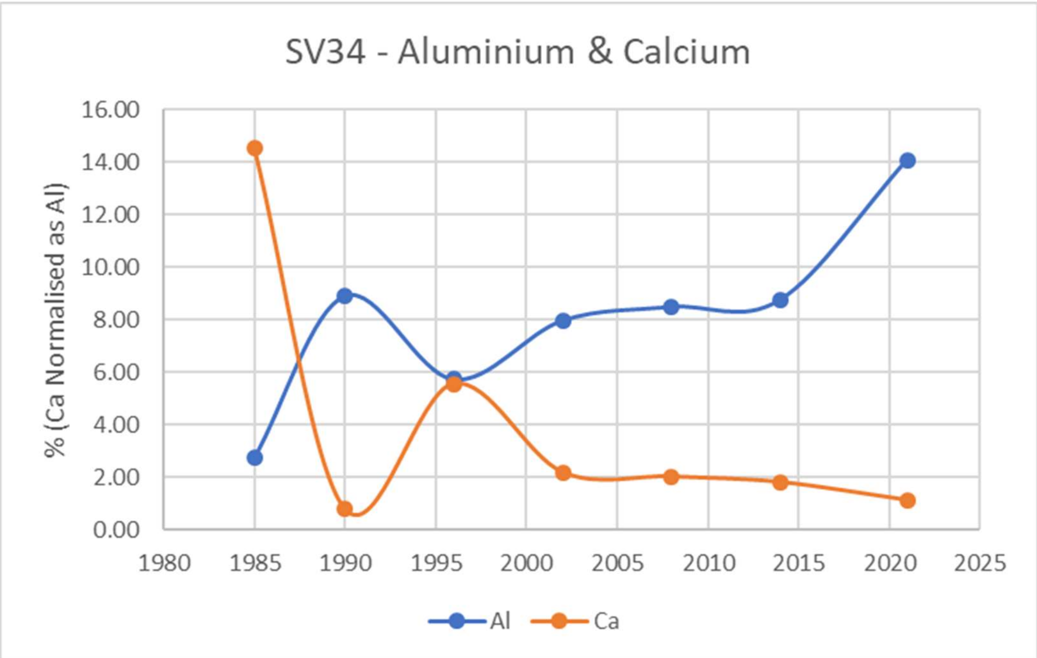

Figure 82 – SV34 Aluminium and Calcium in % (m/m - dry sed.) Calcium normalised as Aluminium.

3.4.3.4 Calbeck Ness SV35

For station SV35, the mud content in 2021 was 8.3% which was 3.7% lower than in 2018. The organic content in 2021 was 1.31% which was the same as in 2018.

The concentration of total aliphatic hydrocarbons (TAH) at station SV35 is generally low (<10µg.g^{-1}) and has not changed significantly. The 2021 result was +1.1 standard deviations from the historic mean for 2004-2018, indicating some change. The relative standard deviation between the 3 TAH grab replicates was 6.4% indicating low variation in the sediment composition for TAH. The percentage of UCM in the TAH is close to the historic mean for 2004-2018 and is with 1 standard deviations from the historic mean.

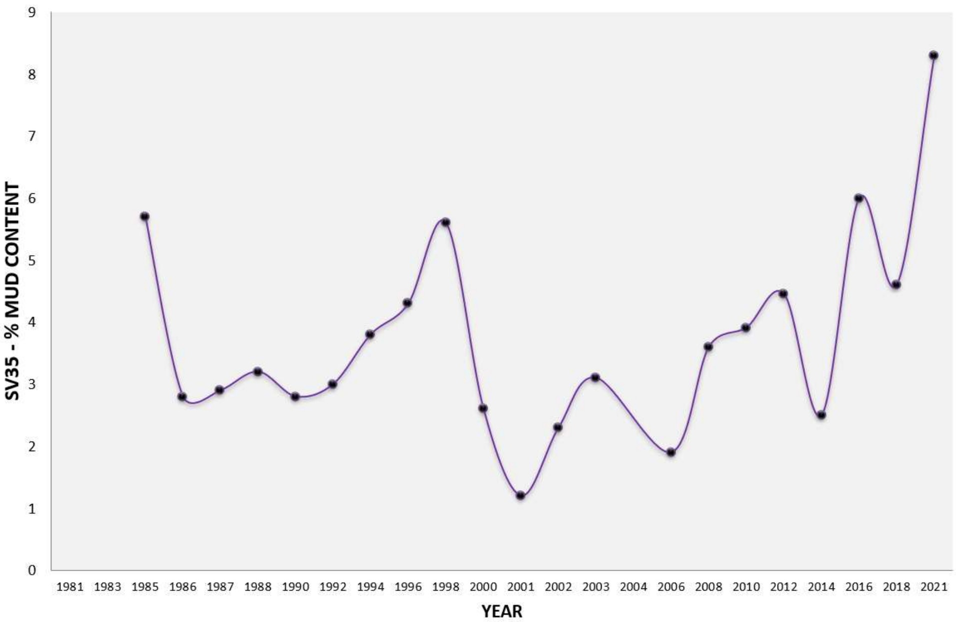

Figure 83 – SV35 Percentage Mud content

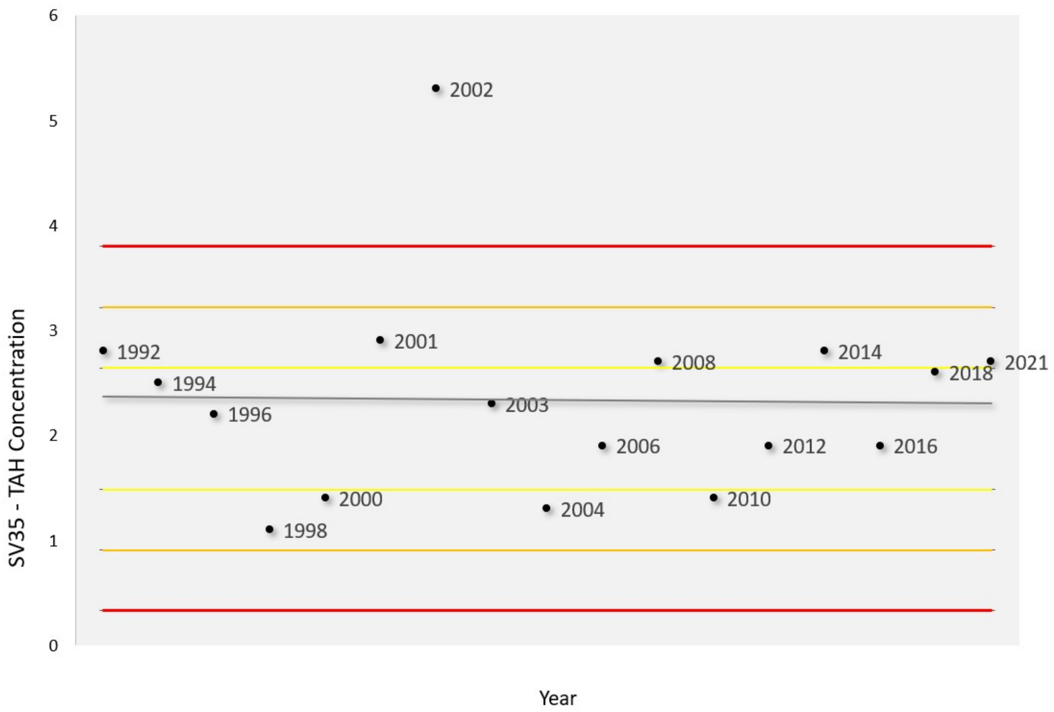

Figure 84 – SV35 Total Aliphatic Hydrocarbon concentration (µg.g^{-1} dry wt. sed.)

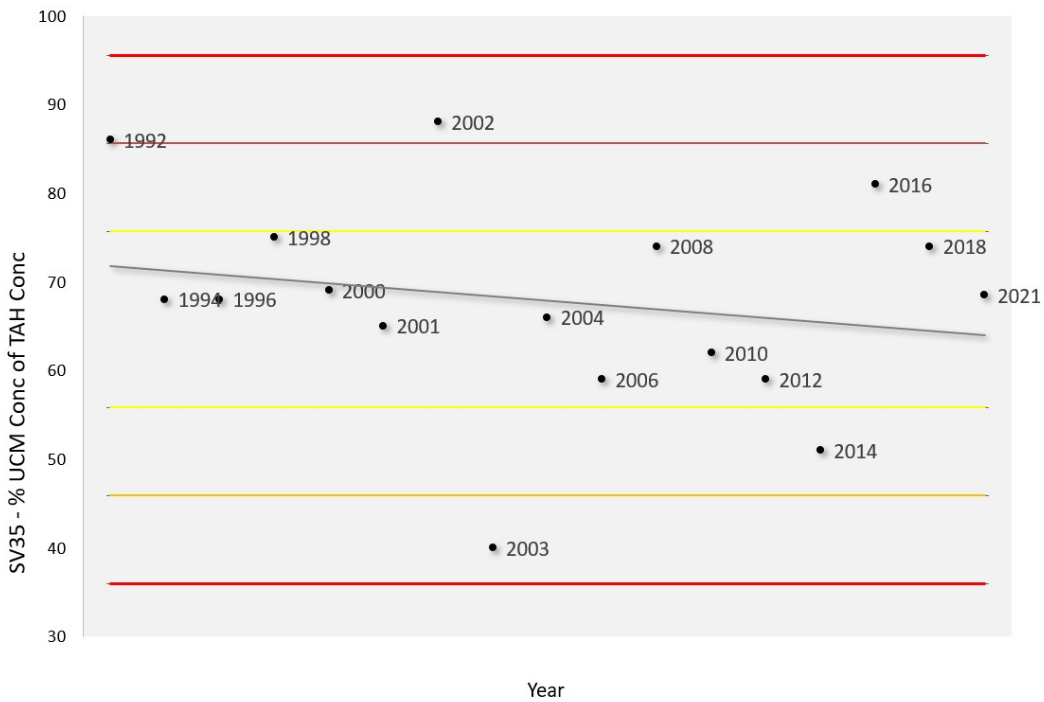

Figure 85 – SV35 Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

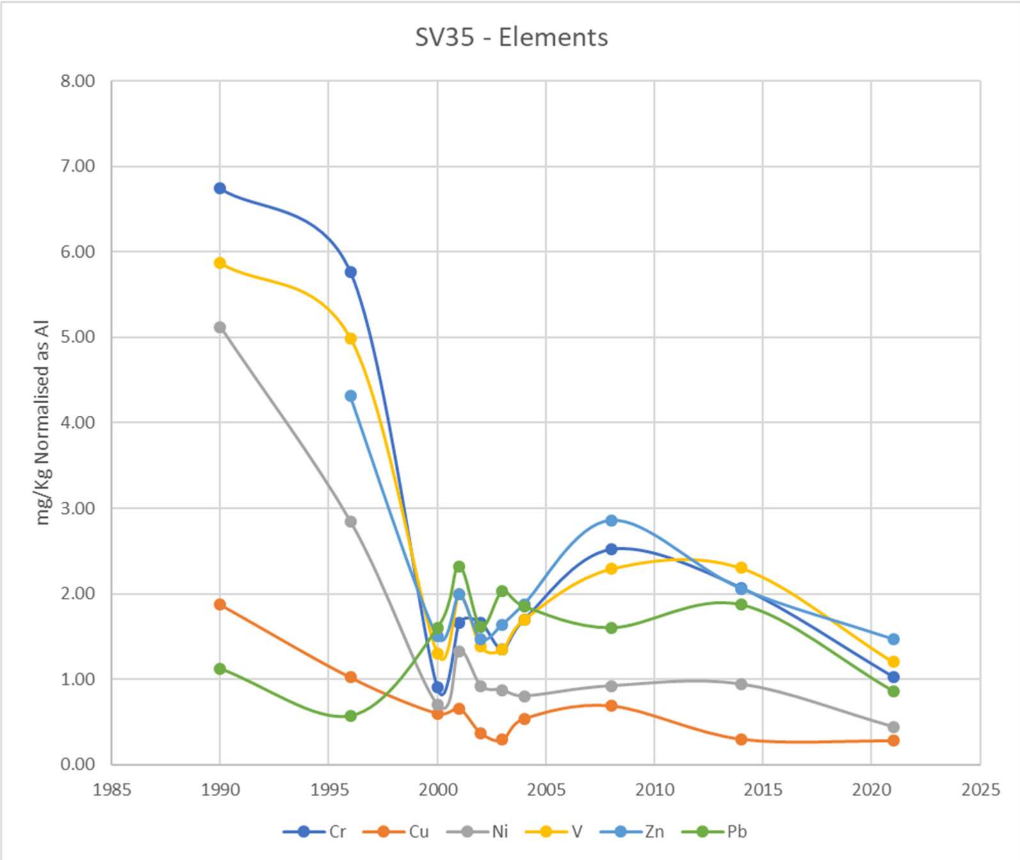

Figure 86 – SV35 Elements in mg/Kg (dry sed. normalised as Aluminium).

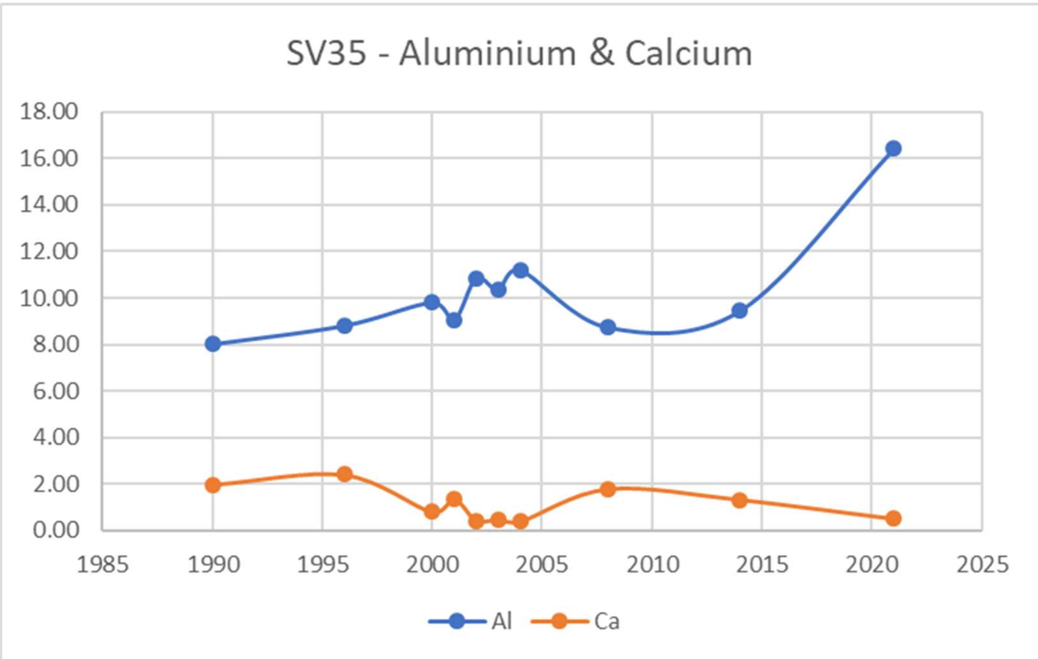

Figure 87 – SV35 Aluminium and Calcium in % (m/m - dry sed.) Calcium normalised as Aluminium.

3.4.3.5 Calbeck Ness SV36B

In 2016 the coordinates for station SV36 were revised as the original coordinates were within a 200m exclusion zone of pipe line assets. In 2016 and 2018 at the new station SV36B, it has not been possible to obtain satisfactory grab samples. SV36 was not sampled in 2021.

3.4.3.6 Calbeck Ness SV37B

In 2016 the coordinates for station SV37 were revised as the original coordinates were within a 200m exclusion zone of pipe line assets. In 2018 at the new station SV37B, three sediment samples were obtained from the grab sampling operation, but there had been many misfires due to brittle stars. In 2021 2 unsatisfactory grab samples were obtained from 5 grab attempts. Video assessment of the station was performed during the 2021 survey and determined that the location SV37B was at the edge of a brittle star bed. A location with a more uniform sediment was identified that will be proposed as a revised station for SV37 for future surveys.

3.4.4 GARTHS VOE (STATIONS 6, 6A, 6F TO 32)

3.4.4.1 Garths Voe SV6

For station SV6, the mud content in 2021 was 31.5% which was 0.5% lower than in 2018. The organic content in 2021 was 4.89% which was 1.6% lower than the 2018 result.

The concentration of total aliphatic hydrocarbons (TAH) at station SV34 was comparable to the 2014-2018 results and is within 1 standard deviation of the historic mean for 2004-2018. The relative standard deviation between the 3 TAH grab replicates was 18.6% indicating moderate variation in the sediment composition for TAH. As in 2016-2018, the percentage of UCM in the TAH continues to be higher than the historic mean but is within 1 standard deviation of the historic mean.

The concentration of 2-6 ring PAH concentration at station SV6 in 2021 was lower than in 2018. The 2021 result was within 1 standard deviation of the historic mean 2004-2018, indicating that there had been little change. The percentage of 4-6 ring PAHs of the total PAHs was consistent with the historic mean, indicating there had been little change.

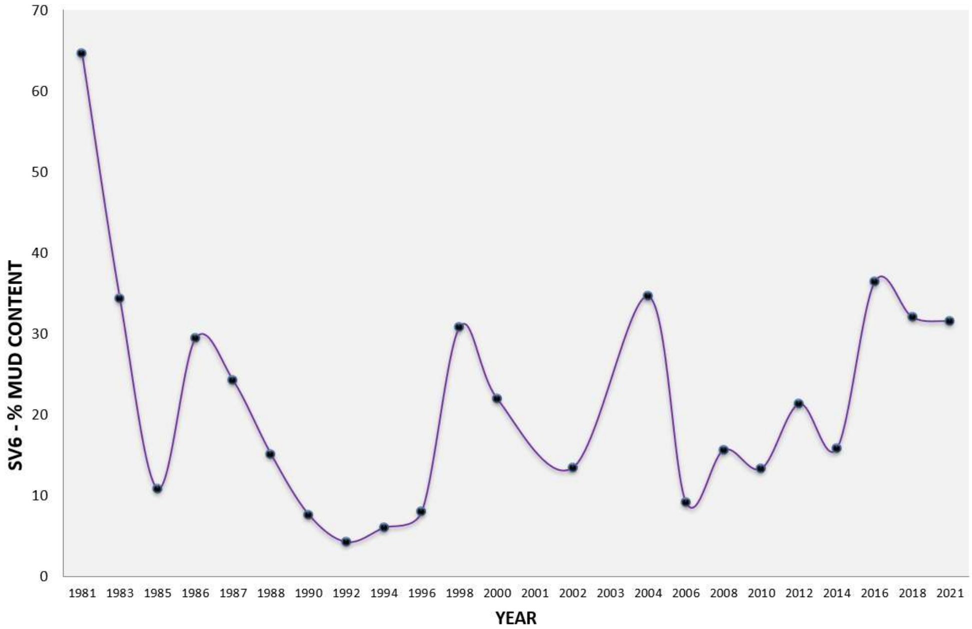

Figure 88 – SV6 Percentage mud content

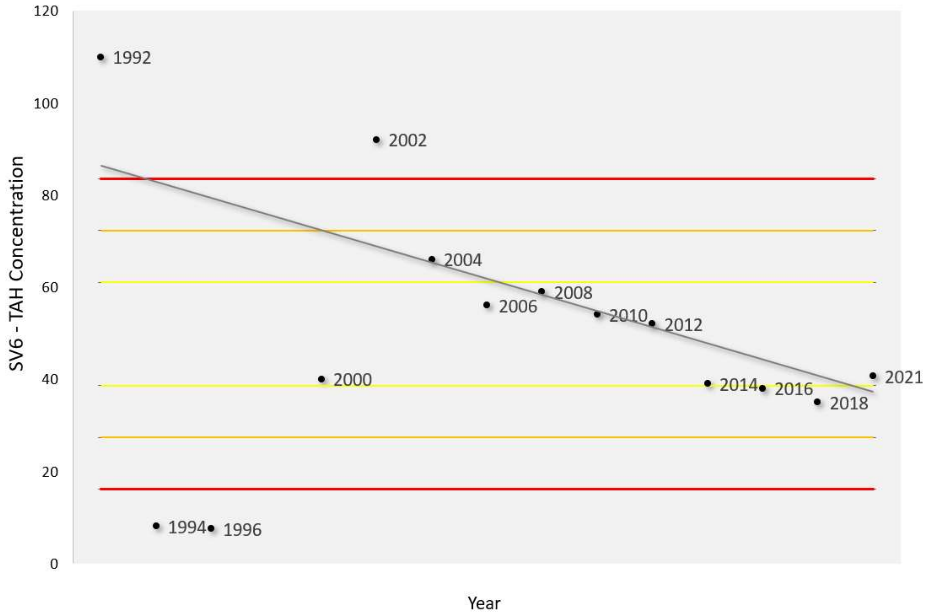

Figure 89 – SV6 Total Aliphatic Hydrocarbon concentration (µg.g^{-1} dry wt. sed.)

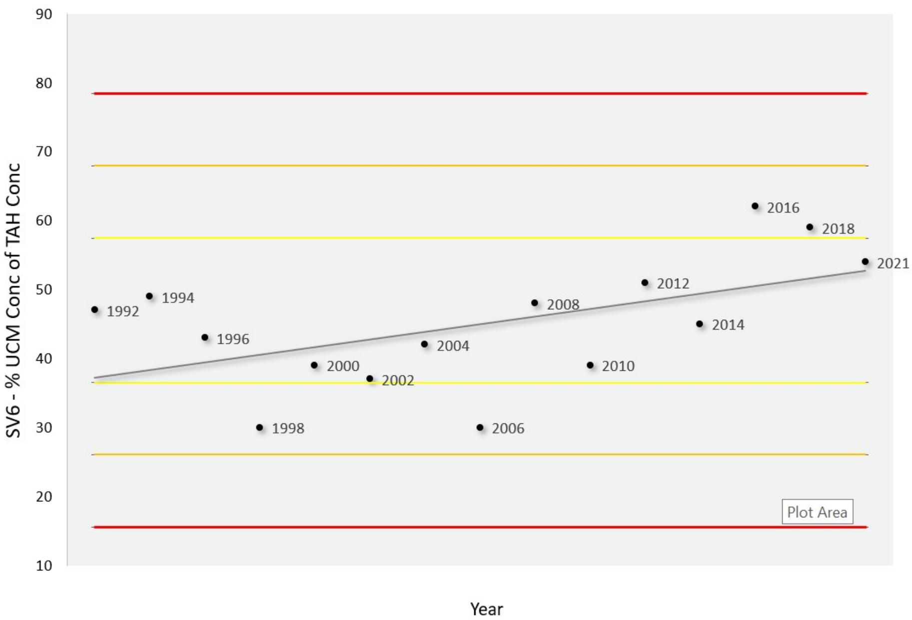

Figure 90 – SV6 Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

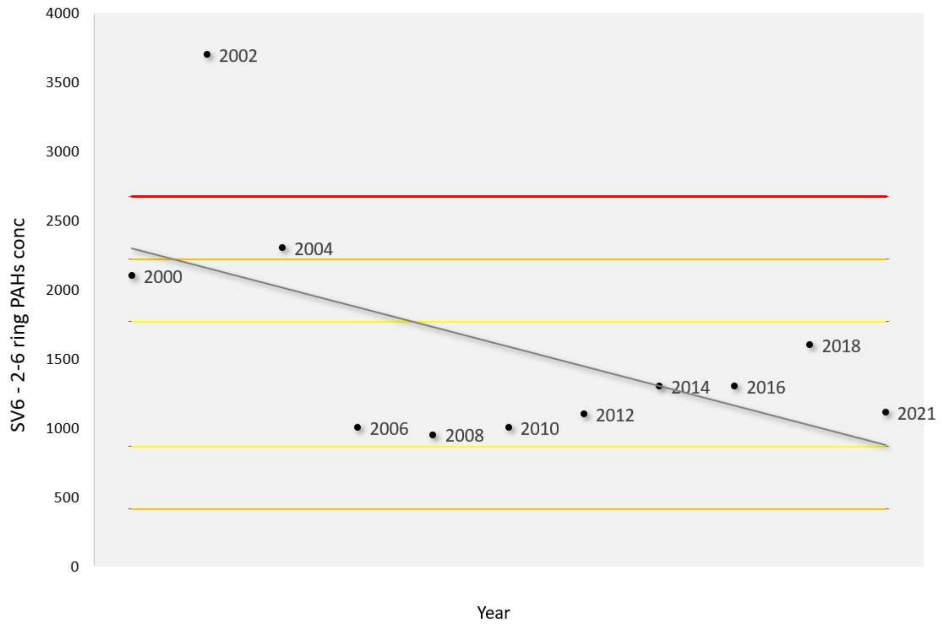

Figure 91 – SV6 2-6 ring PAH concentration (ng/g^{-1} dry sed.)

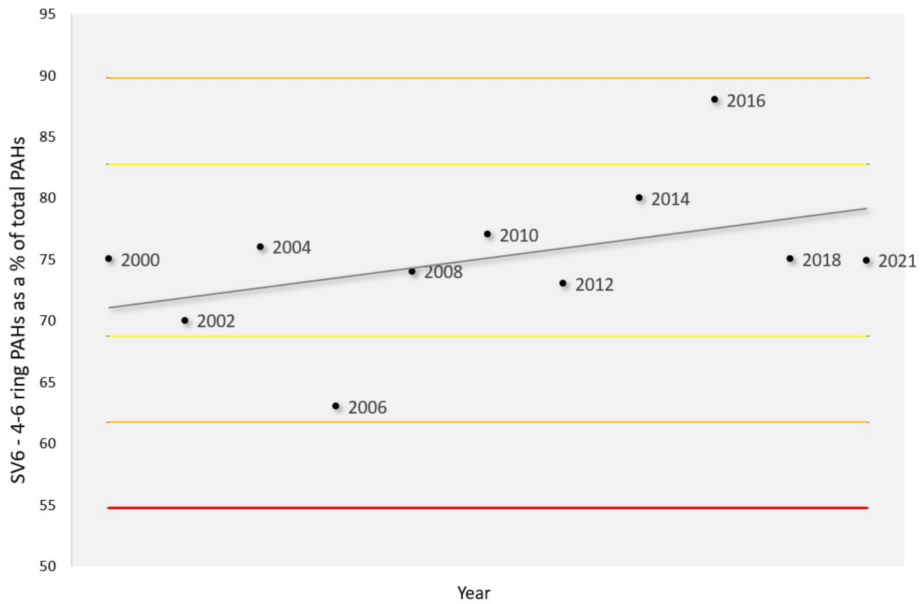

Figure 92 – SV6 4-6 ring PAHs as a percentage of the total PAHs (%)

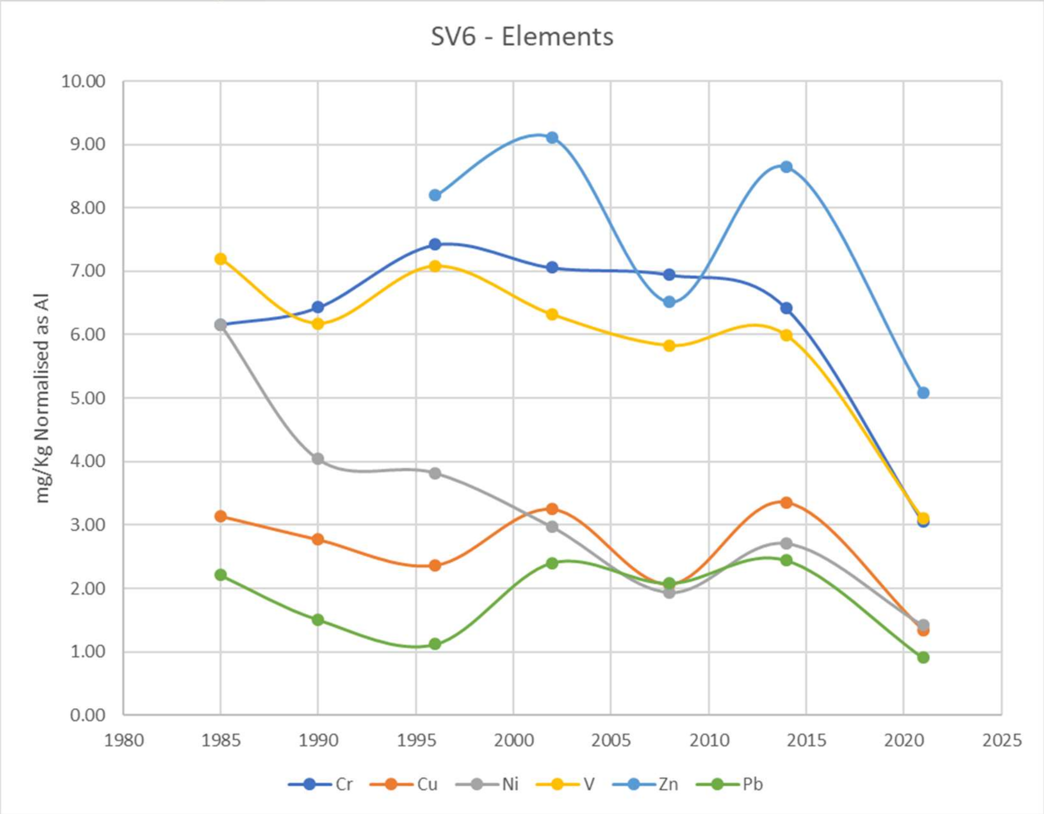

Figure 93 – SV6 Elements in mg/Kg (dry sed. normalised as Aluminium).

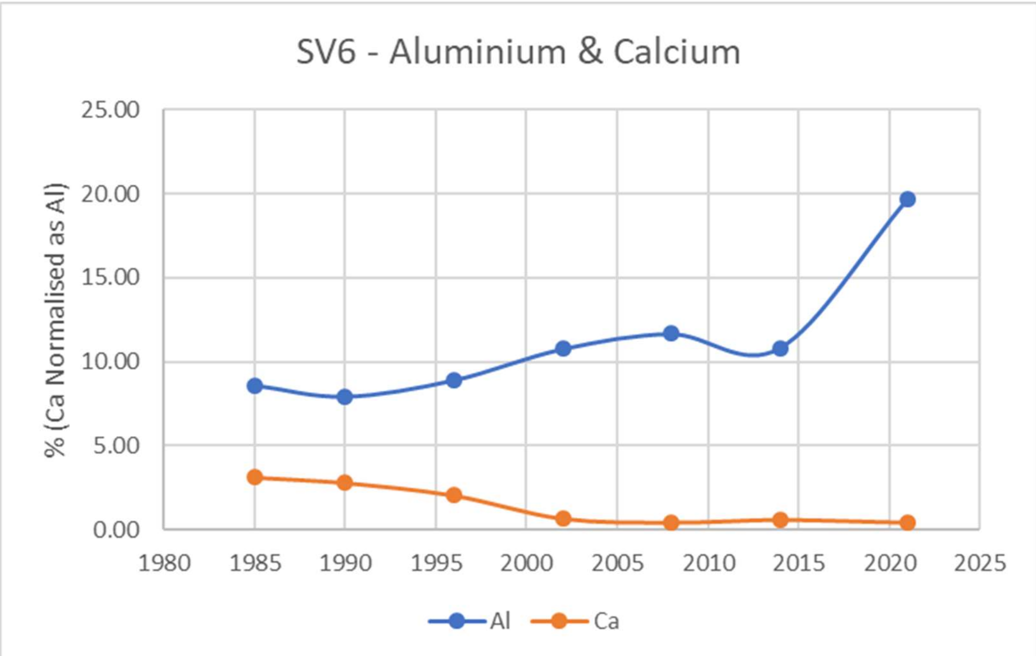

Figure 94 – SV6 Aluminium and Calcium in % (m/m - dry sed.) Calcium normalised as Aluminium.

3.4.4.2 Garths Voe SV6A

For station SV6, the mud content result in 2021 was 28.5% which was 1.9% lower than in 2018. The organic content in 2021 was 7.6% which was 5.3% lower than the 2018 result.

The concentration of total aliphatic hydrocarbons (TAH) at station SV6A was higher than in 2018. The 2021 result was within 1 standard deviation from the historic mean for 2004-2018 indicating little change from the historic mean. The relative standard deviation between the 3 TAH grab replicates was 25% indicating moderate variation in the sediment composition for TAH. The percentage of UCM in the TAH is lower than in 2018 but is within 1 standard deviation of the historic mean for 2004-2018.

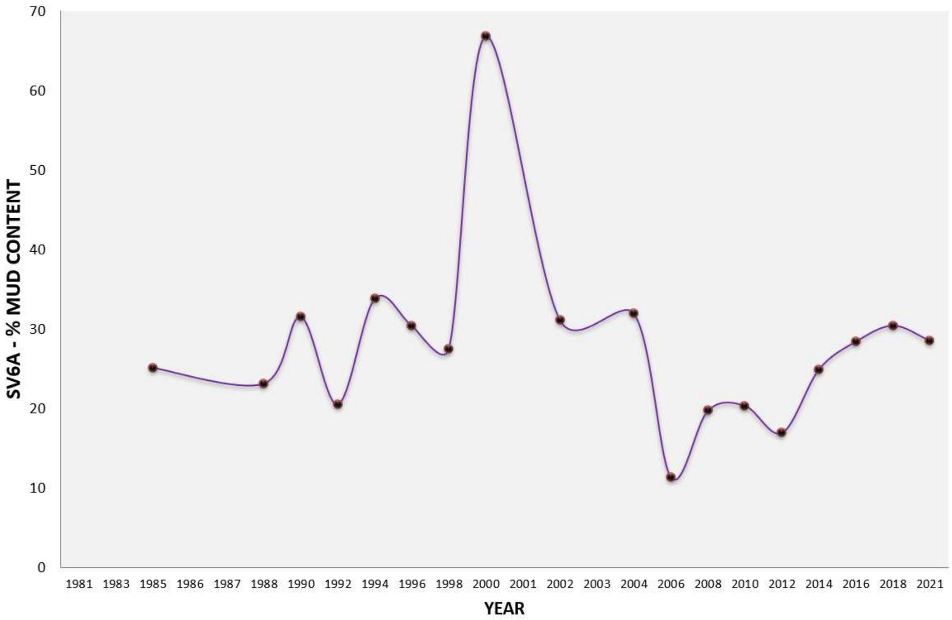

Figure 95 – SV6A Percentage mud content

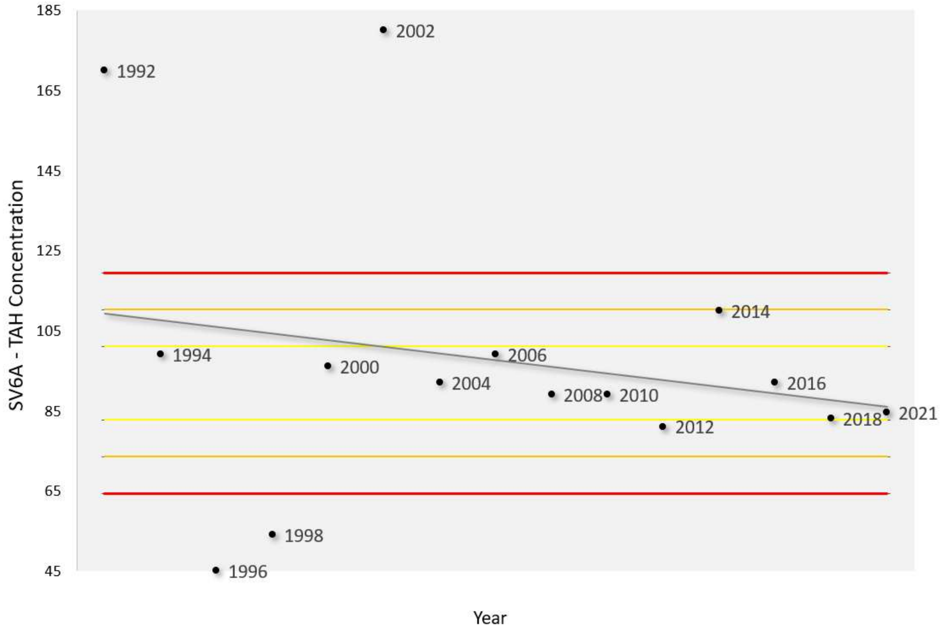

Figure 96 – SV6A Total Aliphatic Hydrocarbon concentration (µg.g^{-1} dry wt. sed.)

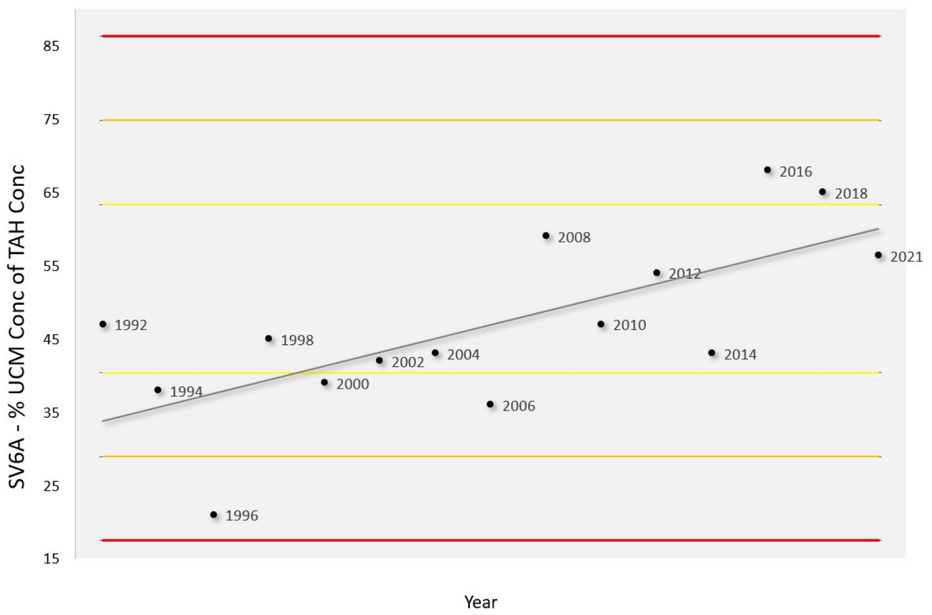

Figure 97 – SV6A Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

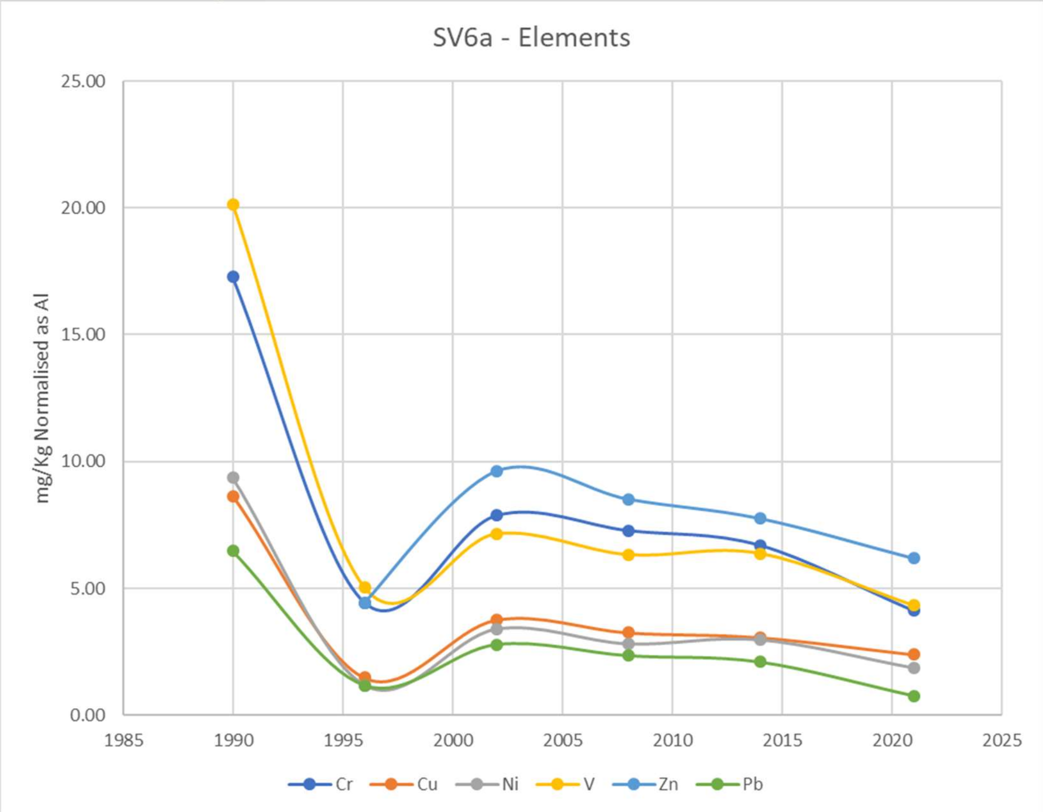

Figure 98 – SV6a Elements in mg/Kg (dry sed. normalised as Aluminium).

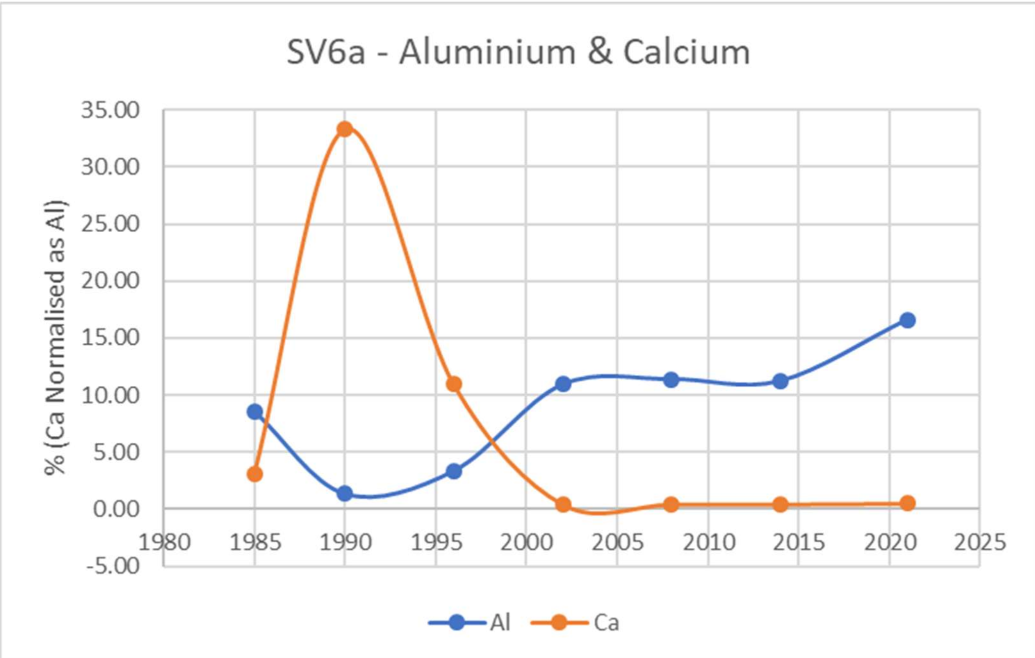

Figure 99 – SV6a Aluminium and Calcium in % (m/m - dry sed.) Calcium normalised as Aluminium.

3.4.4.3 Garths Voe SV6F

For station SV6F, the mud content in 2021 was 30.1% which was 6.4% lower than in 2018. The organic content in 2021 was 11.5% which was 0.3% lower than in 2018.

The concentration of total aliphatic hydrocarbons (TAH) at station SV6F was higher than in 2018. The 2021 result was within 1 standard deviation from the historic mean 2004-2018 indicating little change. The relative standard deviation between the 3 TAH grab replicates was 14.2% indicating low variation in the sediment composition for TAH. The percentage of UCM in the TAH is lower than the 2016-2018 results but is similar to the historic mean, indicating little change.

The concentration of 2-6 ring PAH concentration at station SV34 in 2021 was similar to the 2018 result but was lower than the historic mean for 2004-2018. The 2021 result was -1.0 standard deviation from the historic mean. The percentage of 4-6 ring PAHs of the total PAHs was similar to the 2018 result and was within 1 standard deviation from the historic mean, indicating little change.

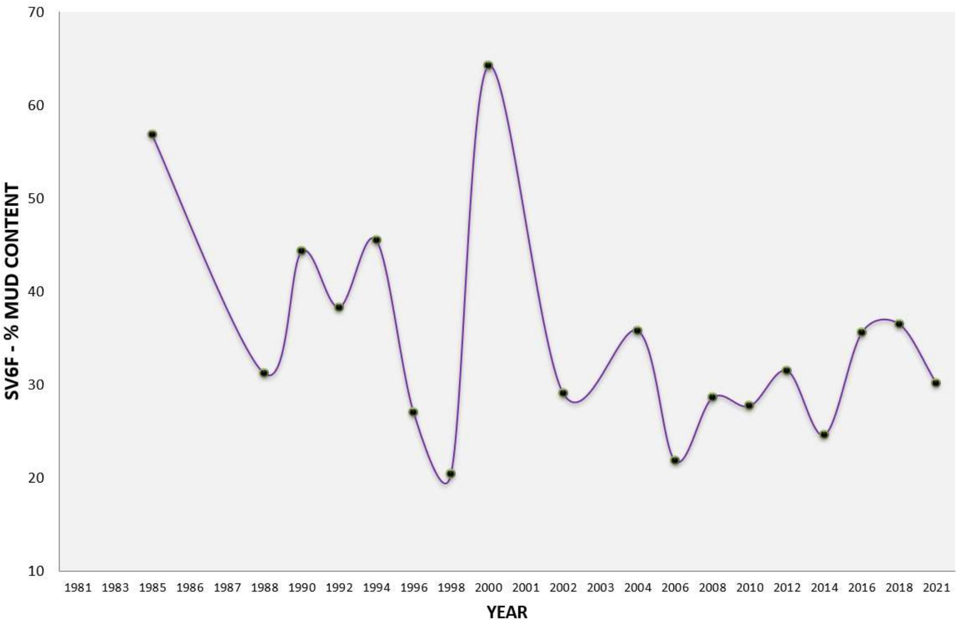

Figure 100 – SV6F Percentage mud content

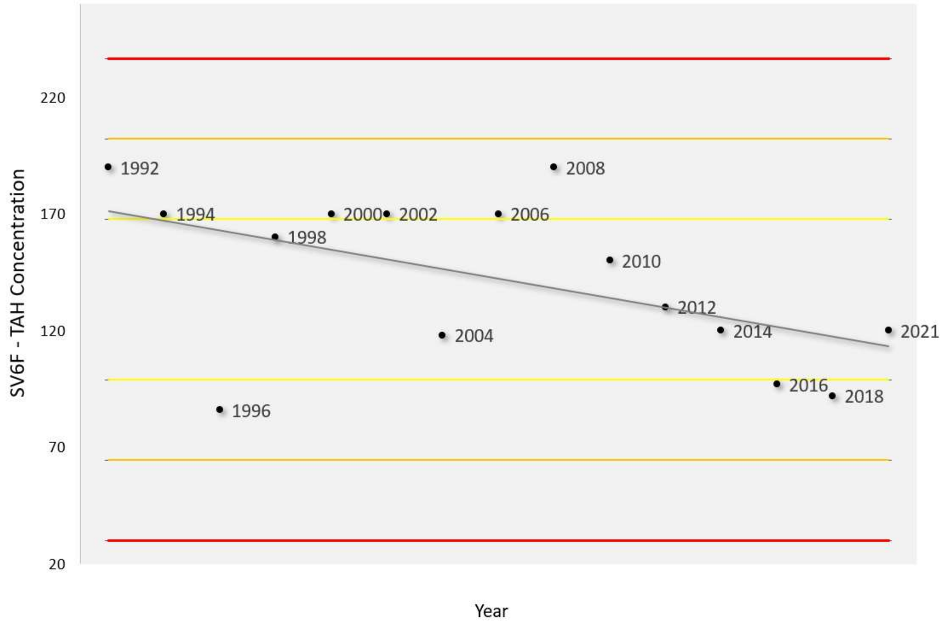

Figure 101 – SV6F Total Aliphatic Hydrocarbon concentration (µg.g^{-1} dry wt. sed.)

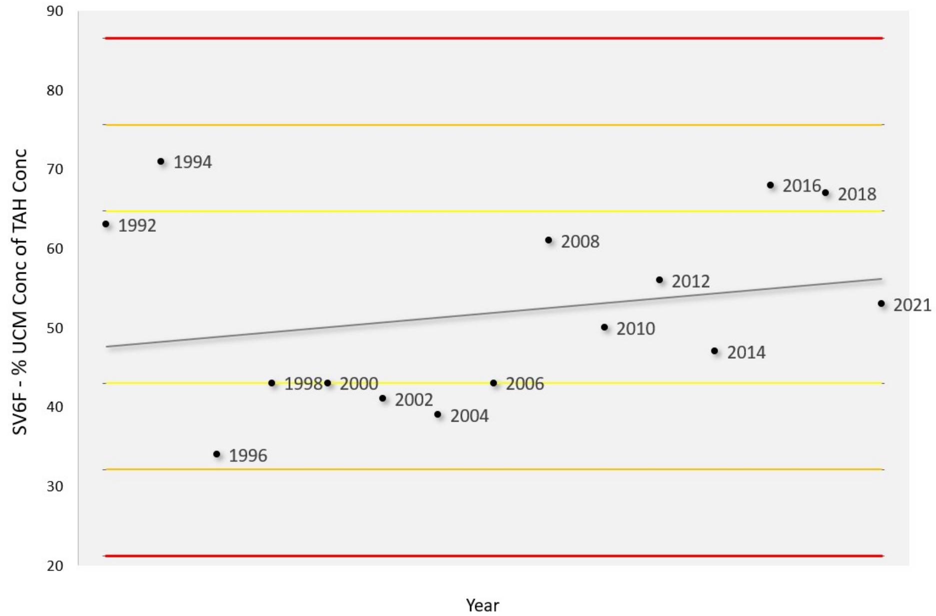

Figure 102 – SV6F Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

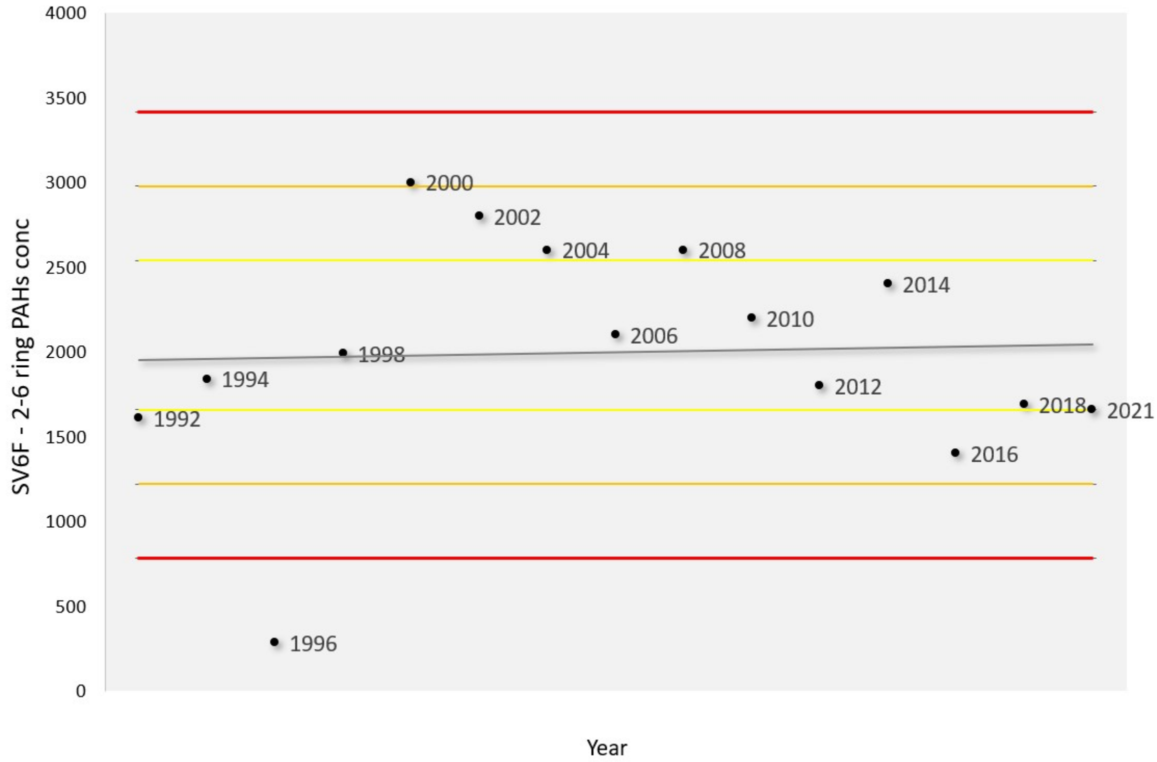

Figure 103 – SV6F 2-6 ring PAH concentration (ng.g^{-1} dry sed.)

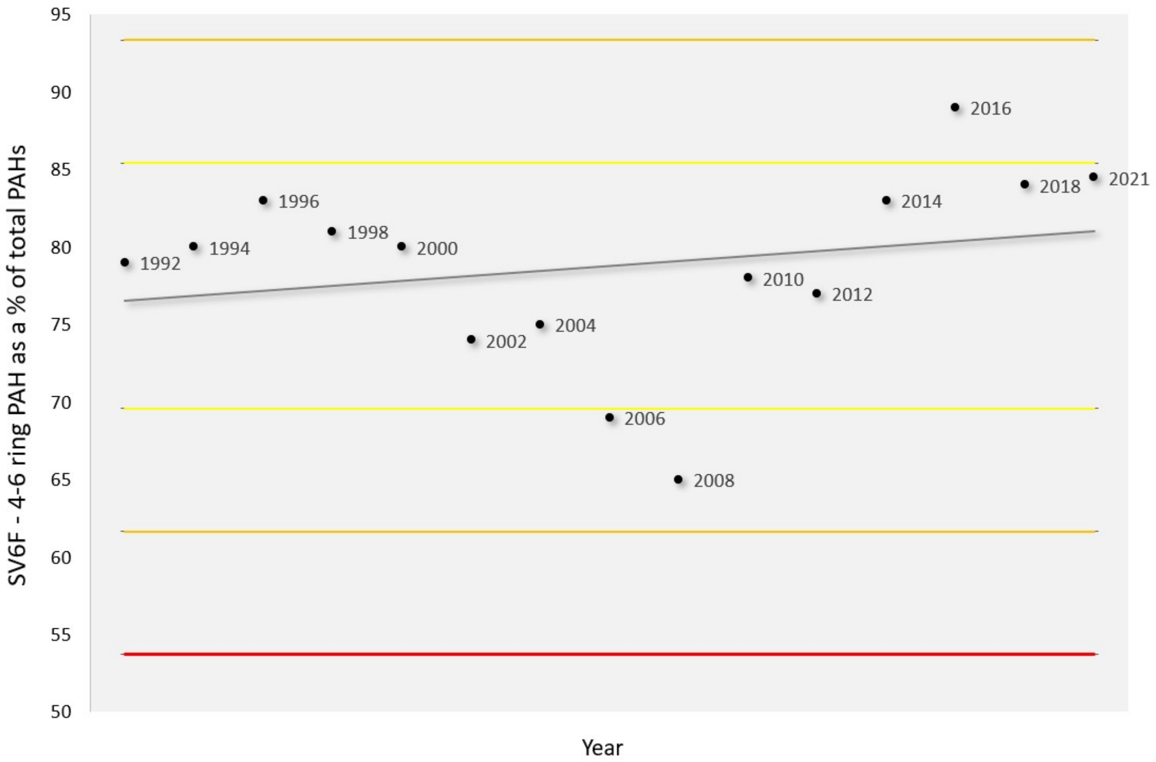

Figure 104 – SV6F 4-6 ring PAHs as a percentage of the total PAHs (%)

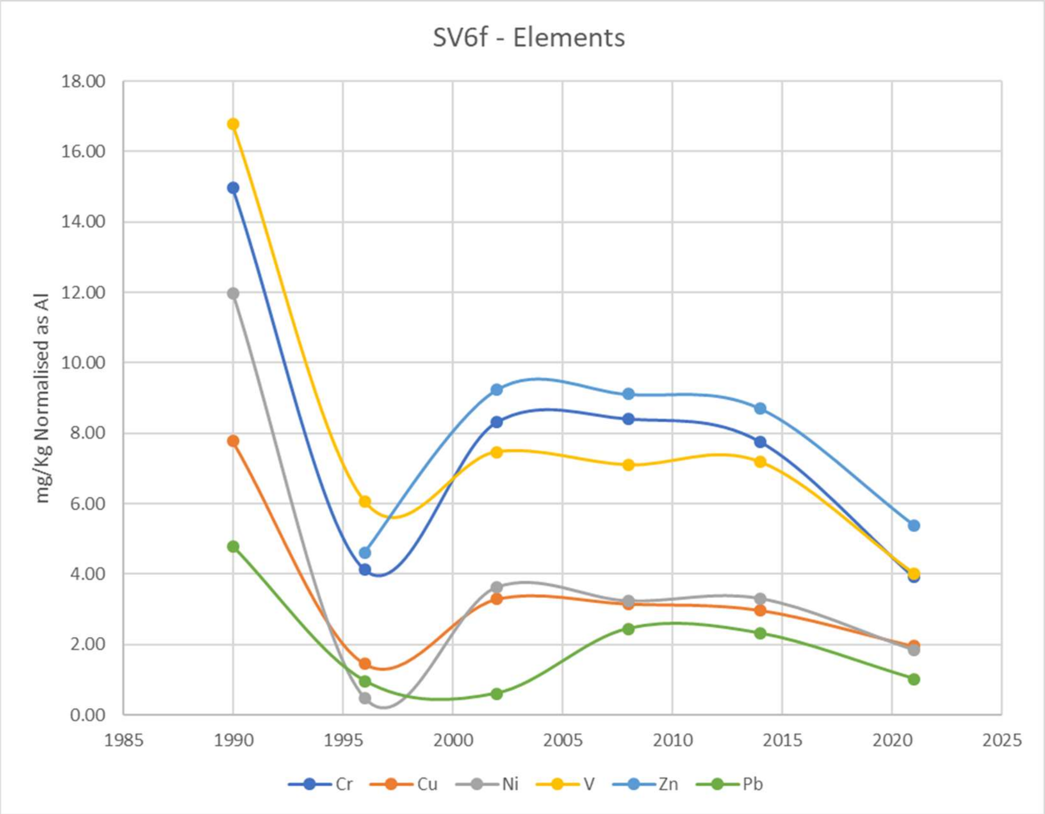

Figure 105 – SV6f Elements in mg/Kg (dry sed. normalised as Aluminium).

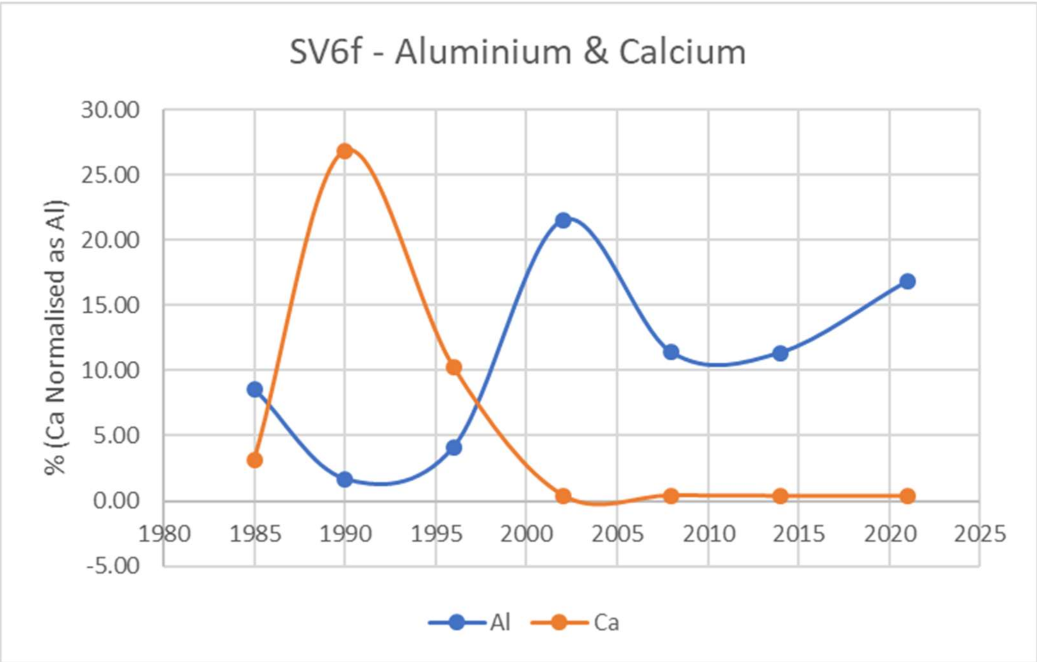

Figure 106 – SV6f Aluminium and Calcium in % (m/m - dry sed.) Calcium normalised as Aluminium.

3.4.4.4 Garths Voe SV32

For station SV32, the mud content in 2021 was 41.6% with was 3.8% lower than in 2018. The organic content in 2021 was 11.6% which is 2.1% lower than the 2018 result.

The concentration of total aliphatic hydrocarbons (TAH) at station SV32 was higher than the 2018 result. The 2021 result was within 1 standard deviation from the historic mean for 2004-2018 and indicates little change. The relative standard deviation for the TAH was 6.2% for the three grab samples analysed indicating low variation in the sediment composition for TAH. The percentage of UCM in the TAH was lower than in 2018 and was within 1 standard deviation from the historic mean, indicating that there had been little change.

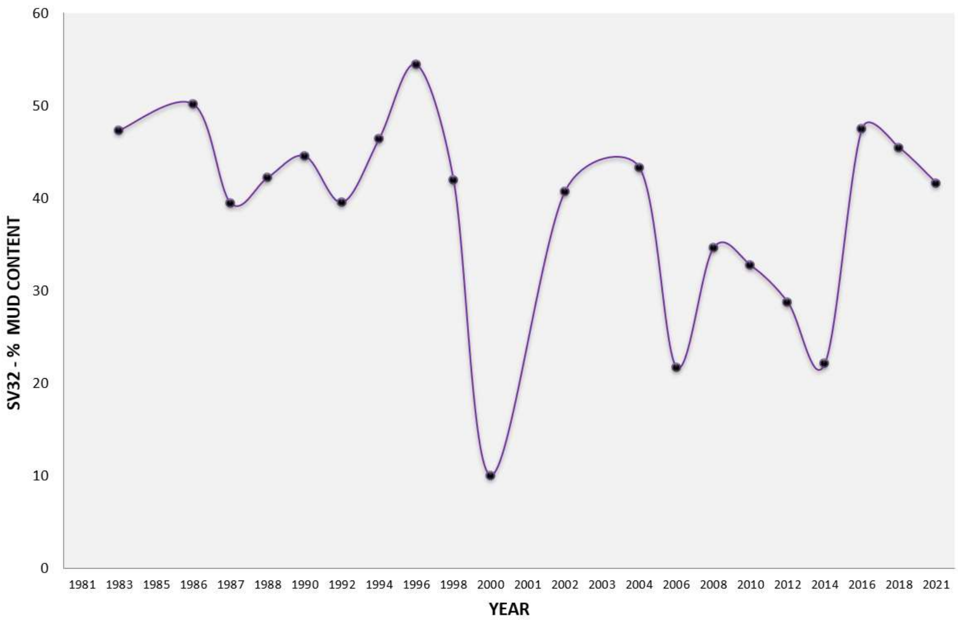

Figure 107 – SV32 Percentage mud content

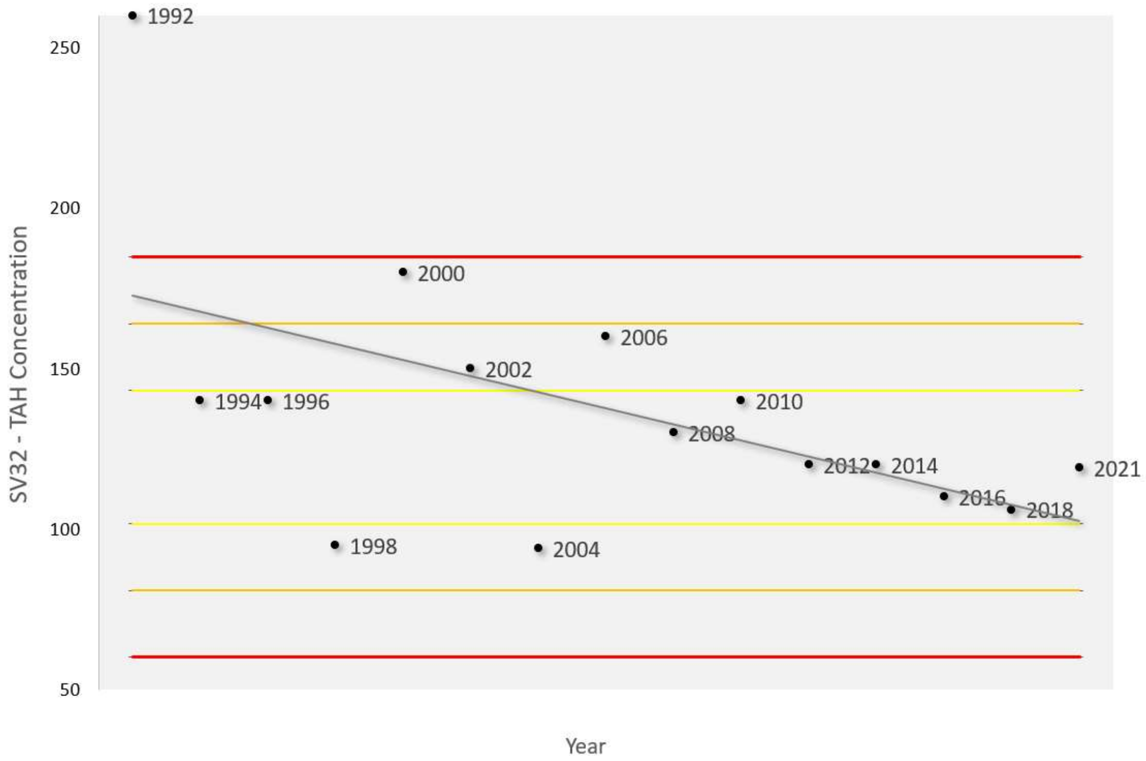

Figure 108 – SV32 Total Aliphatic Hydrocarbon concentration ($\mu g.g^{-1}$ dry wt. sed.)

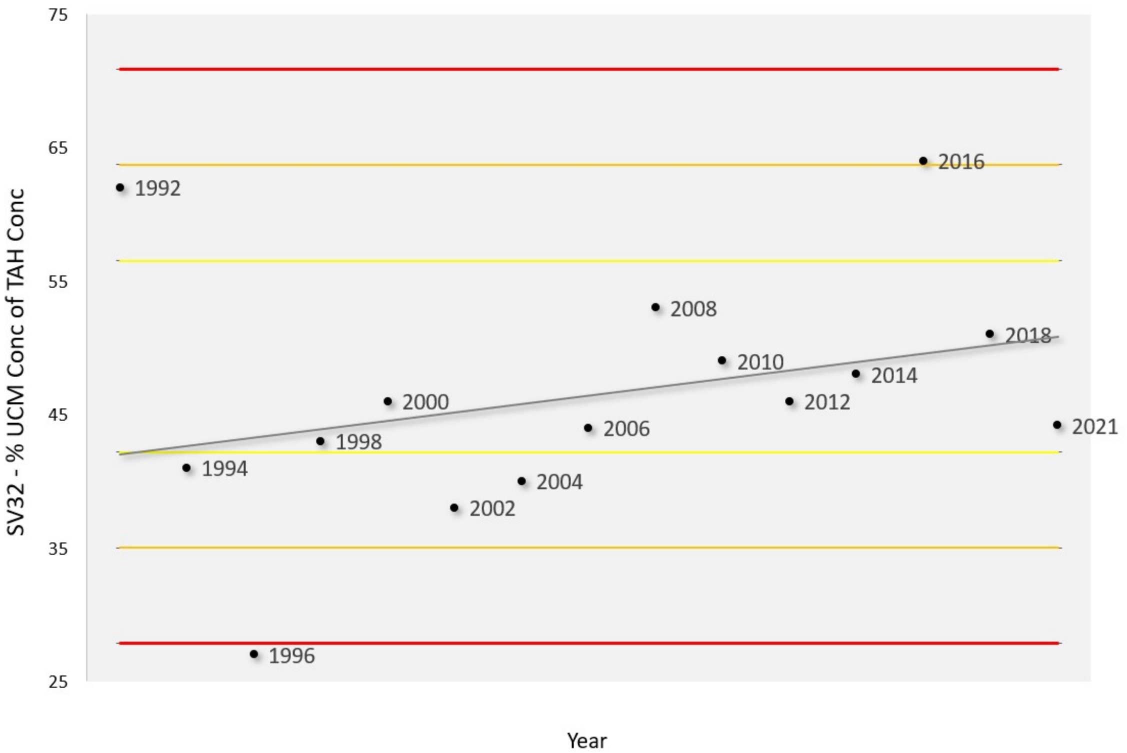

Figure 109 – SV32 Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

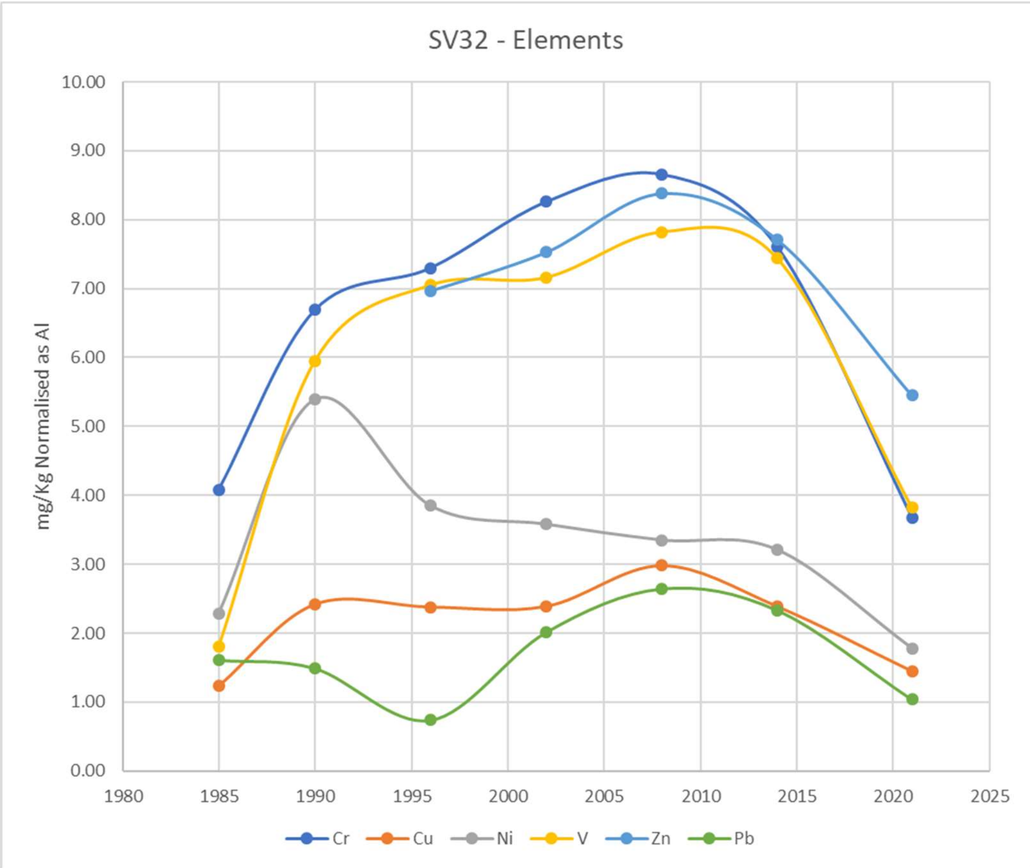

Figure 110 – SV32 Elements in mg/Kg (dry sed. normalised as Aluminium).

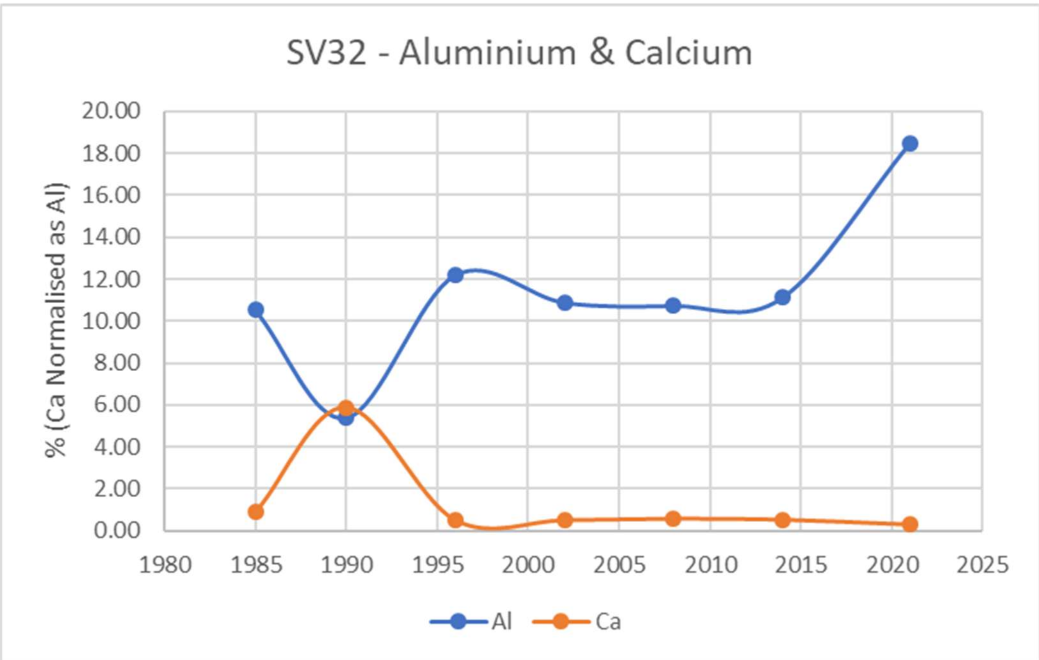

Figure 111 – SV32 Aluminium and Calcium in % (m/m - dry sed.) Calcium normalised as Aluminium.

3.4.5 GLUSS VOE (STATIONS GV1 TO GV3)

The proportions of mud at all three Gluss Voe stations varied in 2021. At GV1 the mud content was the same as in 2018 and the textural group classification continued to be Sandy Gravel. At GV2 the mud content was higher 2.5% than in 2018 (1.3%) but the textural group classification remained as Sandy Gravel. At GV3 the 2021 textural group classification was Sandy Gravel, the mud content had fallen from 4.3% in 2018 to 3.0% in 2021.

In previous reports the current and historic particle size distribution analysis was not included in tabulated format and has not been expressed in chart format in this section.

As in previous surveys, the organic contents remained low in these stations, with values ranging from 0.52% to 0.80% (compared with 0.4% to 0.83% in 2018).

3.4.5.1 Gluss Voe GV1

The concentration of total aliphatic hydrocarbons (TAH) at station GV1 is generally low (<10µg.g^{-1}) the 2021 result has not changed significantly against the historic mean. The 2021 result was within 1 standard deviation from the historic mean for 2004-2018, indicating little change has occurred. The percentage of UCM in the TAH is historically very varied at this station. The percentage of UCM in the TAH for 2021 is within 1 standard deviation of the historic mean, indicating there has been little change. The standard deviation between the three grab samples analysed for this parameter was 8.6%.

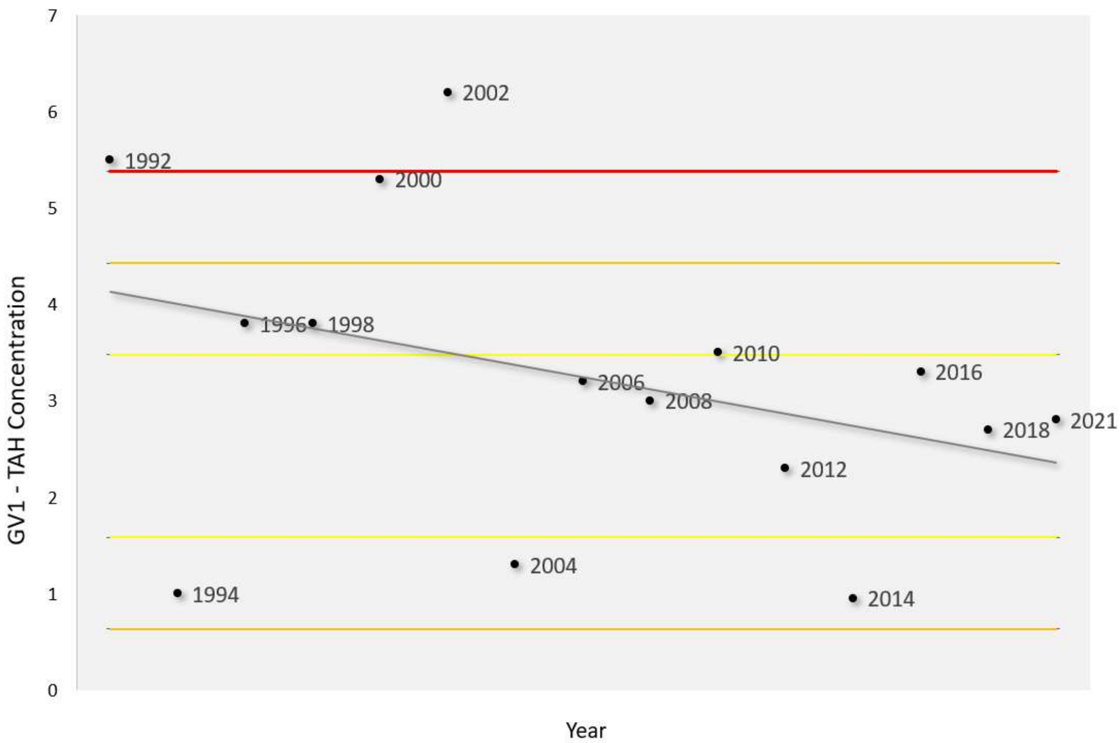

Figure 112 – GV1 Total Aliphatic Hydrocarbon concentration (µg.g^{-1} dry wt. sed.)

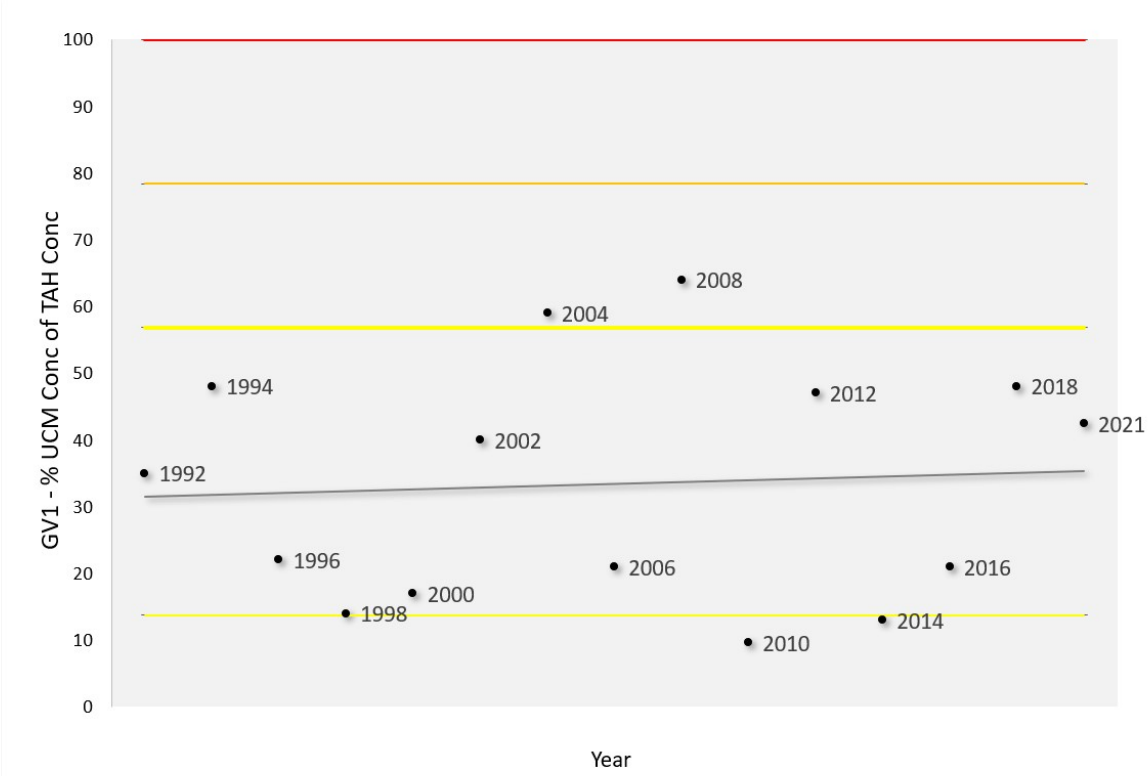

Figure 113 – GV1 Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

3.4.5.2 Gluss Voe GV2

The concentration of total aliphatic hydrocarbons (TAH) at station GV2 is generally low (<10µg.g^{-1}) the 2021 result has not changed significantly against the 2018 result but there was some change against the historic mean. The 2021 result was -1.2 standard deviations from the historic mean for 2004-2018. The percentage of UCM in the TAH is historically very varied at this station, the percentage of UCM in the TAH result for 2021 was lower than in 2016-2018 and was higher than the historic mean. The 2021 result is within 1 standard deviation from the historic mean for 2004-2018. The standard deviation between the three grab samples analysed for this parameter was 16.2%.

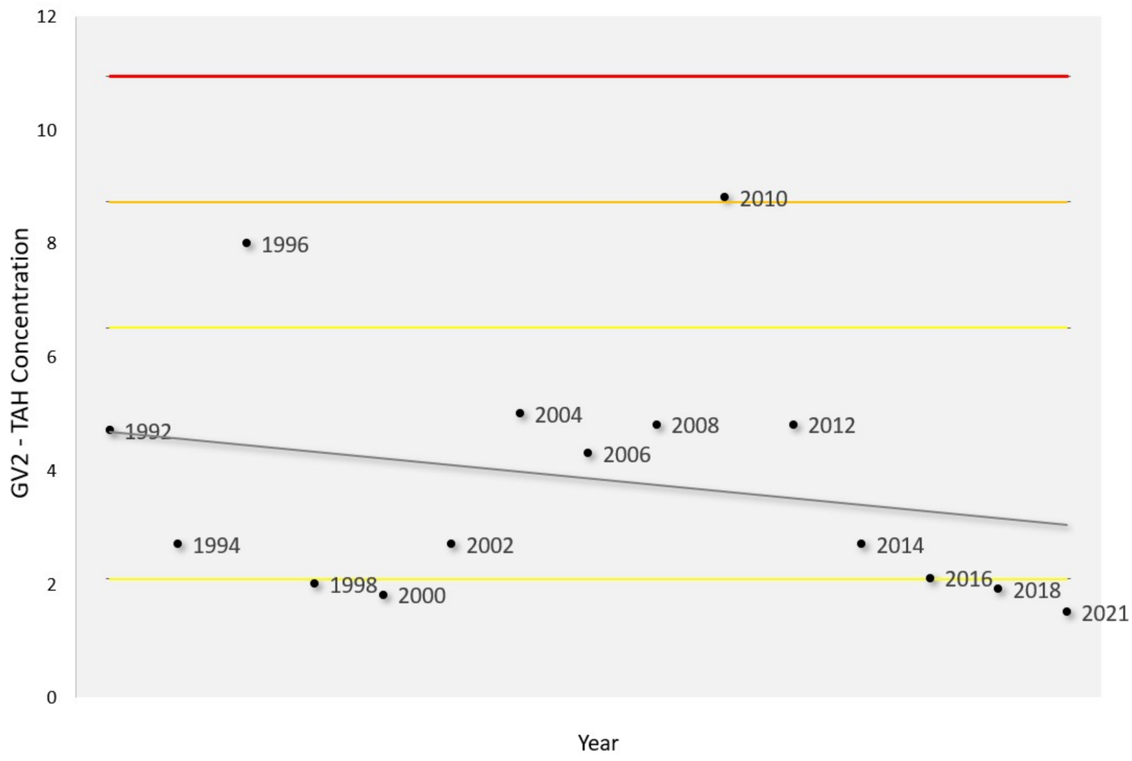

Figure 114 – GV2 Total Aliphatic Hydrocarbon concentration (µg.g^{-1} dry wt. sed.)

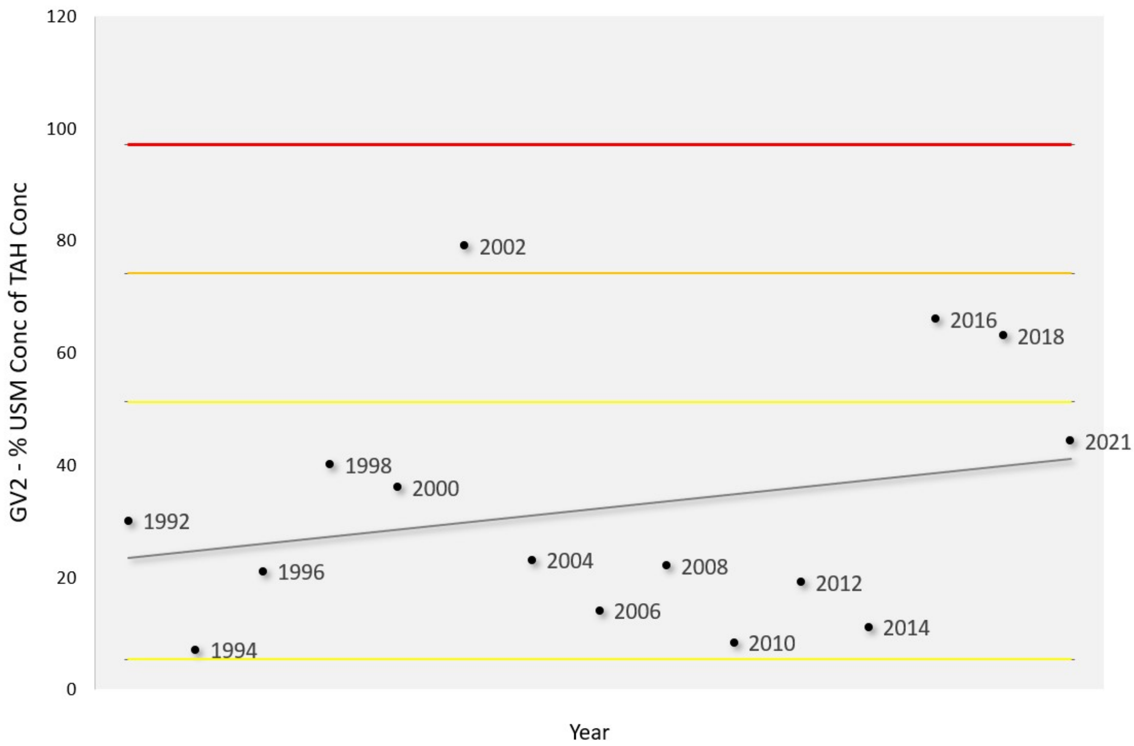

Figure 115 – GV2 Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

3.4.5.3 Gluss Voe GV3

The concentration of total aliphatic hydrocarbons (TAH) at station GV3 is generally low (<10µg.g^{-1}) the 2021 result was lower than the 2018 result and the historic mean. The 2021 result was within 1 standard deviation from the historic mean. The percentage of UCM in the TAH is historically very varied at this station. The percentage of UCM in the TAH result for 2018 is comparable to the 2016 result. The 2018 result is within 1 standard deviation from the historic mean, indicating little change against the historic mean.

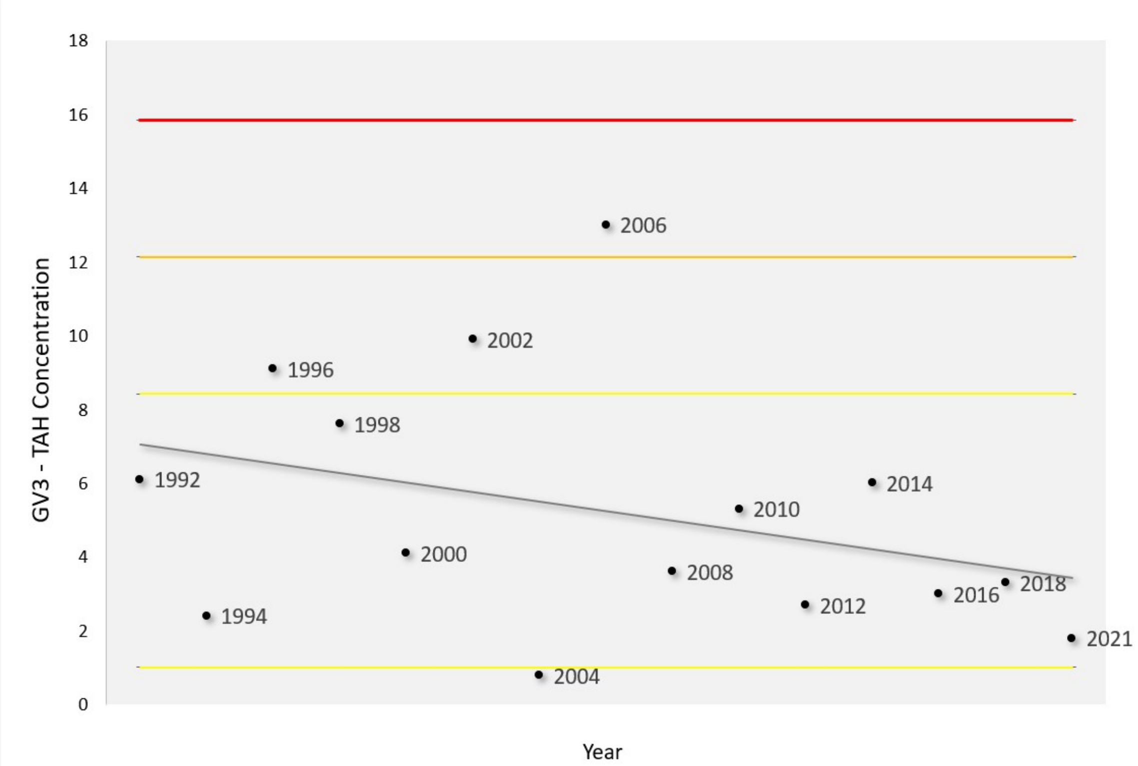

Figure 116 – GV3 Total Aliphatic Hydrocarbon concentration (µg.g^{-1} dry wt. sed.)

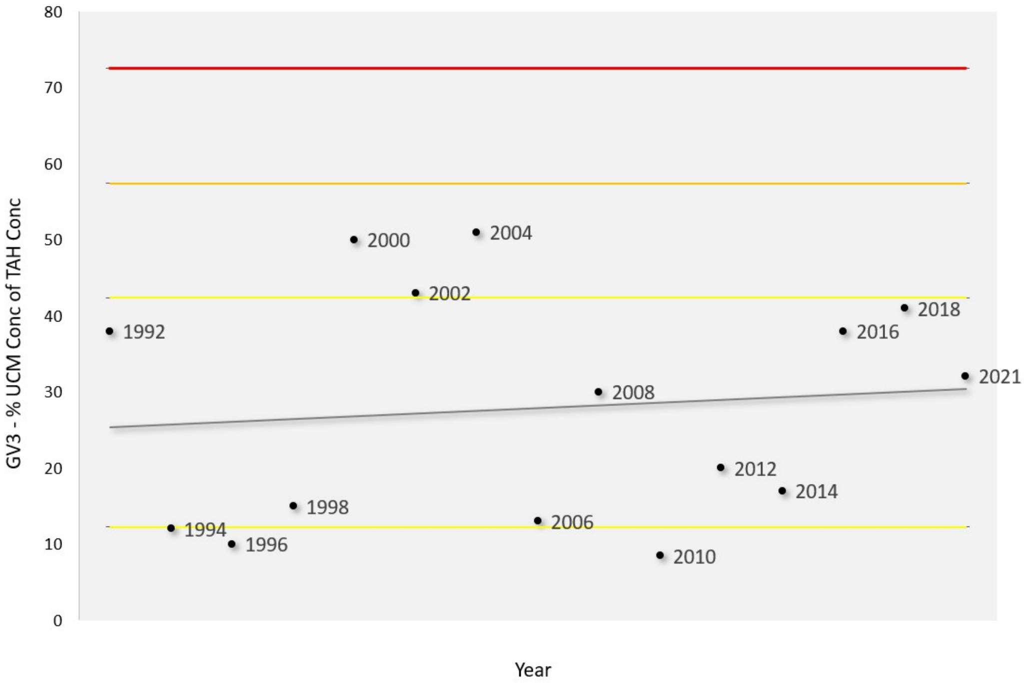

Figure 117 – GV3 Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

3.4.6 Houb of Scatsta (Stations HS1 to HS3)

The proportions of mud at all three Houb of Scatsta stations in 2021 was similar to the levels in 2018. As in 2018, the HS1 classification in 2018 was assigned as Sandy Gravel, the mud content had increased slightly from 1.6% in 2018 to 1.7% in 2021. At HS2 the 2021 classification was assigned as Sand, the mud content had increased from 5.5% in 2018 to 5.6% in 2021. At HS3 the 2016 classification was assigned as Slightly Gravelly Sand, the mud content had risen slightly from 4.2% in 2018 to 4.7% in 2021.

In previous reports the current and historic particle size distribution analysis was not included in tabulated format and has not been expressed in chart format in this section.

As in previous surveys, the organic contents remained low in these stations, with values ranging from 1.46% to 2.30% (compared with 1.22% to 1.95% in 2018).

3.4.6.1 Houb of Scatsta HS1

The concentration of total aliphatic hydrocarbons (TAH) at station HS1 is generally low (<10µg.g^{-1}). The 2021 result has not changed significantly against the 2016-2018 result or the historic mean. The 2021 result was within 1 standard deviation from the historic mean 2004-2018. The percentage of UCM in the TAH is historically very varied at this station. The percentage of UCM in the TAH is within 1 standard deviation of the historic mean and indicates there has been little change against the historic mean.

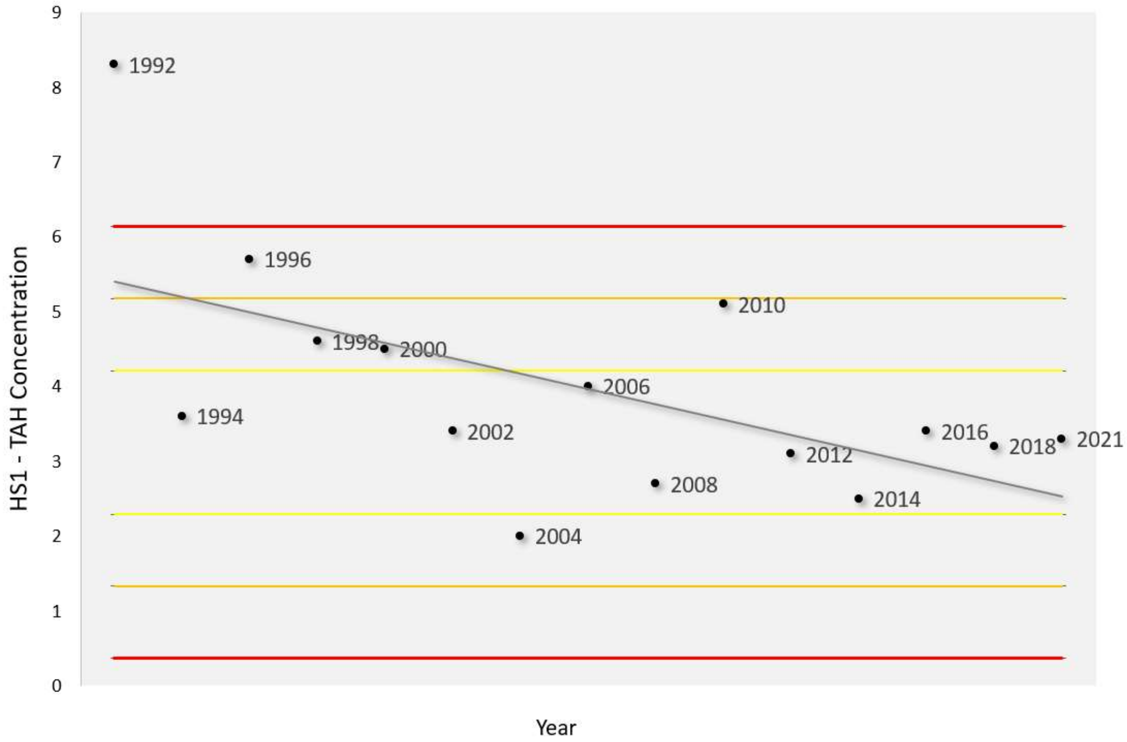

Figure 118 – HS1 Total Aliphatic Hydrocarbon concentration (µg.g^{-1} dry wt. sed.)

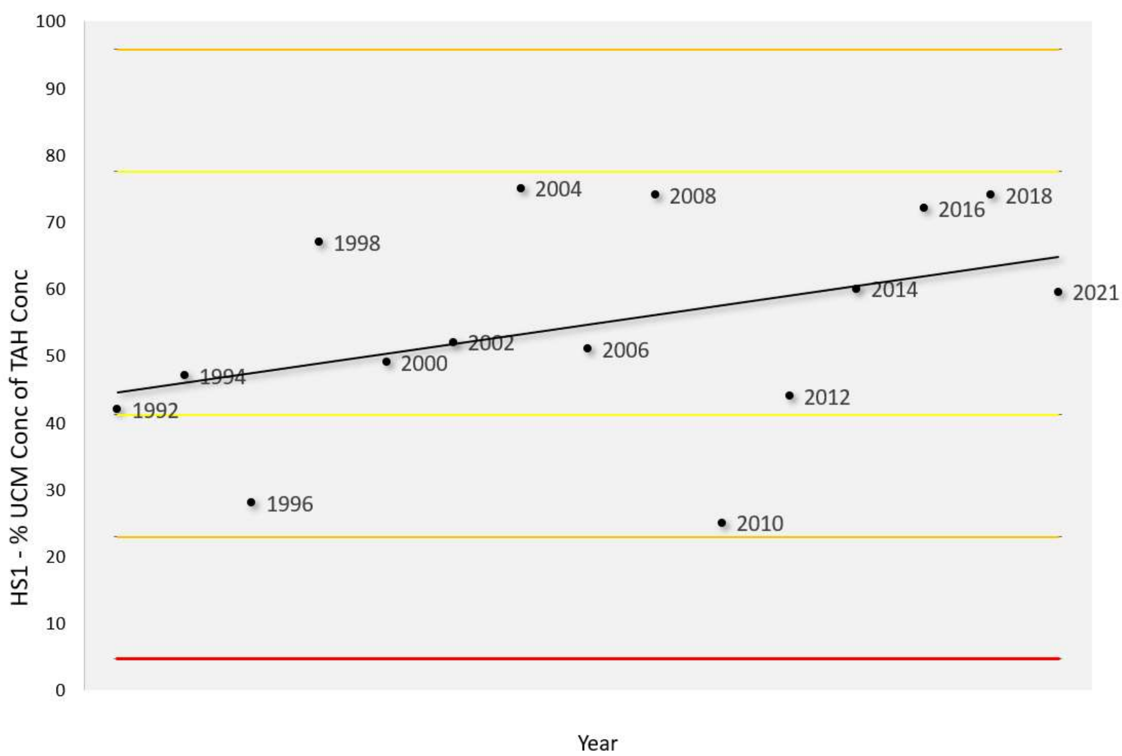

Figure 119 – HS1 Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

3.4.6.2 Houb of Scatsta HS2

The concentration of total aliphatic hydrocarbons (TAH) at station HS2 is generally low (<10µg.g^{-1}) the 2021 result was lower than the 2018 result and the historic mean. The 2021 result was -1.8 standard deviations from the mean indicating some change. The percentage of UCM in the TAH result for 2018 is comparable with the 2016 result. The 2021 result is within 1 standard deviation from the historic mean 2004-2018, indicating some little change against the mean.

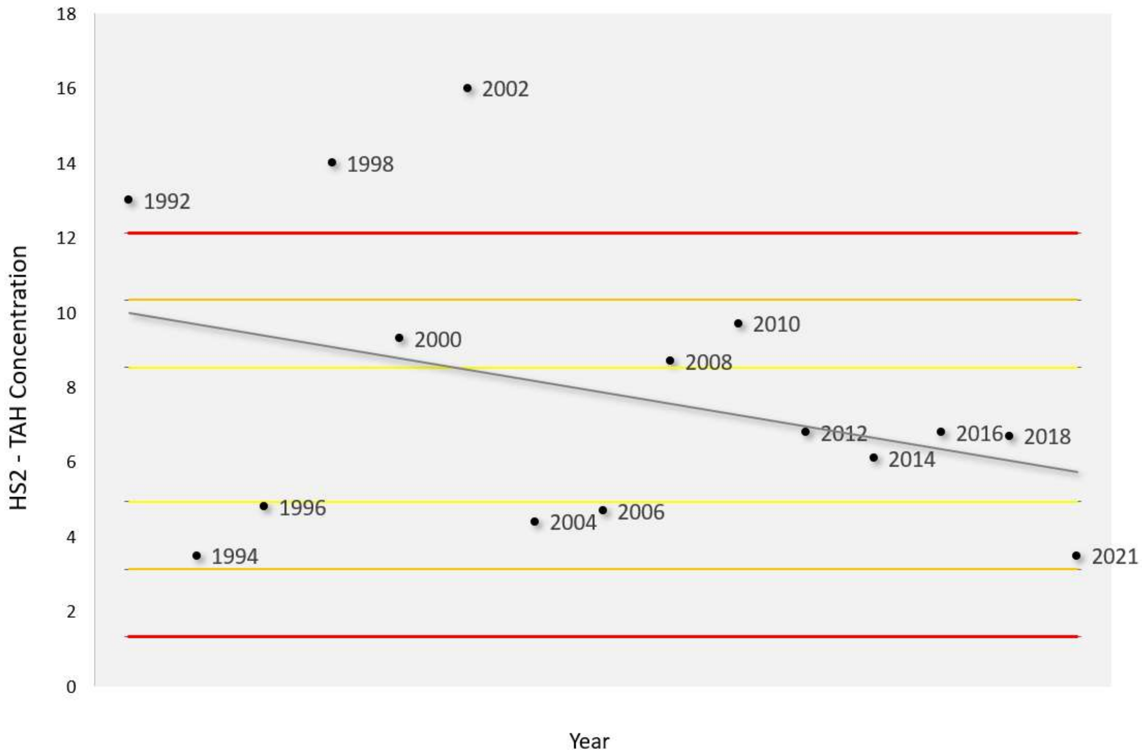

Figure 120 – HS2 Total Aliphatic Hydrocarbon concentration (µg.g^{-1} dry wt. sed.)

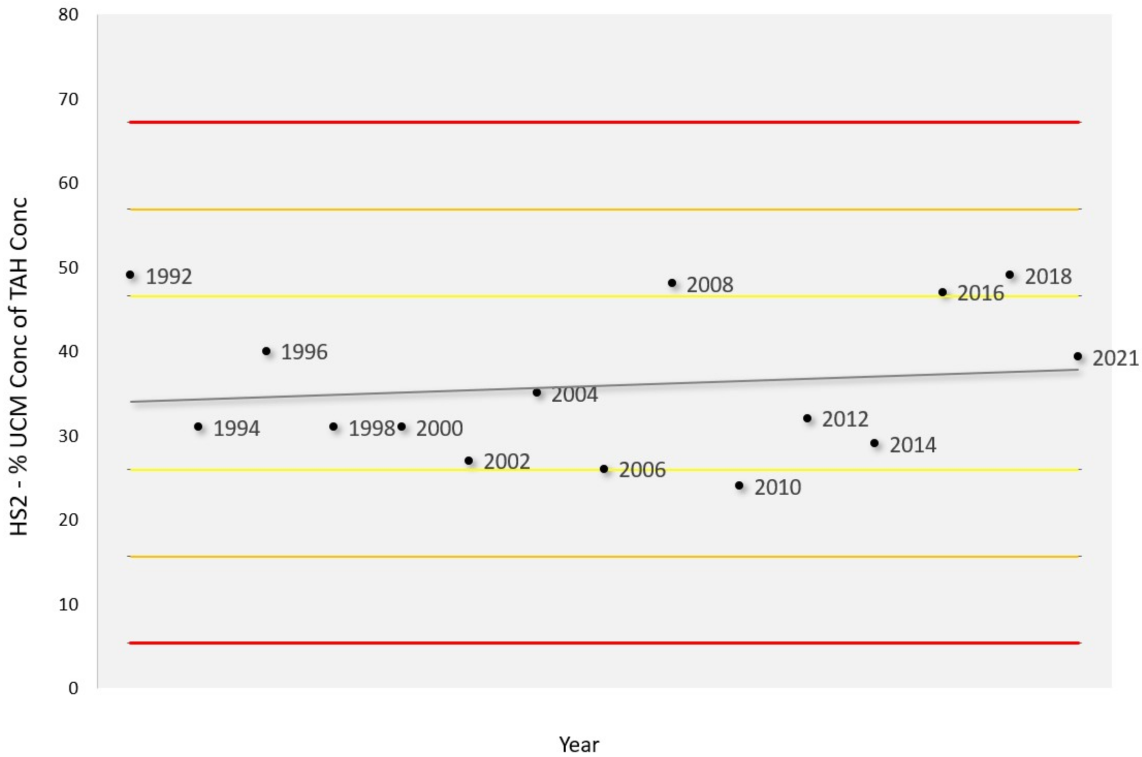

Figure 121 – HS2 Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

3.4.6.3 Houb of Scatsta HS3

The concentration of total aliphatic hydrocarbons (TAH) at station HS3 is generally low (<20µg.g^{-1}) the 2021 result has not changed significantly against the 2016 result or the historic mean. The 2021 result was within 1 standard deviation from the historic mean 2004-2018. The percentage of UCM in the TAH is historically very varied at this station. The percentage of UCM in the TAH result for 2021 is close to the historic mean. The 2021 result was within 1 standard deviation from the historic mean, indicating little change against the historic mean.

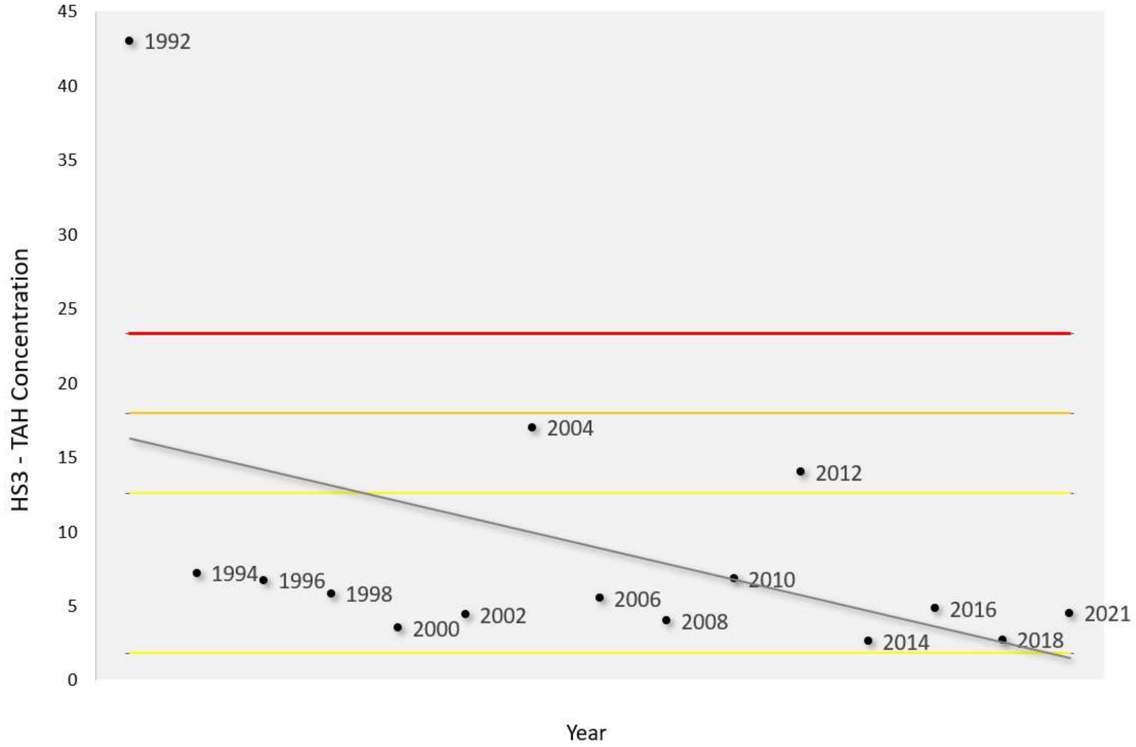

Figure 122 – HS3 Total Aliphatic Hydrocarbon concentration (µg.g^{-1} dry wt. sed.)

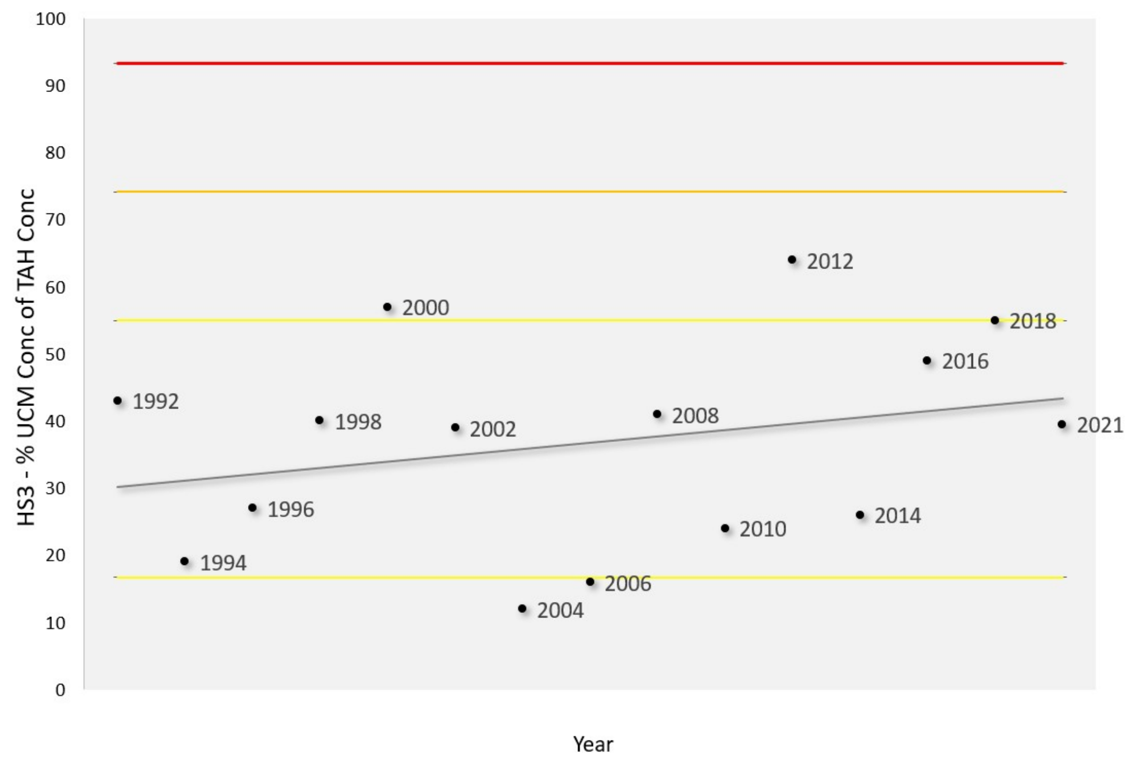

Figure 123 – HS3 Percentage UCM concentration of Total Aliphatic Hydrocarbon concentration (%)

3.4.7 Orka Voe (Stations OV1B to OV5B)

The coordinates for stations positioned in the Orka Voe area were revised as the original coordinates were within a 200m exclusion zone of pipe line assets. At the new stations OV1B-OV5B, sediment samples were obtained from the grab sampling operation, but the amount of sediment retrieved was not sufficient for full quantitative macrobenthic analysis and hence no particle size or TOC analysis was performed. A small amount of sediment was sub-sampled for hydrocarbon analysis. The hydrocarbon levels observed in 2018 were in dynamic contrast to the historic levels as the new coordinates were moved to the edge of the sediment bed, and the hydrocarbon content increased from OV1B towards OV5B, historically the hydrocarbon content has increased from OV5 towards OV1.

In 2021 a significant change was observed in the hydrocarbon concentrations compared to 2018. A similar hydrocarbon concentration was observed at all the Orka Voe stations, see table 4.

Given the relocation of the site and the observed difference in the ground at the station no comparison has been made to the historic data.

4 CONCLUSIONS

4.1 Sediments

Overall sediment character was broadly comparable with that found during recent surveys, with most of sediments being classified as gravelly muddy sands. However, most of the stations show some variations in the relative proportions of sand, mud or gravel compared with the characteristics noted in 2018. The mud contents of the benthic sediments are comparable to the 2018 results with <10% changes, which continues to be noticeably higher than the historic mean result for period 2000-2018. For some stations there are spikes of higher mud content in the historic data and many of the 2016-2021 results correlate with the levels observed in the 2004 survey. The methodology for the particle size analysis and mud content have changed in 2016 to the NMBAQC protocols and higher levels of mud are likely to be observed due to differences between the gravimetric and volumetric measurements.

The organic matter content of the sediments is generally similar to the 2018 survey, with a mean organic content of 4.7% in 2021, 5.7% in 2018. As is normally observed, the highest content of organic matter was observed at station SV1.

4.2 HYDROCARBONS

The total aliphatic hydrocarbon (TAH) levels in the Sullom Voe sediments range from 1.4 μg.g^{-1} to 124 μg.g^{-1} in 2021. As in the previous surveys (except 2010), the highest level was recorded at station SV1 in the Inner Basin. The overall observed levels of total aliphatic hydrocarbons in 2021 had decreased against the mean result for all sites (except SV36B, SV37B and OV1B-OV5B) of the historic data from the period 2004-2018. The average total aliphatic hydrocarbon result for all stations (except SV36B, SV37B and OV1B-OV5B) in 2021 was 28.4 μg.g^{-1}, the 2018 average result was 29.9 μg.g^{-1}, and the average historic mean for period 2004-2018 was 36.4μg.g^{-1}. Concentrations generally decrease northwards along the main Sullom Voe axis to concentrations similar to open-water North Sea sediments. There is no clear evidence for any fundamental alteration in the distribution of hydrocarbons in the sediments in 2021 compared with the 2018 survey.

The percentage of unresolved complex mixture (UCM) in the total aliphatic hydrocarbon was higher than in previous surveys during 2004-2018 at all except 1 marine stations. This increase was on average for all stations equivalent to +0.81 standard deviations from the historic mean for period 2004-2018. The average result for all stations in 2018 was 60.8%, the 2018 average result was 65.4%, and the average historic mean for period 2004-2014 was 53.9%.

In 2021 a significant change was observed in the hydrocarbon concentrations at the revised Orka Voe stations compared to 2018. A similar hydrocarbon concentration was observed at all the Orka Voe stations ranging from 5.1-5.6 μg.g^{-1}. Little change was observed at OV1 station, but on average for OV2-OV5 stations the total aliphatic hydrocarbon (TAH) levels were 14 μg.g^{-1} lower than in 2018.

The hydrocarbon analysis for the seven stations (SV36B, SV37B and the OV1B-OV5B) which were re-located in 2016, are tabulated in this report but due to significant changes in their position on the sediment bed and to the hydrocarbon content there is insufficient data to perform trend analysis. No satisfactory grab samples were obtained at these stations and hence hydrocarbon analysis has not been performed.

GC-MS analyses of aromatic hydrocarbons reveal the presence of PAH derived from petrogenic and pyrolytic (combustion) sources in the sediments, although as on previous surveys those from pyrolytic sources predominate (i.e. 4-6 ring PAHs, with parent compounds dominant over the alkylated derivatives). In 2021 for the seven sediments analysed from unchanged stations, the proportion of 4-6 ring PAHs range from 73.8-86.7% of the total PAH, which was higher than the level in 2018 which was 71-84%. The mean concentration of 2-6 ring PAHs has decreased for the unchanged stations from 1230 ng.g^{-1} in 2018 to 1203 ng.g^{-1} in 2021. Three of the seven unchanged stations have shown slight decreases, three have shown increases and one shown no change in the percentage 4-6 ring PAHs of the total PAHs since the 2018 survey. On average this was -0.31 standard deviations from the historic mean for period 2004-2018. As in previous surveys, due to the high energy environment and relatively coarse sediments, stations 34 (161 ng.g^{-1}), OV1B (24.8 ng.g^{-1}) and OV5B (82.5 ng.g^{-1}) have much lower concentrations of 2-6 ring PAHs compared to the rest of the stations.

4.3 Major and Trace Element Analysis

The 2021 survey included sampling of all tidal station for major and trace elements analysis, the last time this analysis was included in the survey was in 2014 and is typically performed every 6 years.

Initially, the 2021 samples were analysed for major and trace elements by an ISO 17025 and MMO accredited laboratory. However due to major methodology difference, the full sample matrix was not digested in the extraction process and the results obtained (especially aluminium) were not found to be consistent with the anticipated data ranges in the historic dataset.

The methodology used was the same as detailed in the 2014 Survey Report (Appendix 2) and includes a full digestion of the sediment matrix with hydrofluoric acid and then a hydrochloric acid digestion. Analysis is performed by ICP-MS or ICP-OES and quantified by comparing the results against a calibration curve for each of the target analytes.

The results for SV1 demonstrated a significant change in the normalised major and trace elements. This station typically has very high mud content and contribution from terrestrial organic matter and low content of shell-based sediment. The change in the normalised trace elements is related to the significant change in the aluminium concentration.

The trace elemental results in mg/Kg (dry sediment) un-normalised were similar than in 2014 at all stations. The elemental results in mg/Kg (dry sediment) results are normalised against the aluminium result to mitigate against the effects of particle size before they are compared to the historic dataset. The aluminium results historically have been stable for the Sullom Voe sediments.

At all stations except SV12 and SV17 the concentrations of aluminium were higher and at some station considerably higher than the historic data set, especially station SV1. As aluminium is used to normalise the trace elements, the higher aluminium results at some stations may account for the lower concentrations of trace elements observed in compared to the historic data set.

The normalised trace element results that are reviewed against the historic data set remain <10 mg/Kg even where there has been a significant change observed.

The most abundant trace element analysed at all of stations was strontium, ranging from 327 mg/kg (Station SV1) to 1386 mg/kg (Station SV12), compared with 465-1585 mg/kg in 2014. Barium was the second most abundant element analysed, with values ranging from 129 mg/kg (Station OV5B) to 465 mg/kg (Station SV6), compared with 291-768mg/kg in 2014.

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End of Report