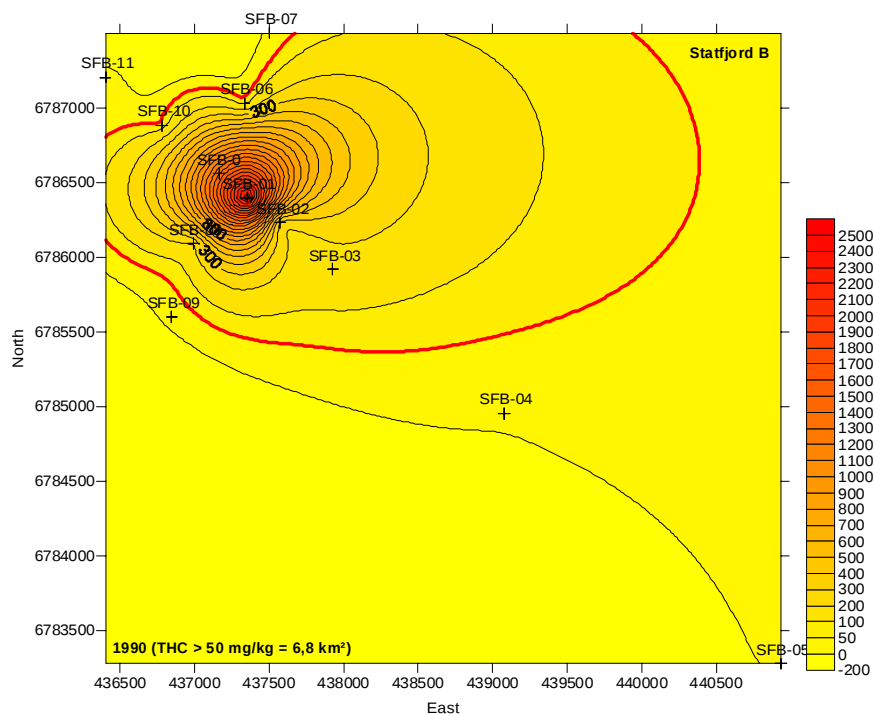

TECHNICAL NOTE

OLJEINDUSTRIENS LANDSFORENING

CUTTING PILES - AREA CONTAMINATED WITH THC



REPORT No. 2004-0492

REVISION No. 01

DET NORSKE VERITAS

TECHNICAL NOTE

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Client: Oljeindustriens Landsforening	Client ref.: Bente Jarandsen	
Summary: This note has shown that it is possible to estimate the area contaminated with THC > 50 mg/kg, and also to evaluate the changes in area size during a period of 10-15 years. Even though the number of stations around each installation has been reduced in the recent years, the contaminated area can still be estimated, and the results show that the contaminated areas have decreased from 50% to 90% at all installations. The reason why is not discussed in this note.		

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Report title: Cutting Piles - Area contaminated with THC		
Work carried out by: Tor Jensen		
Work verified by: Sam-Arne Nøland		
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THC
Contaminated area

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1 INTRODUCTION

DNV Consulting has been asked by OLF to prepare a note that describes a historical development of the total hydrocarbon content in sediments in the vicinity of selected installations in the Norwegian sector.

This note is based on environmental data from previous monitoring surveys carried out by oil companies from 1990 to 2002.

According to the Norwegian Activities regulations¹ regional environmental surveys shall be carried out by the operators every third year. The Norwegian sector is divided into 11 regions, as shown in Figure 1.1. Biological, chemical and physical parameters are included in the survey.

Collected data are stored in a the MOD database (Environmental Monitoring Database), owned by OLF and operated by DNV.

A large cutting piles project has lately been carried out (UKOOA Drill Cuttings Initiative). One of the conclusions (regarding THC) was that the “THC is the key parameter regarding biological effects”, and that “50 mg THC/kg in sediments was considered to be the limit for contaminated areas”.

Based on these conclusions this note gives a brief summary of the THC contaminated area ($> 50 \text{ mg/kg}$) for some selected installations in the Norwegian Sector. Rogalandsforskning (2000) has conducted a study to quantify the total amount of cuttings discharged on the Norwegian Continental Shelf. The study also intended to quantify residual cuttings materials left under/around the installations (see Appendix A). As shown by Rogalandsforskning the number of cuttings piles at Norwegian sector is higher than those presented in this report.

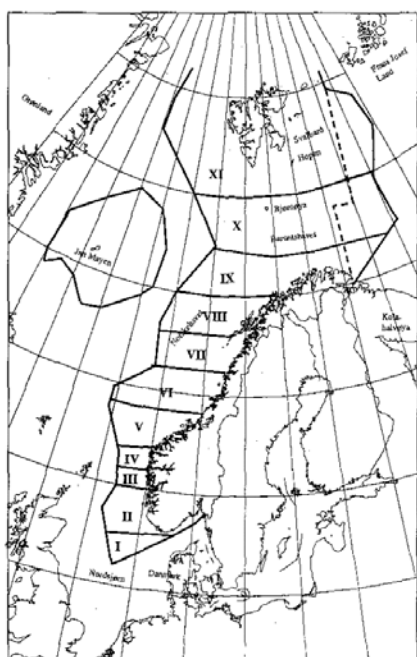


Figure 1.1. Overview of the 11 regions for sediment monitoring in the Norwegian sector.

¹ (http://www.npd.no/regelverk/r2002/frame_e.htm)

TECHNICAL NOTE

2 MATERIAL AND METHODS

A contour and surface mapping program has been used to calculate the area contaminated with THC, (SURFER, version 8 from Golden Software). The accuracy of the contour plot is depending on the number of data available. If the number of sampling stations is low the accuracy of the estimation of contaminated area is also low. In the SURFER program a total of twelve different models with different properties can be used. The most suitable model to present our data (where the number of observations often is less than ten) is the *Kriging* model (see Appendix B for details). It is important to have in mind that all maps that have been drawn in this report only illustrate the major trends in the data. Ten or fewer points are not enough to define more than a general trend in the data. The other option when calculating the contaminated area is to calculate the radius represented by the stations that are contaminated. This can be difficult when the last station in a sampling grid (e.g. 1000m from the installation) is contaminated. The SURFER model will in such cases take into account neighbouring stations and calculate the trend in the data in a much better way.

In this note some examples of contour plots are shown for each field/installation, and in Appendix C all plots are enclosed.

Table 2-1 gives an overview of installations included in this note.

The sampling grid is normally designed with stations located 250m to 5000m from the installation in four different directions. If none of the stations are contaminated the minimum distance is by default set to be less than 250m, and the contaminated area calculated to 0.2 km² (πr^2).

Table 2-1. Overview of installations included in this note.

Region	Installation	Year
Statfjord region	Statfjord A	1990-91-92-93-96-99-2002
	Statfjord B	1990-91-92-93-96-99-2002
	Statfjord C	1990-91-92-93-96-99-2002
	Gullfaks A	1990-91-92-93-96-99-2002
	Gullfaks B	1990-91-92-93-96-99-2002
	Gullfaks C	1990-91-92-93-96-99-2002
	Tordis	1993-94-95-96-99-2002
	Snorre	1991-92-93-94-96-99-2002
Oseberg region	Brage	1992-93-94-98-2001
	Troll	1994-98-2001
	Oseberg F	1991-92-93-94-98-2001
	Oseberg C	1992-93-94-98-2001

TECHNICAL NOTE

3 RESULTS AND COMMENTS

3.1 Statfjord A

Contaminated area

Table 3-1 shows the THC concentrations from all stations at Statfjord A. Stations with concentrations > 50 mg/kg are marked with red colour. Some contour plots are given in Figure 3-1 (see Appendix C for all contour plots).

Table 3-1. THC content at at Statfjord A (mg THC/kg sediments).

ID	Degree	Distance	East	North	1990	1991	1992	1993	1994	1996	1999	2002
SFA0	0	0	438509	6791968								
SFA 1	130	250	438696	6791802		3110	92	736	810	803	232	265
SFA 2	130	500	438885	6791638	2120	1340	20	469	350	483	100	149
SFA 3	130	1000	439263	6791309	168	137	9	415	88	56	50	37
SFA 4	130	2500	440394	6790327	18	17	20	34	20	18	20	11
SFA 5	130	5000	440491	6788716	6	7	11	20		9	16	7
SFA 6	190	500	438413	6791476	108	51	8	38		77	37	12
SFA 7	190	1000	438318	6790985	14	18	21	21		21	27	11
SFA 8	310	500	438131	6792295		155	108	141	85		172	33
SFA 9	310	1000	437754	6792623	110	72	66	49	30		29	13
SFA 10	29	500	438759	6792398	198	63	32	184	29		51	30
SFA 11	29	1000	439008	6792833	35	18	18	28	12		26	9
SFA 12	190	2500	438073	6789510							15	8
SFA 14	310	2000	436979	6793254							12	10

Comments

From 1990 to 1993 the sampling grid did not restricted the area contaminated with THC in the 310 degree direction. The sampling grid was also too small in 1994 and 1996 to give good estimate of the contaminated areas for those years. But both in 1999 and 2002 the surveys covered the whole area.

The reduction in contaminated area from 1993 to 2002 is estimated to be about 76% (se Table 3-2). The contaminated area from 1990 to 2002 is illustrated in Figure 3.1.

Table 3-2. Calculated area contaminated with THC > 50 mg/kg, Statfjord A.

Year	1990	1991	1992	1993	1994	1996	1999	2002
Area contaminated	5.2 km ²	4.5 km ²	1.1 km ²	6.7 km ²	4.4 km ²	4.7 km ²	2.9 km ²	1.6 km ²

TECHNICAL NOTE

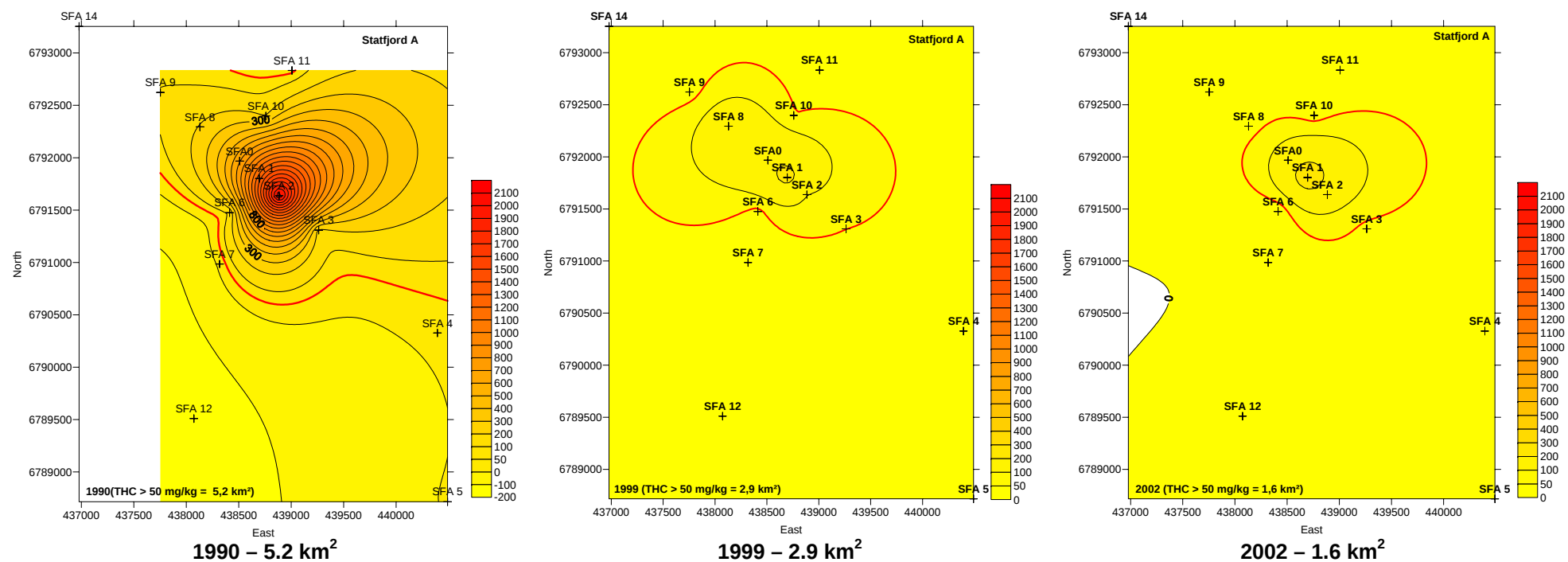


Figure 3-2. Contour plot of THC concentrations at Statfjord A in 1990 (left), 1999 (middle) and 2002 (right). 50 mg/kg concentration is marked as a red line in the plot.

TECHNICAL NOTE

3.2 Statfjord B

Contaminated area

Table 3-3 shows the THC concentrations from all stations at Statfjord B. Stations with concentrations > 50 mg/kg are marked with red colour. Some contour plots are shown in Figure 3-3, (see Appendix C for all contour plots).

Table 3-3. THC content at Statfjord B (mg THC/kg sediments).

Stasjon	Retning	Avstand	East	North	1990	1991	1992	1993	1996	1999	2002
SFB-0	0	0	437165	6786558							
SFB-01	130	250	437355	6786398	2480	413	28	165	1236	141	393
SFB-02	130	500	437576	6786228	216	71	5	64	73	27	42
SFB-03	130	1000	437928	6785917	178	79	7	35	18	23	15
SFB-04	130	2500	439078	6784951	6	13	11	14	14	10	10
SFB-05	130	5000	440934	6783274	4	7	6	9	11	9	
SFB-06	200	500	437334	6787030	61	38	44	22	39	18	20
SFB-07	200	1000	437504	6787499	14	12	10	15	10	6	8
SFB-08	310	500	436993	6786089	190	61	24	49	26	26	22
SFB-09	310	1000	436847	6785599	18	27	16	21	13	9	10
SFB-10	20	500	436783	6786881	60	60	33	68	28	25	23
SFB-11	20	1000	436402	6787202	20	20	13	20	20	16	13

Comments

The station grid established in 1990 covered the contaminated area. In 1990 nearly 7 km² was contaminated and in 2002 1.2 km² was contaminated (see Table 3-4).

Table 3-4. Calculated area (km²) contaminated with THC > 50 mg/kg at Statfjord B.

Year	1990	1991	1992	1993	1996	1999	2002
Area contaminated	6.8	3.1	0	1.3	2.7	0.5	1.2

TECHNICAL NOTE

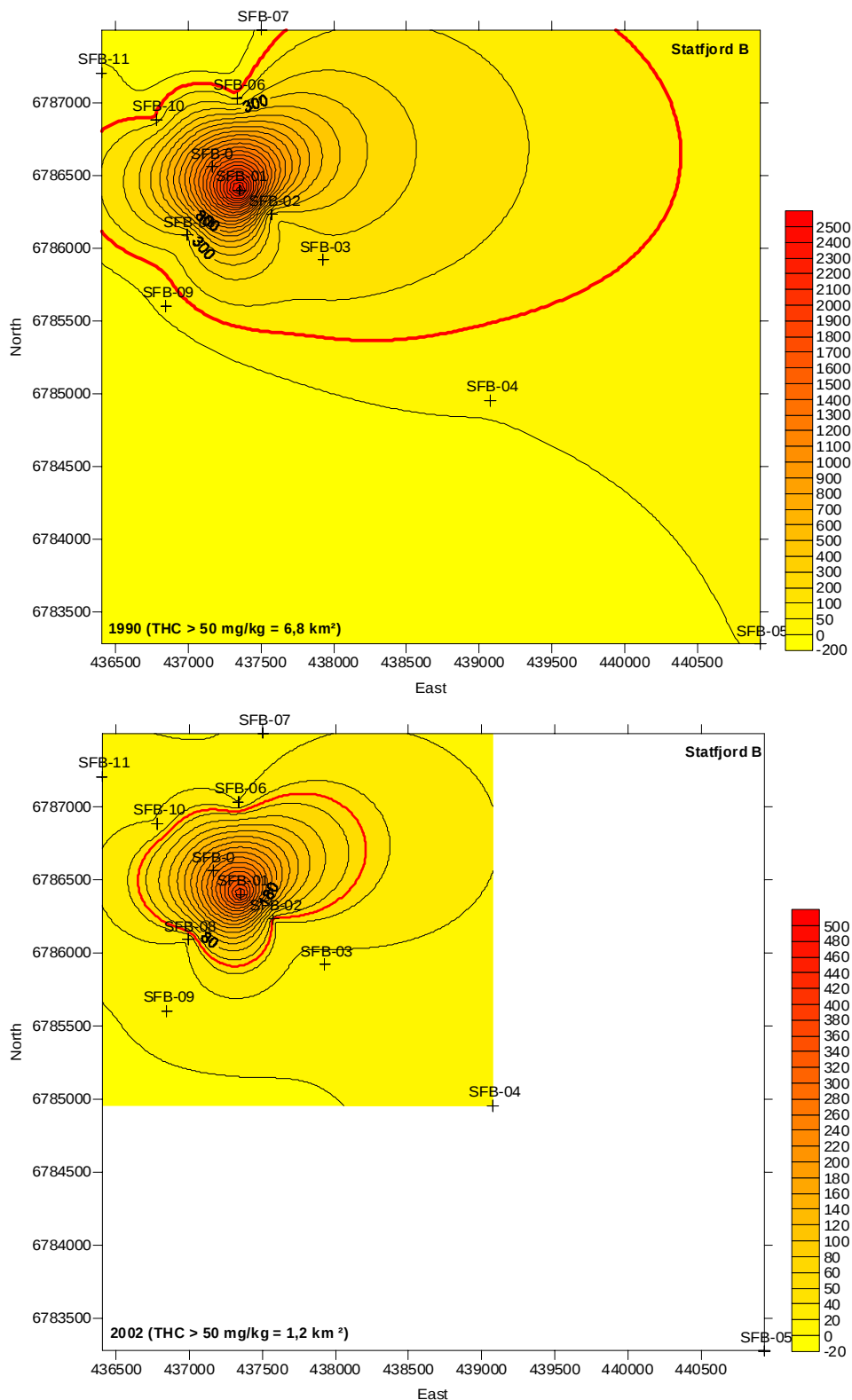


Figure 3-3. Contour plot of THC concentrations at Statfjord B in 1990 (above) and 2002 (below). 50 mg/kg concentration is marked as a red line in the plot. (Note the differences in the concentration scale).

TECHNICAL NOTE

3.3 Statfjord C

Contaminated area

Table 3-5 shows the THC concentrations from all stations at Statfjord C. Stations with concentrations > 50 mg/kg are marked with red colour. Some contour plots are shown in Figure 3-4 (see Appendix C for all contour plots).

Table 3-5. THC content at Statfjord C (mg THC/kg sediments).

Stations	Degree	Distance	East	North	1990	1991	1992	1993	1996	1999	2002
SFC-00	0	0	441196	6796478							
SFC-1	130	250	441385	6796315	38360	45300	18800	5860	5517	372	1284
SFC-2	130	500	441573	6796150	10320	7940	5310	655	314	154	137
SFC-03	130	1000	441950	6795822	466	200	557	180	205	76	44
SFC-4	130	2500	443083	6794838	14	65	19	9	9	7	12
SFC-5	130	5000	444970	6793202	6	7	7	11	6	5	6
SFC-6	130	10000	448744	6789923	2	6	5	7	6	7	4
SFC-7	210	500	440938	6796050	54	235	84	35	83	44	9
SFC-8	210	1000	440681	6795621	9	45	12	8	9	14	8
SFC-9	295	500	440747	6796697	140	340	109	57	87	84	21
SFC-10	295	1000	440296	6796915	6	20	13	14	13	13	7
SFC-11	40	500	441523	6796854	470	253	159	52	14	14	11
SFC-12	40	1000	441851	6797232	6	49	13	13	8	8	4

Comments

The maximum THC concentration decreased significantly from 1991 to 1992 (from 45 300 mg/kg to 18 800 mg/kg) at station SFC-1 (see Table 3-5). Generally, the stations covered the whole area very well. The contaminated area was at the highest in 1992 with 4.6 km², and decreased to 1.8 km² in 2002 (60% reduction), see Table 3-6.

Table 3-6. Calculated area (km²) contaminated with THC > 50 mg/kg at Statfjord C.

Year	1990	1991	1992	1993	1996	1999	2002
Area contaminated	4	3.4	4.6	3.4	3.4	2.5	1.8

TECHNICAL NOTE

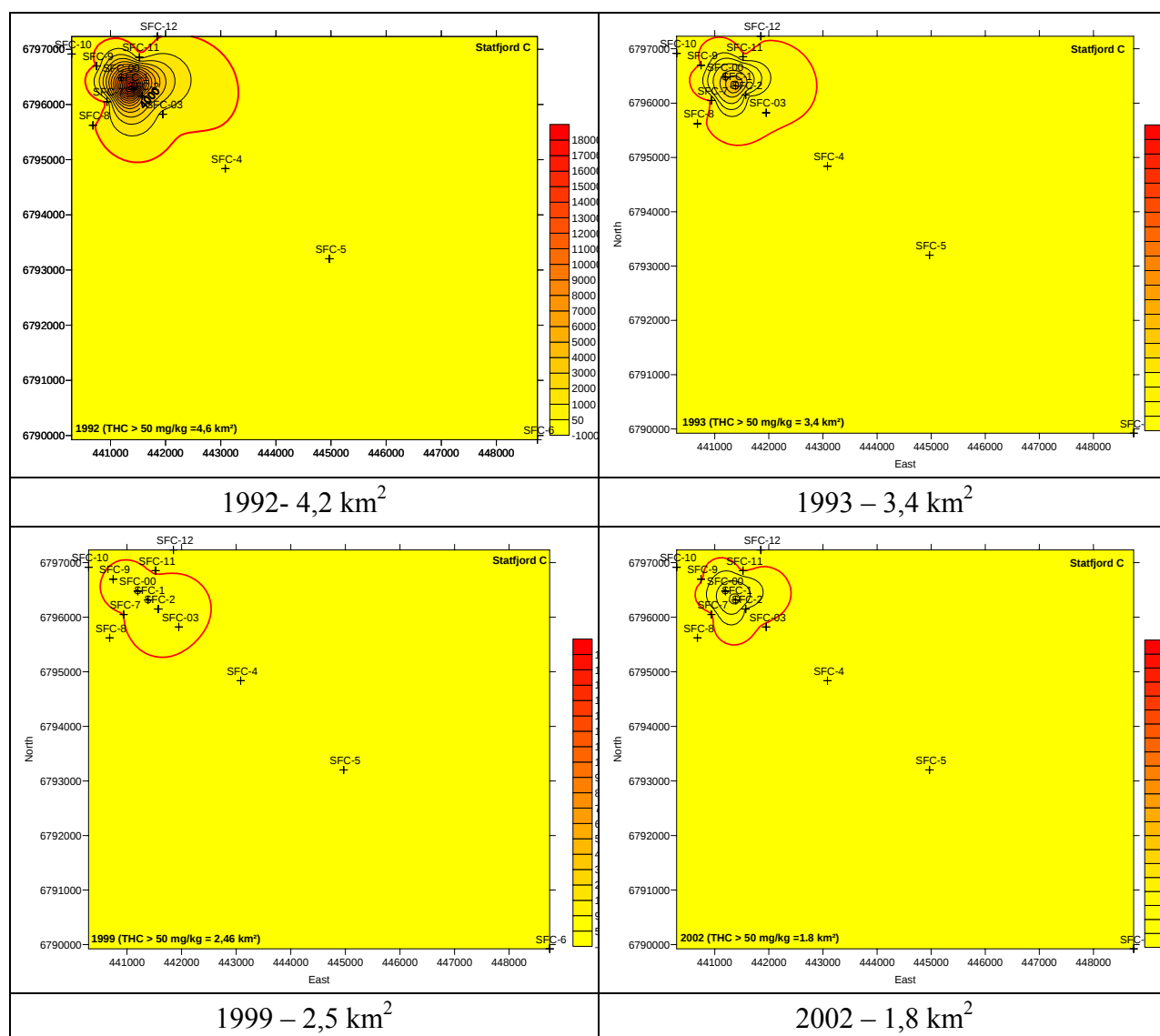


Figure 3-4. Contour plot of THC concentrations at Statfjord C (1992-2002). 50 mg/kg concentration is marked as a red line in the plot.

TECHNICAL NOTE

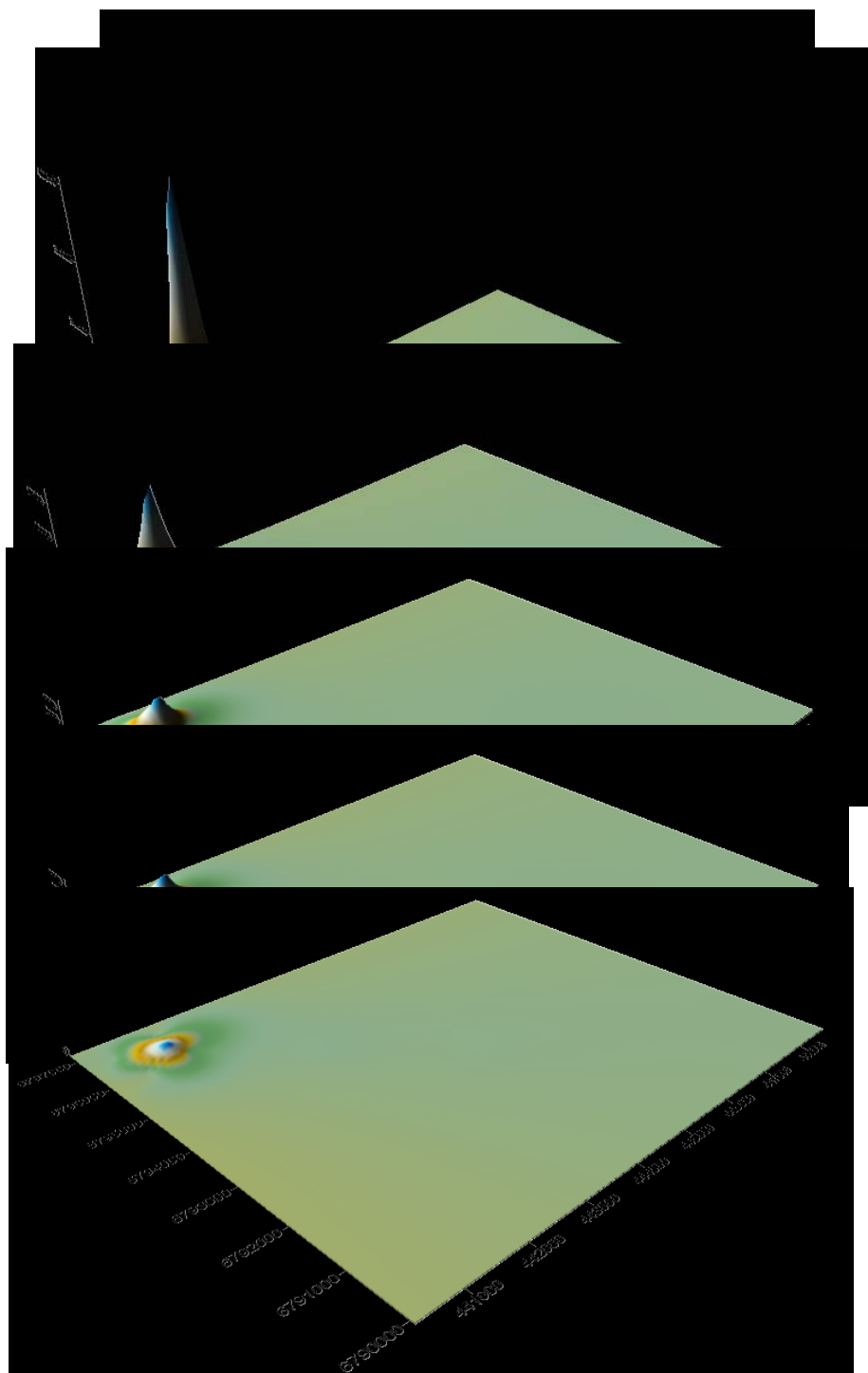


Figure 3-5. Contour and surface plot of THC concentrations at Statfjord C from 1990 to 2002 (in front).

TECHNICAL NOTE

3.4 Gullfaks A

Contaminated area

Table 3-7 shows the THC concentrations from all stations at Gullfaks A. Stations with concentrations > 50 mg/kg are marked with red colour. Contour plots are shown in Figure 3-6 (see Appendix C for all contour plots).

Table 3-7. THC content at Gullfaks A (mg THC/kg sediments).

Stations	Degree	Distance	East	North	1990	1991	1992	1993	1996	1999	2002
GFA-00	0	0	456388	6782833							
GFA-01	150	250	456769	6782514	1351	471	299	8	713		
GFA-02	130	500	457149	6782194	42	7	18	5	29	18	37
GFA-03	130	1000	458299	6781281	3	1	3	4	12	13	17
GFA-04	130	2500	458299	6781281						4	5
GFA-05	60	500	456821	6783077	7	9	8	12	5	6	10
GFA-06	60	1000	457256	6783322	1	5	2	6	5	4	
GFA-07	240	500	455952	6782587	4	5	4	6	5	6	4
GFA-08	340	250	456264	6783059						6	
GFA-09	340	500	456339	6783333	3	3	4	5	9	7	11
GFA-10	340	1000	456055	6783776	2	2	4	5			
GFA-11	340	5000	454676	6787536	1	2	1	3	2	3	3
GFA-12	150	2500	457608	6780654	2	2	3	3			
GFA-13	150	5000	458894	6778500	2	3	2				
GFA-14	150	7000	459895	6776768	2	4	2				
GFA-15	60	2050	458160	6783859	2	2	2				
GFA-16	240	1000	455514	6782344	4	3	4	5			
GFA-17	240	2000	454669	6781832	3	4	3				

Comments

The THC concentration at GFA-1 decreased significantly from 1990 to 1993, but was found to be high in 1996. Unfortunately this station was not followed up in the following surveys. The contaminated area decreased from 6.5 km² in 1990 to 0.2 in 1993 and in 1999 and 2002 (none of the stations was contaminated), but in 1996, due the high concentration at GFA-1, the contaminated area was calculated to more than 3 km².

Table 3-8. Calculated area (km²) contaminated with THC > 50 mg/kg at Gullfaks A

Year	1990	1991	1992	1993	1996	1999	2002
Area contaminated	6.5	2.5	1.7	0.2	3.1	0.2	0.2

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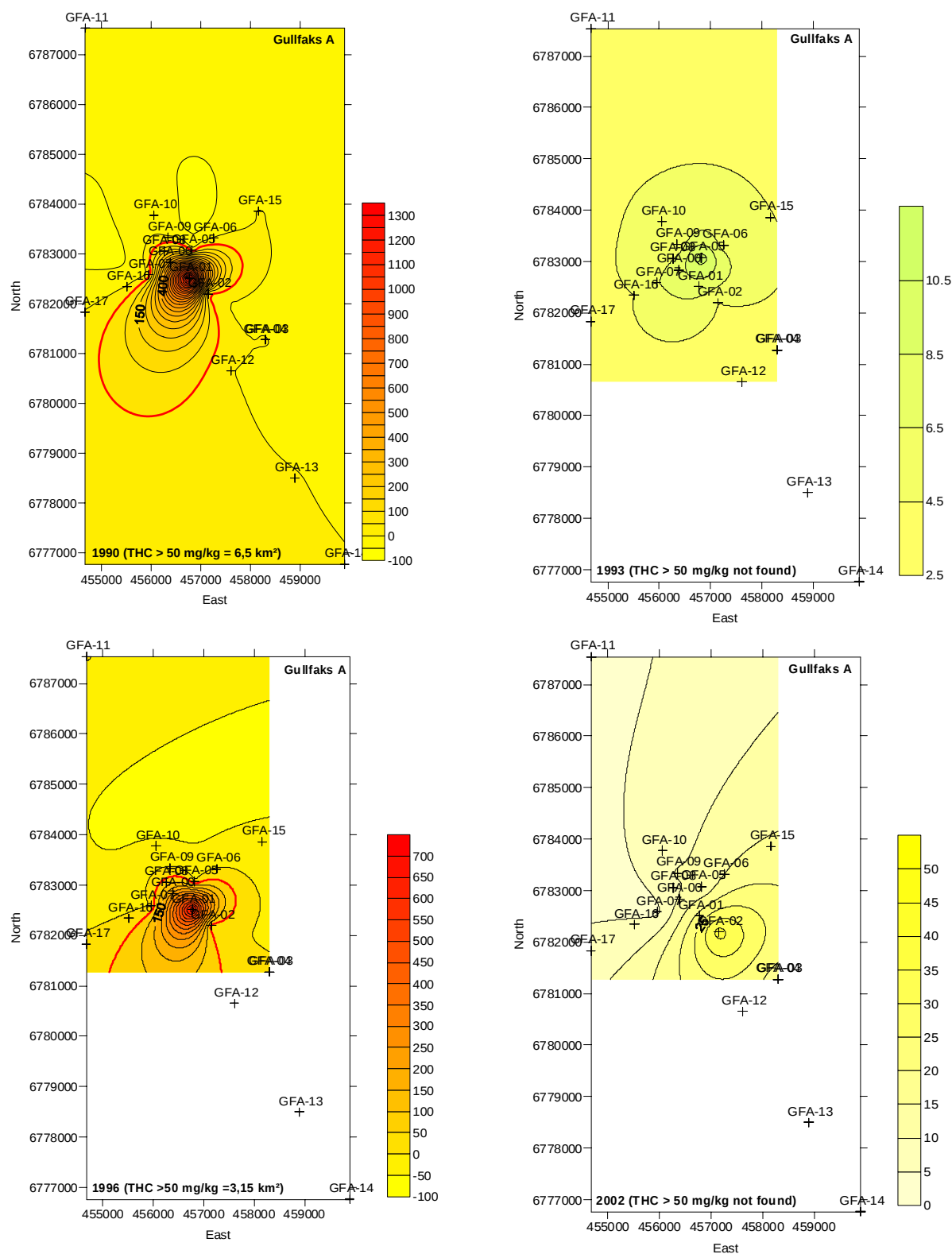


Figure 3-6. Contour plot of THC concentrations at Gullfaks A in 1990 and 1993 (above) and 1996 and 2002 (below). 50 mg/kg concentration is marked as a red line in the plot. (Note the differences in the concentration scale)

TECHNICAL NOTE

3.5 Gullfaks B

Contaminated area

Table 3-9 shows the THC concentrations from all stations at Gullfaks B. Stations with concentrations > 50 mg/kg are marked with red colour. Contour plots are shown in Figure 3-7 (see Appendix C for all contour plots).

Table 3-9. THC content at Gullfaks B (mg THC/kg sediments).

Station	Degree	Distance	East	North	1990	1991	1992	1993	1996	1999	2002
GFB-00			457076	6785813							
GFB-1	150	250	457198	6785589	4080	1810	822	245	140	26	45
GFB-2	150	500	457320	6785371	404	292	30	7	62	14	20
GFB-3	150	1000	457564	6784934	6	30	8	8		6	6
GFB-4	150	2500	458176	6783847	2	2	2	8	4	1	5
GFB-5	150	5000	452315	6785733	1	1	1		2		
GFB-6	60	500	457511	6786052	2	6	9	3	2	1	2
GFB-7	60	1000	457947	6786298	1	2	4	3	2		
GFB-8	60	2000	458818	6786785				3			
GFB-9	240	500	456604	6785642	6	7	3	3	6		4
GFB-11	330	500	456831	6786243	2	2	4	3	3	2	40
GFB-12	330	1000	456586	6786689	1	3	1	3			
GFB-13	330	5000	454629	6790167	1	1	1	3			
GFB-14	150	7000	460588	6779731	1	1	1				
GFB-17	240	1000	456132	6785478	2	2	3	3			

Comments

The calculated contaminated area decreased from 3.2 km² in 1990 to 0.5 km² in 1993. None of the stations were found to be contaminated in 1999 and 2002.

Table 3-10. Calculated area (km²) contaminated with THC > 50 mg/kg at Gullfaks B.

Year	1990	1991	1992	1993	1996	1999	2002
Area contaminated	3.2	2.8	1.4	0.5	0.6	0.2	0.2

TECHNICAL NOTE

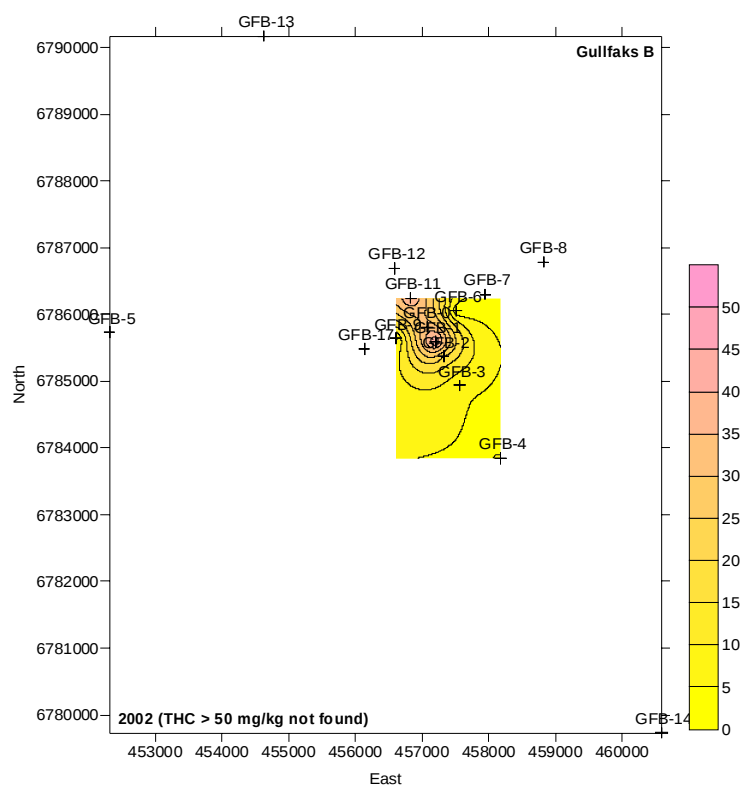
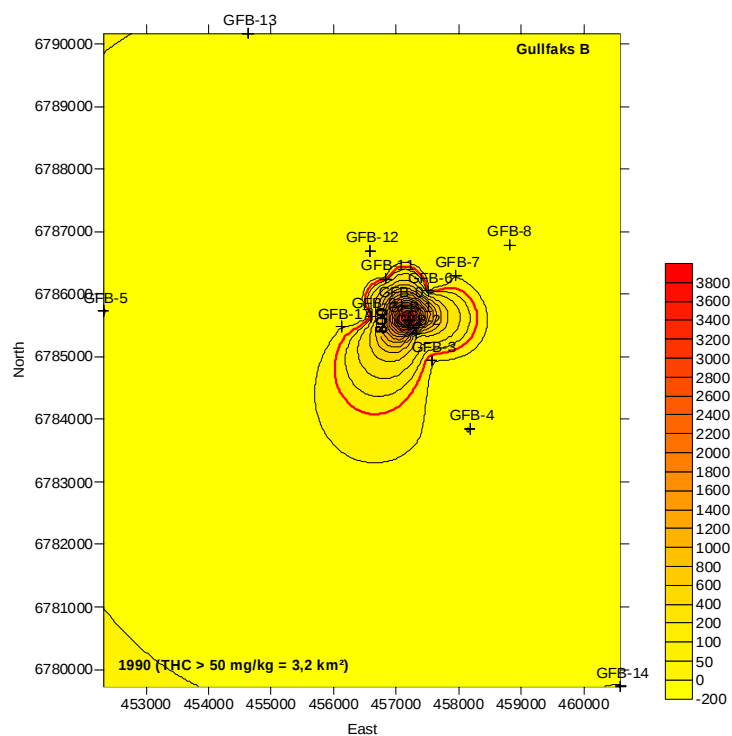


Table 3-11. Contour plot of THC concentrations at Gullfaks B in 1990 (above) and 2002 (below). 50 mg/kg concentration is marked as a red line in the plot.

TECHNICAL NOTE

3.6 Gullfaks C

Contaminated area

Table 3-12 shows the THC concentrations from all stations at Gullfaks C. Stations with concentrations > 50 mg/kg are marked with red colour. Contour plots are shown in Figure 3-7 (see Appendix C for all contour plots).

Table 3-12. THC content at Gullfaks C (mg THC/kg sediments).

ID	Degree	Distance	East	North	1990	1991	1992	1993	1994	1996	1999	2002
GFC-0	0	0	460990	6787110								
GFC-1	140	250	461148	6786914	604	1670	595	340	290	156	496	181
GFC-2	140	500	461307	6786720	148	428	142	116	81	108	213	66
GFC-3	140	1000	461624	6786333	50	115	23	65	26	35	32	12
GFC-4	140	2500	462576	6785175	4	40	7	18	9	10	13	9
GFC-5	140	5000	464160	6783243	2	7	3	7	9	6	9	6
GFC-6	50	500	461376	6787422	8	10	6	7	14	6	7	
GFC-7	50	1000	461763	6787739	3	2	3	5	8	6		
GFC-8	250	500	460518	6786939	6	3	3	6	9	6	10	
GFC-9	250	1000	460046	6786774	6	4	3	4	7	4		
GFC-10	320	500	460672	6787491	6	11	7	12	8	5	5	
GFC-11	320	1000	460356	6787879	2	5	3	6	6	4		
GFC-12	320	5000	457821	6790969	1	2	2	4	5	4	6	
GFC-13	140	7000	465446	6781710			3			6		

Comments

The THC concentration was found to be high at station GFC-1 in 1991, decreasing until 1996, higher in 1999 and than low again in 2002. This also reflects the contaminated area, see Table 3-13.

The survey in 2002 included sampling stations from only one direction. To calculate the contaminated areas in 2002 is therefore impossible.

Table 3-13. Calculated area (km²) contaminated with THC > 50 mg/kg at Gullfaks B.

Year	1990	1991	1992	1993	1994	1996	1999	2002
Area contaminated	2.5	8.1	2.0	2.4	1.2	1.0	2.4	0.3

TECHNICAL NOTE

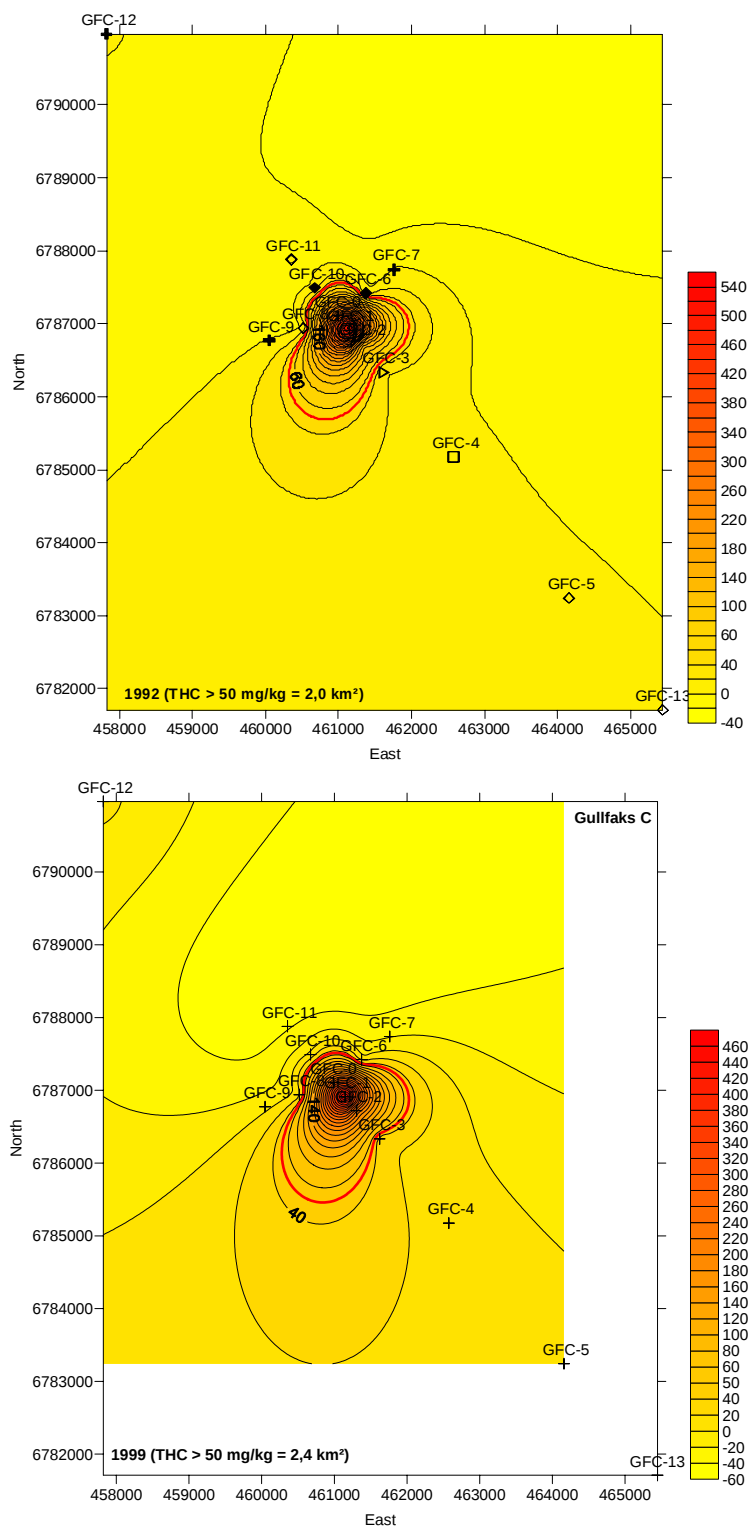


Figure 3-7. Contour plot of THC concentrations at Gullfaks C in 1991 (above) and 1992 (below). 50 mg/kg concentration is marked as a red line in the plot.

TECHNICAL NOTE

3.7 Brage

Contaminated area

Table 3-14 shows the concentrations from all stations at Brage. Stations with concentrations > 50 mg/kg are marked with red colour. Some contour plots are shown in Figure 3-8 (see Appendix C for all contour plots).

Table 3-14. THC content at Brage (mg THC/kg sediments).

Station	Degree	Distance	East	North	1992	1993	1994	1998	2001
BRA-1	330	15000	167402	6740395	4	5	6	5	6
BRA-2	330	4000	172006	6730413	4	7	3		
BRA-3	330	2000	172845	6728595	4	6	5		4
BRA-4	330	1000	173278	6727646	3	5	5	36	7
BRA-5	330	500	173466	6727293	4	38	8	6	7
BRA-6	330	250	173610	6727056	20	44	370	13	18
BRA-7	150	250	173789	6726592	11	2434	1570	1848	184
BRA-8	150	500	173878	6726360	20	914	1090	264	121
BRA-9	150	1000	174111	6725891	20	129	144	168	45
BRA-10	150	2000	174523	6724958	6	17	24	25	10
BRA-11	150	4000	175358	6723203	3	7	5	10	5
BRA-12	60	4000	177321	6728454	4	5	4		
BRA-13	60	2000	175502	6727615	3	5	4		
BRA-14	60	1000	174615	6727189	4	6	5	9	4
BRA-15	60	500	174157	6727007	72	19	21	14	9
BRA-16	60	250	173928	6726915	31	420	135	73	36
BRA-17	240	250	173470	6726733	5	36	6	20	7
BRA-18	240	500	173231	6726531	5	8	2	9	5
BRA-19	240	1000	172773	6726348	3	5	5	7	7
BRA-20	240	2000	171866	6725937	4	3	4		
BRA-21	240	4000	170047	6725098	3	6	4		

Comments

The area contaminated with THC was low in 1992, increasing to nearly 6 km² in 1994, and then reduced to 0.2 km² in 2001, see Table 3-15.

Table 3-15. Calculated area (km²) contaminated with THC > 50 mg/kg at Brage.

Year	1992	1993	1994	1998	2001
Area contaminated	0.	5.3	5.9	2.4	0.2

TECHNICAL NOTE

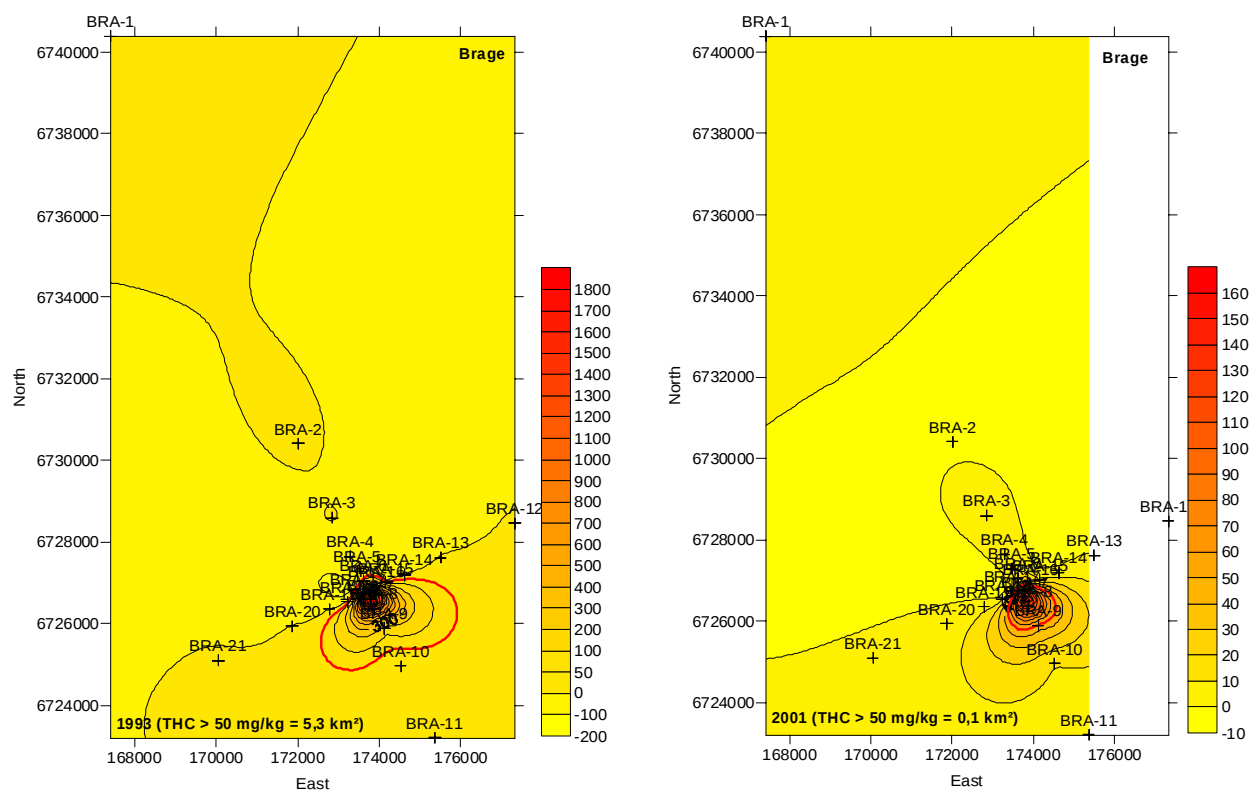


Figure 3-8. Contour plot of THC concentrations at Brage in 1993 (left) and 2001 (right). 50 mg/kg concentration is marked as a red line in the plot.

TECHNICAL NOTE

3.8 Oseberg F

Contaminated area

Table 3-16 shows the THC concentrations from all stations at Oseberg Feltcenter. Stations with concentrations > 50 mg/kg are marked with red colour. Some contour plots are shown in Figure 3-9 (see Appendix C for all contour plots).

Table 3-16. THC content at Oseberg F (mg THC/kg sediments).

Station	Degree	Distance	East	North	1991	1992	1993	1994	1998	2001
OSEF-1	315	10000	483493	6713642	1	2	3	4	5	5
OSEF-3	135	1500	491782	6705037	350	15	6	6		
OSEF-4	315	1500	489508	6707604	1	4	4	3	2	2
OSEF-6	315	500	490220	6706934	6	40	13	19	4	11
OSEF-7	260	350	490219	6706489					58	483
OSEF-8	147	300	490713	6706265					637	355
OSEF-9	135	500	490933	6706153	234	585	36	16	50	51
OSEF-10	135	750	491097	6706041	34	59	14	9	13	23
OSEF-11	145	1500	491425	6705260	2	5	4	3	10	12
OSEF-12	135	3000	492725	6703899					6	6
OSEF-13	135	5000	494115	6703027	1	3	4	3	7	4
OSEF-15	55	1500	491815	6707376					5	5
OSEF-16	60	750	491209	6706932					7	7
OSEF-17	45	500	490935	6706932	22	57	8	7	9	16
OSEF-18	45	250	490888	6706845	48600	1160	36	28	12	
OSEF-20	225	750	490181	6706138	11	9	19	34	6	9
OSEF-21	225	1500	489502	6705488	3	4	9	6		4
OSEF-22	225	3000	488590	6704547	4	7	5	5		
OSEF-23	225	5000	487176	6703133	3	10	11	6		
OSEF-29	180	1000	490711	6705668	101	13	30	28		
OSEF-32	135	7000	495659	6701720	1	4	2	3		
OSEF-33	315	5000	487176	6710203	1	3	3	3		
OSEF-34	315	3000	488590	6708789	0	2	4	2		
OSEF-35	315	750	490181	6707198	3	50	12	8		
OSEF-36	315	250	490435	6706845	284	248	93	86		
OSEF-37	135	250	490888	6706491	11300	1130	356	139		
OSEF-38	45	3000	492832	6708789	1	3	3	3		
OSEF-39	45	1500	491771	6707728	1	4	3	2		
OSEF-40	45	750	491241	6707198	5	11	6	4		
OSEF-41	225	500	490357	6706314	13	62	30	44		

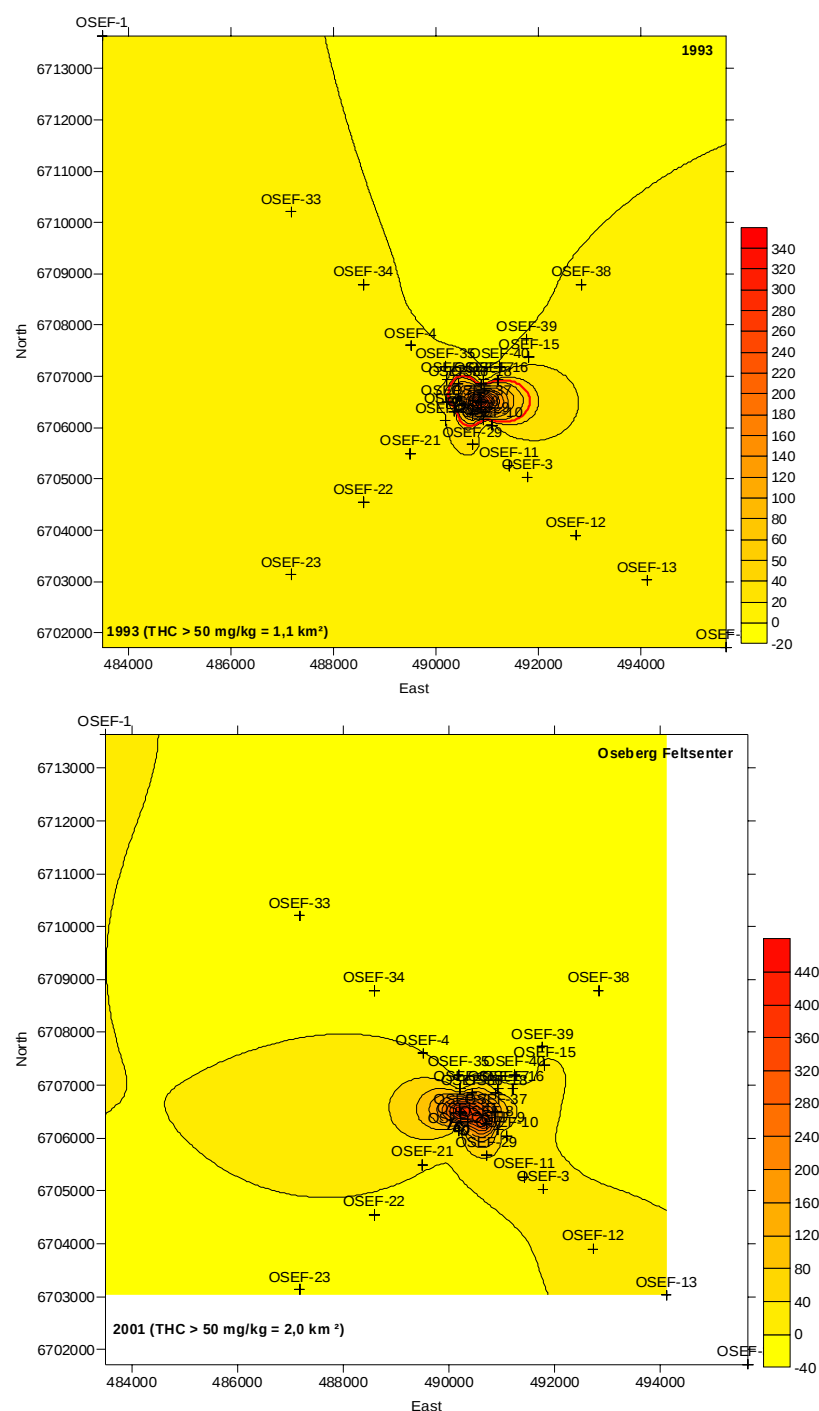
Comments

The THC concentration was extremely high at station OSEF-18 in 1991, with a significant decrease from 1991 to 1993. The extremely high concentration in 1991 can explain the “over-calculated” contaminated area in 1991. The contaminated area decreased from 1992, and increased in the period 1994 to 2001.

TECHNICAL NOTE

Table 3-17. *Calculated area (km²) contaminated with THC > 50 mg/kg at Oseberg Feltcenter.*

Year	1991	1992	1993	1994	1998	2001
Area contaminated	“24”	4.6	1.1	0.6	1.3	2.,0

**Figure 3-9.** *Contour plot of THC concentrations at Oseberg Feltcenter in 1991 (above) and 1994 (below). 50 mg/kg concentration is marked as a red line in the plot.*

TECHNICAL NOTE

3.9 Oseberg C

Contaminated area

Table 3-16 shows the THC concentrations from all stations at Oseberg C. Stations with concentrations > 50 mg/kg are marked with red colour. Some contour plots are shown in Figure 3-9 (see Appendix C for all contour plots).

Table 3-18. *THC content at different Oseberg C (mg THC/kg sediments)*

Station	Degree	Distace	East	North	1992	1993	1994	1998	2001
OSEC-1	335	9901	483560	6728344	2	3	3	6	3
OSEC-2	335	4000	485972	6722936	2	3	3		
OSEC-3	335	2000	486836	6721132	2	5	2		
OSEC-4	335	1000	487301	6720309	7	6	5	7	5
OSEC-5	335	500	487518	6719751	11	4	11	25	7
OSEC-6	325	250	487572	6719529	20	4	32	205	13
OSEC-7	180	250	487734	6719082				2100	91
OSEC-8	150	500	487953	6718970	314	8	119	316	81
OSEC-9	150	1000	488225	6718524	22	22	20	41	14
OSEC-10	150	2000	488715	6717631	6	1100	6	10	4
OSEC-11	150	3520	489479	6716292	2	693	3	4	4
OSEC-12	30	3399	489422	6722258	4	5	3		
OSEC-13	30	2000	488714	6721051	2	2	3		
OSEC-14	30	1000	488231	6720195	3	21	4	5	3
OSEC-15	30	500	487956	6719750	31	2	6	15	5
OSEC-16	30	250	487845	6719528	87	2	92	80	20
OSEC-17	235	250	487516	6719195	37	2	6	236	11
OSEC-18	235	500	487296	6719084	8	3	6	19	8
OSEC-19	235	1000	486912	6718751	3	3	3	3	5
OSEC-20	235	2000	486075	6718161	2	2	3		
OSEC-21	235	5265	483422	6716258	3	4	4		
OSEC-24	90	1000	488700	6719328	81	50	44		
OSEC-25	150	5000	490200	6714998	2	33	3		
OSEC-26	150	7000	491200	6713266	2	16	3		
OSEC-27	150	250	487822	6719110	2170	6	707		

Comments

In 1992 the contaminated area was calculated to 2.5 km². In 1993 both the 2000m and 3500m stations were contaminated (with no stations outside these stations), and therefore it is impossible to calculate the contaminated area for that year, see Table 3-17.

Table 3-19. *Calculated area (km²) contaminated with THC > 50 mg/kg at Oseberg C.*

Year	1992	1993	1994	1998	2001
Area contaminated	2.5	“42.1”	1.3	3.5	0.3

TECHNICAL NOTE

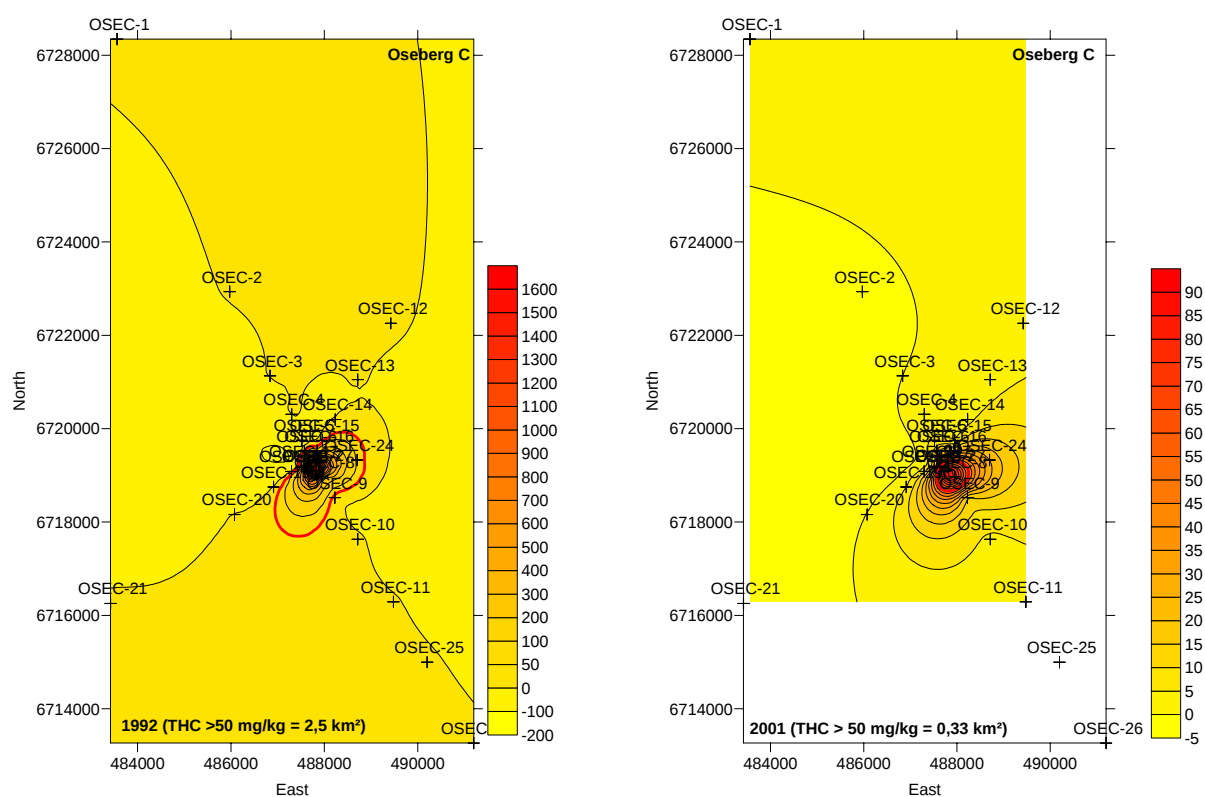


Figure 3-10. Contour plot of THC concentrations at *Oseberg C* in 1992 (left) and 2001 (right).. 50 mg/kg concentration is marked as a red line in the plot.

TECHNICAL NOTE

3.10 Valhall

Contaminated area

Table 3-20 shows the THC concentrations from all stations at Valhall from surveys carried out in 1996, 1999 and 2002. Stations with concentrations > 50 mg/kg are marked with red colour in the table. The contour plots are shown in Figure 3-11.

Table 3-20. THC content at different Valhall (mg THC/kg sediments)

Stations	Degree	Distance	North	East	1996	1999	2002
Valhall	0	0	6237316	524424			
VH-3	74	1000	6237592	525385			60,5
VH-04	74	2000	6237868	526346	14,86	10,78	12,7
VH-05	74	4000	6238367	528374	7,57	7,91	
VH-08	164	500	6236836	524561			274
VH-09	164	1000	6236266	524754	41,75	65,03	26,7
VH-10	164	2000	6235359	525038	13,23	10,96	12,8
VH-11	164	4000	6233655	525513	7,31	8,50	8,6
VH-12	164	6000	6231338	525837	5,74	5,68	
VH-16*	254	1000	6237041	523462	137,00	34,03	16,5
VH-16	254	2000	6236699	522501		10,20	7,9
VH-17	254	4000	6236318	520439	6,79	6,72	
VH-21	320	500	6237699	524102			17,2
VH-22	344	1000	6238193	524196	22,37	14,91	12,1
VH-23	344	2000	6239139	524180	8,66	8,24	8,2
VH-24A	254	15000	6233312	510041	6,10	5,12	4,8

Comments

In 1996 the contaminated area was calculated to 8.8 km². In 1996 only the 1000m and 4000m stations were sampled in the 254 degree direction. Since the 1000m station was contaminated the area was overestimated. With a “normal” value at 2000m the area had decreased to about 4,4 m². In 1999 only station VH-10 (164°/1000m) was contaminated with THC > 50 mg/kg. In 2002 station VH-3 and VH-08 were both contaminated with THC (> 50 mg/kg). In 1996 and 1999 the 2000m station (VH-04) was the closest in the 74° direction. A manual calculation (simply by making a circle based on contaminated station, and then calculate the area) gives the following areas: 1996 – 4,4 km²; 1999 – 3,8 km² and 2002 – 2,7 km², nearly 40% decrease.

Table 3-21. Calculated area (km²) contaminated with THC > 50 mg/kg at Valhall.

Year	1996	1999	2002
Area contaminated (SURFER)	8,8 ¹	0,6	3,5
Area contaminated (manually)	4,4	3,8	2,7

¹ Due to lack of one station in 164 degree direction. Would probable been around 4,4 if “all” stations was taken

TECHNICAL NOTE

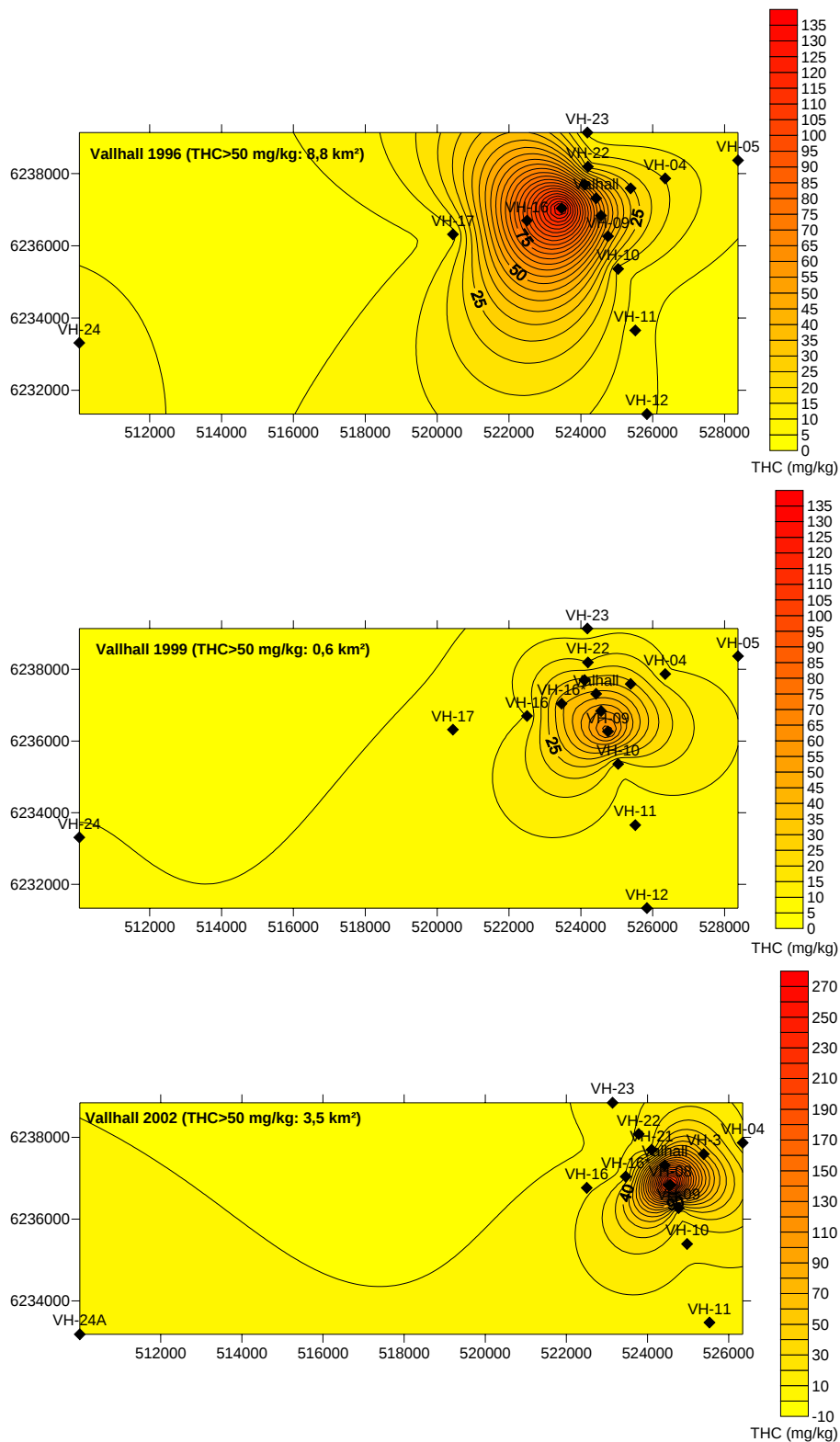


Figure 3-11. Contour plot of THC concentrations at Valhall in 1996 (above), 1999 (middle), and 2002(bottom)). 50 mg/kg concentration is marked as a red line in the plot. Note the difference in the scale.

TECHNICAL NOTE

3.11 Ekofisk 2/4A

Contaminated area

DNV carried out a characterisation of the cutting pile at Ekofisk 2/4A in 2002 (DNV 2003). An extract from the report is given here.

The shape of the cuttings pile was measured using a ROV, and a contour plot of the bottom surface is shown in Figure 3-12 and compared with earlier depth measurements.

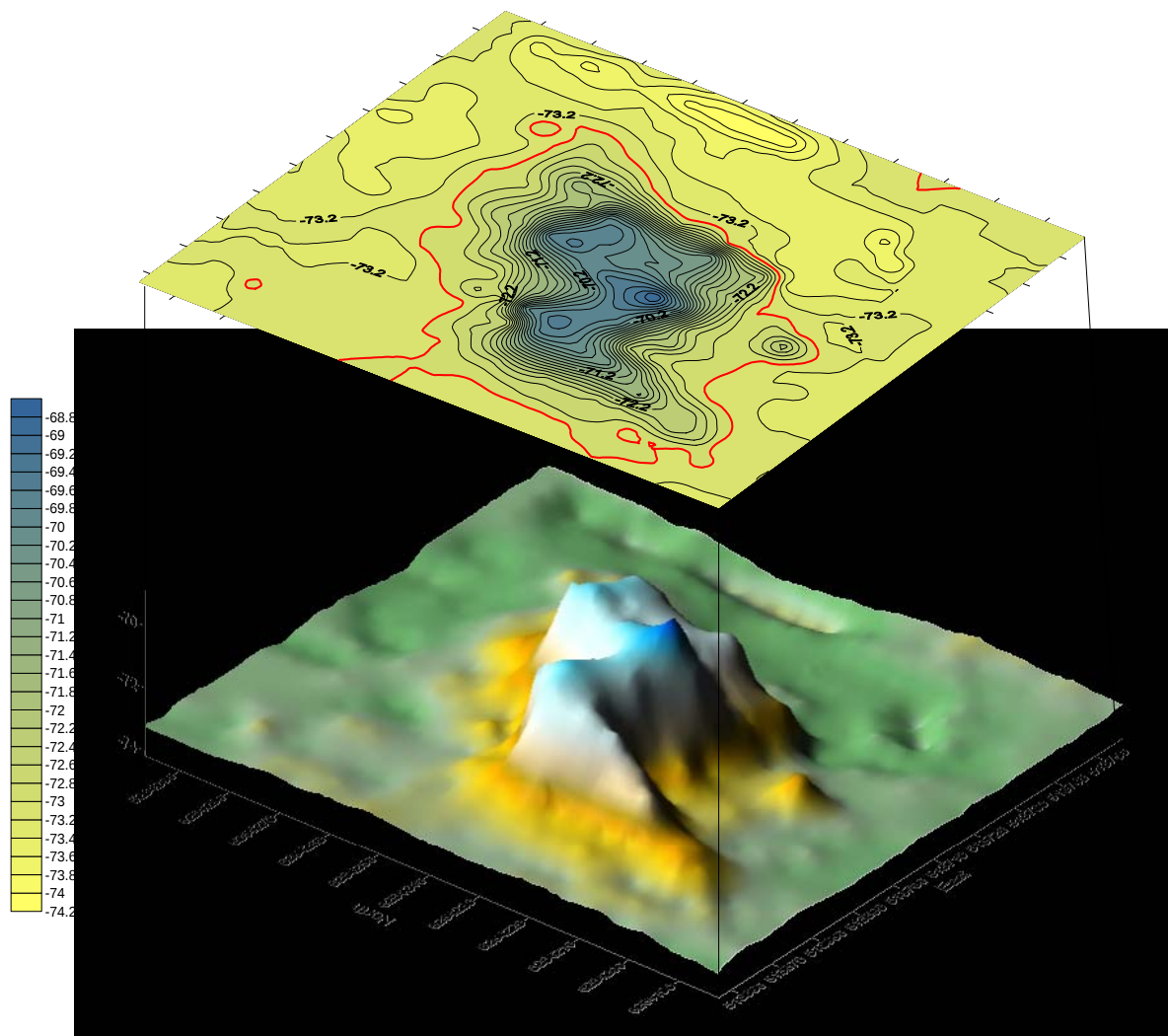


Figure 3-12. Depth contour of the cuttings pile area. Note that the depth intervals are in meter and length intervals in 10meters (1:10 ratio). The boundary of the cuttings pile is set to 73m (depth contour, shown as a red boundary in the upper map).

TECHNICAL NOTE

Comparing the estimated volumes¹ of the cuttings pile in 1998 and 2002 shows that the pile had decreased by approx. 20% from 1998 to 2002, see

Table 3-22. Depth measuring was done during ROV surveys, and since different echosounders were used, the calculations are subject to some uncertainty (maximum depth in 1998 was 74.0 and in 2002 74.2m). This is considered to be a minor difference. The volume is calculated as everything above “ground level”, and the differences in pile volume in 1998 and 2002 turned out the same when varying the ground level from 72 – 73.5m, see Table 3-19. This means that the reduction of the cuttings pile has been considerable the last four years, probably due to erosion. The water depth at the highest point of the pile has increased from 67.5m in 1998 to 68.7m depth in 2002, i.e. the top of the pile has been reduced by approx. 1.2m. This is a reasonable reduction based on RF’s estimated relationship between pile height and length of time the pile has been dormant (RF 1999), which was 26 cm per year. In the same study the erosion rate at Ekofisk 2/4 A was estimated to be 158 m³/yr.

Table 3-22. *Volume of the cuttings pile calculated from ROV surveys at Ekofisk 2/4 A in 1998 and 2002.*

Cutting piles depth	Volume (m ³) 1998	Volume (m ³) 2002	Reduced volume
72m	2519	2041	(19%)
72,5m	3719	2962	(20%)
73m	5569	4374	(21%)
73,5m	9996	8082	(19%)

In Figure 3-13 the THC concentrations based on all stations are plotted as a contour plot. The area with concentrations > 50 mg/kg is calculated to 0.25 km².

It is possible to compare this area with the 1999-regional survey. The total area with concentrations > 50 mg/kg was 0.58 m² in 1999, see Figure 3-13. Thus the contaminated area (> 50 mg THC/kg) has decreased from 0.58 m² in 1999 to 0.25m² in 2002.

¹ The estimated volume differs from the volume calculated by RF in 1999 because of different methods of calculation (the estimated volumes will vary with the definition of the “ground floor” etc.). In the current comparison the RF and DNV data from 1998 and 2002 respectively have been utilised in the same manner.

TECHNICAL NOTE

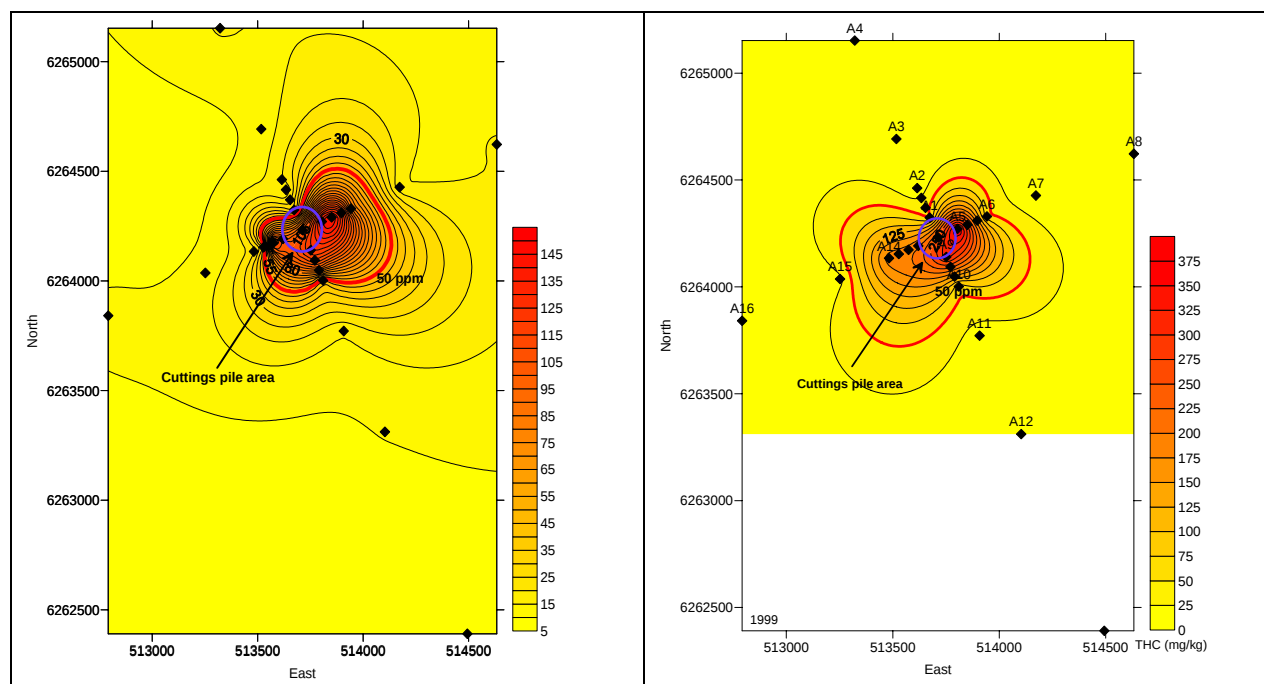


Figure 3-13. Area contaminated with THC (red line is the 50 mg/kg boundary and the blue circle represents the cuttings pile), 1999 (left) and 2002(right).

TECHNICAL NOTE

3.12 Conclusions

This note has shown that it is possible to estimate the area contaminated with THC > 50 mg/kg, and also to evaluate the change in area size during a period of 10-15 years. Even though the number of stations around each installation has been reduced in the recent years, the reduced area can still be estimated, see Table 3-17, The results show that the contaminated areas have decreased from 50% to 90% at all installations. The reason why has not been discussed in this note, but the reductions should be compared with the discharges and the THC concentration in deeper layer of the sediments.

Table 3-23. *Calculated area (km²) contaminated with THC > 50 mg/kg at all installations included in this note.*

Year	1990	1991	1992	1993	1994	1996	1998	1999	2001	2002	%
Statfjord A	4	3.4	4.6	3.4		3.4		2.5		1.8	60%
Statfjord B	6.8	3.1	0	1.3		2.7		0.5		1.2	82%
Statfjord C	4	3.4	4.6	3.4		3.4		2.5		1.8	60%
Gullfaks A	6.5	2.5	1.7	0.2		3.1		0.2		0.2	97%
Gullfaks B	3.2	2.8	1.4	0.5		0.6		0.2		0.2	93%
Gullfaks C	2.5	8.1	2.0	2.4	1.2	1.0		2.4		0.3	88%
Brage			0.6	5.3	5.9		2.4		0.2		96%
Oseberg F		“24”	4.6	1.1	0.56		1.3		2.0		56%
Oseberg C			2.5	“42.1”	1.3		3.5		0.3		91%
Valhall						8.8/ 4.4		0,6/ 3.8		3.5/ 2,7	60%

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APPENDIX

A

CUTTINGS DATA

Appendix 1. Cuttings data

Rogalandforskning (2000) has conducted a study to quantify the total amount of cuttings discharged on the Norwegian Continental Shelf. The study also intended to quantify residual cuttings materials left under/around the installations. The latter task was attempted by means of using data from mapped piles and applying these to all fields, and by using existing models (from Ekofisk and UKOOA R&D). It was concluded to be an impossible task based on available data.

For this study however it is considered important to have at least an estimate of the amount of cuttings piles materials left around the installations. The uncertainty in the data is recognised, but a conservative approach is taken to allow for an evaluation of a reasonable “Worst case” scenario. The wording “reasonable” then refers to a process of making the best evaluation of the data for the individual fields with regard to discharge history, water depth and location.

Among the factors considered important are:

- Type of discharge (WBM, OBM, PBM)
- Discharge regime (over board, dumping liner, at seabed)
- Field structure (fixed installation, floater/pre-drilling, satellite)
- Time since discharge
- Geographical location
- Water depth
- Currents

Since the scope of the present study does not include these calculations (supposed to be an input to the study) only a coarse evaluation based on the above factors is made.

The few piles that have been mapped give some indications on the order of magnitude of materials remaining versus that discharged. There is no scientific documentation for this, but it seems to be fair to generally accept that in the order of 20% material is left at a “normal” field. This number also corresponds well with results from the models available (UKOOA and Ekofisk). Based on this, every single field is evaluated on the above parameters and with the indicative percentile as a basis. Large water depth and the use of water based mud are the two most important factors reducing the percentile, oil based mud and low water depth the two single parameters increasing the percentile most. Anyway, this exercise is done to produce input data for the onshore evaluation, and the individual field data are less important. The cuttings data listed below should therefore not be cited or used for any other purpose than this.

To make the data workable for the onshore processing capability evaluation, a split into 5 year time intervals is made. This is based on a subjective evaluation of the time of field cessation, assuming possible cuttings removal to be phased with this activity.

This is only done with respect to fields where OBM or PBM are used (partly or fully).

Table 3-24 Data for estimating remaining amount of cuttings material at individual fields.

Field	Volume (m3	Depth (m)	Drill fluid	More/less than av	Remaining	Pile?	Comment
Aasgard	24774	300	W	0.05	1239	N	15 templates, WBM
Albuskjell	144000	70	O		4200	Y	Mapped
Balder	26272	125	W	0.15	3941	N	Drilling in large area, WBM
Brage	98783	137	P	0.25	24696	Y	SBM, 30 wells, long wells
Cod	20000	79	O		600	Y	Mapped
Draugen	45950	251	W	0.1	4595	N	WBM
Edda	54000	73	O		1000	Y	Mapped
Ekofisk I (center)	120000	73	O	0.1	7600	Y	Mapped
Ekofisk II (center)	8000	76	W	0.2	1600	Y	
Ekofisk 2/4 A	72800	70	P		5300	Y	Mapped
Ekofisk 2/4 B	88000	71	P		4235	Y	Mapped
Ekofisk 2/4 K	54000	71	O, W	0.2	10800	Y	
West Ekofisk (2/4)	60000	67	W		1000	Y	Mapped
Eldfisk	240000	72	P	0.2	48000	Y	
Embla	20000	71	P	0.2	4000		
Frigg	71435	100	W/O		400	N	Mapped
East Frigg	13158	100	O, W	0.1	1316	N	Satelite
North East Frigg	20622	100	W	0.1	2062	N	
Frøy	47312	120	P		490	N	Mapped
Gullfaks A	126895	136	O/W	0.25	31724	Y	
Gullfaks B	137619	143	O/W	0.25	34405	Y	
Gullfaks C	113760	216	O/W	0.25	28440	Y	
Gullfaks Sat	11286	135	W, P	0.1	1129	N	WBM, 5 SBM
Gyda	29008	66	O	0.1	3430	Y	Mapped
Heidrun	28277	350	P	0.05	1414	N	Predrilled, satelite, SBM
Heimdal	31816	120	W	0.1	3182	N	
Hod	6538	72	P	0.2	1308		
Husmus	2330	230	W	0.1	233		
Jotun	5425	125	W	0.15	814	N	Satelite
Lille Frigg	30215	100	W	0.1	3022	N	WBM, satelite
Loke	1957	85	W, P	0.2	391		
Mime	0	80	W				
Njord	5766	330	O, W	0.1	577		No discharge of OBM
Norne	16270	380	W	0.05	814		Predrilled, Satelites
Odin	19481	103	W	0.1	1948	N	
Oseberg A	0	110				N	
Oseberg B	101788	103	O/W/P		6550	Y	Mapped
Oseberg C	67287	108	O/W/P		1100	Y	Mapped
Oseberg Øst	2044	100	W	0.1	204		WBM
Oseberg Sør	7213	100	W, O	0.1	721		WBM
Rogn Sør	4580	286	W	0.1	458		Satelite?
Sleipner	35338	82	P/W	0.2	7068	Y	
Sleipner West	25078	106	W	0.2	5016		
Snorre	120950	310	W, P	0.25	30238	Y	WBM, SBM
SOP	4580	277		0.1	458		
Statfjord A	64340	145	O/W/P	0.25	16085	Y	
Statfjord B	67143	144	O/W/P	0.25	16786	Y	
Statfjord C	63630	146	O/W/P	0.25	15908	Y	
Statfjord East	14633	110	W, P	0.1	1463	N	Satelite
Statfjord North+	14681	120	W	0.1	1468	N	Satelite
Tommeliten	3894	70	W	0.1	389	N	
Tor	64000	67	P/W	0.2	12800	Y	
Tordis	38449	200	P/W	0.1	3845		Satelite
Troll Gas	39409	303	W	0.15	5911		WBM
Troll Oil	137801	320	W	0.1	13780	N	Satelites
Ula	19927	70	P	1	24000	Y	Mapped
Valhall	54051	69	O	0.45	25000	Y	Mapped
Varg	14585	85	W	0.1	1459		WBM
Veslefrikk	50066	175	O, W	0.2	10013	Y	
Vigdis	29327	282	P	0.1	2933		SBM, drilled from floater
Visund	15064	335	W	0.1	1506		WBM
Yme	23203	93	W/P	0.15	3480	Y	WBM
TOTAL	2878810				448540		
	2878810		313354		448540		

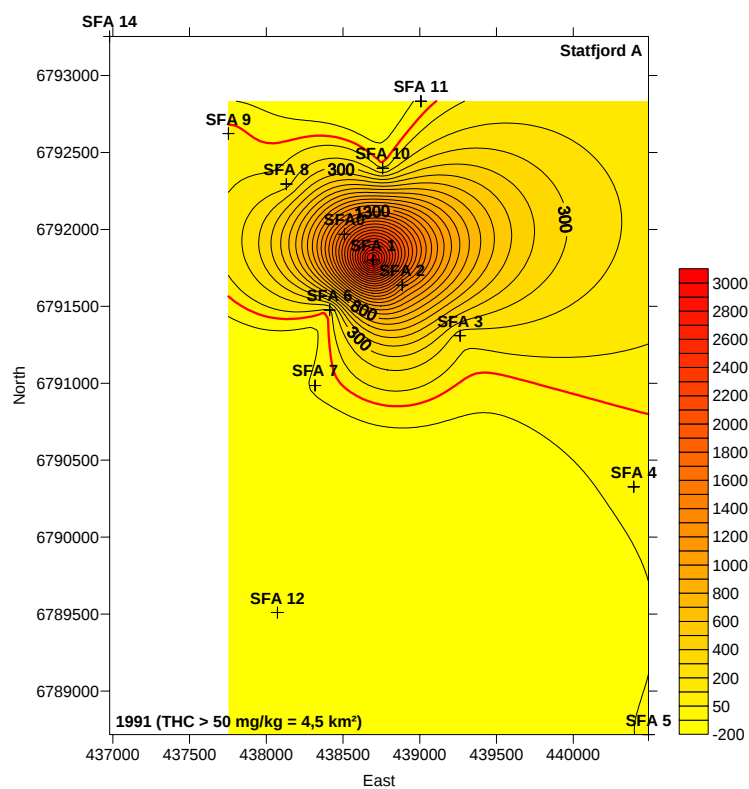
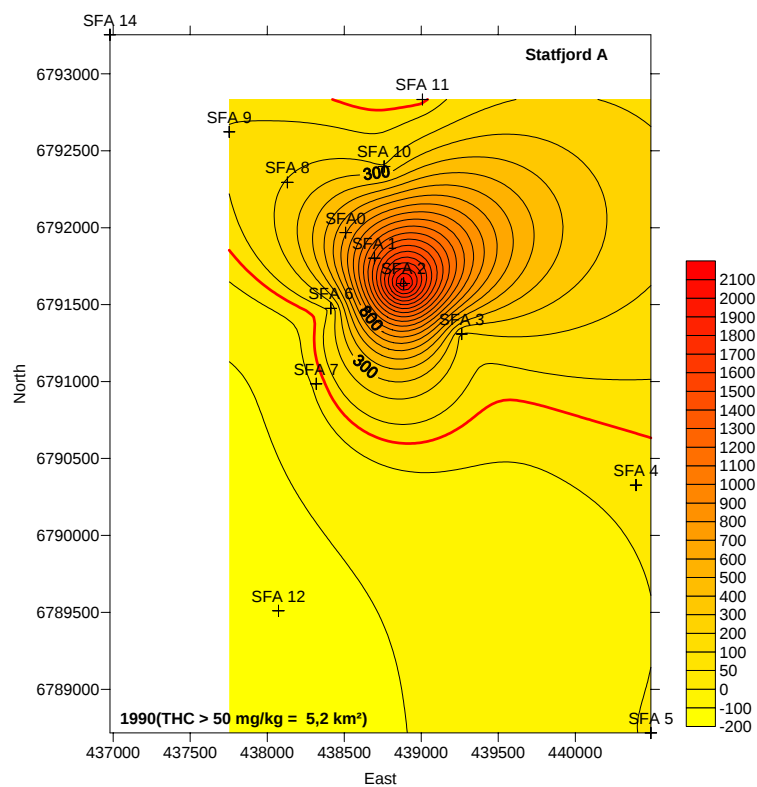
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APPENDIX

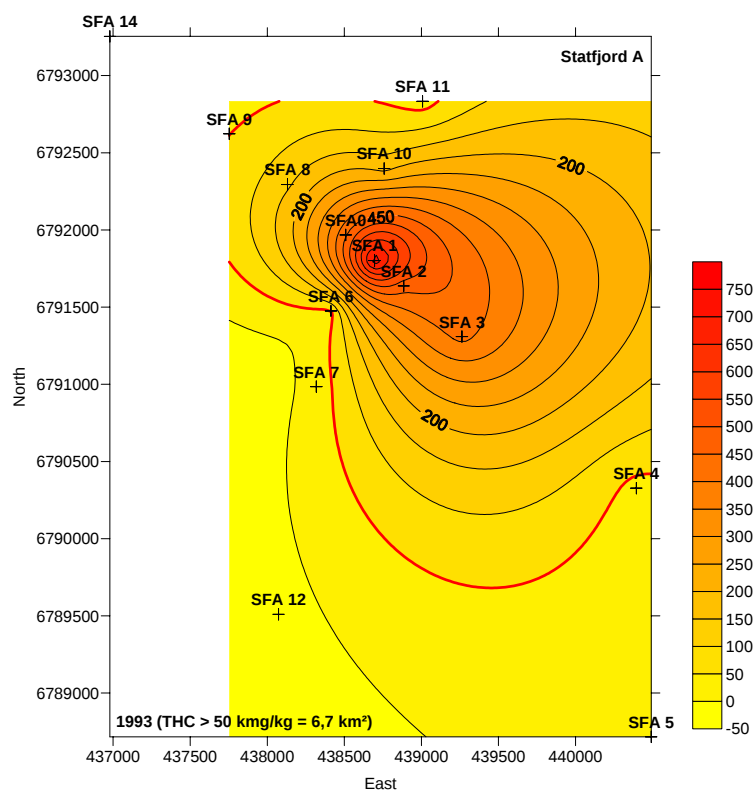
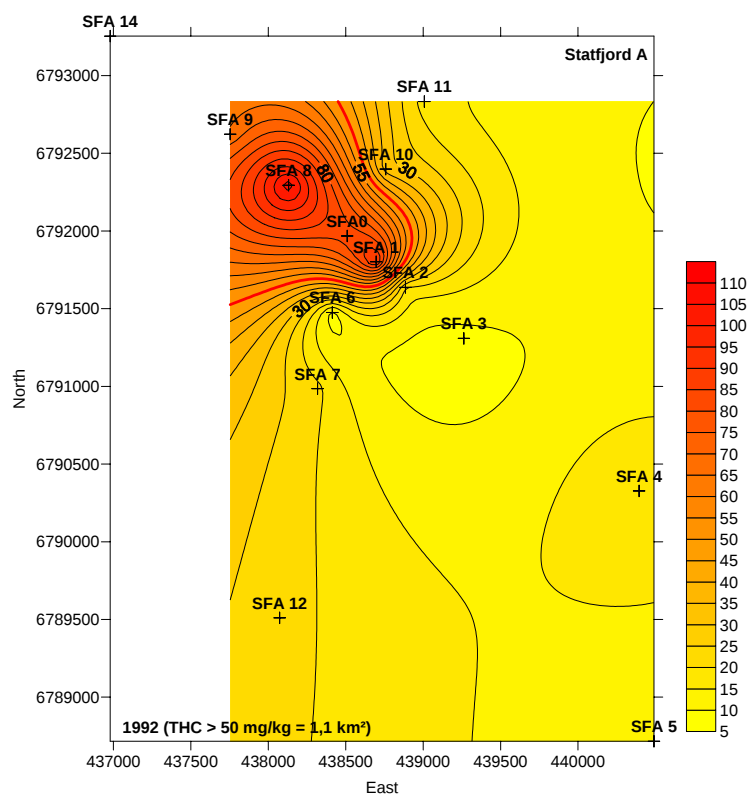
B

CONTOUR PLOTS

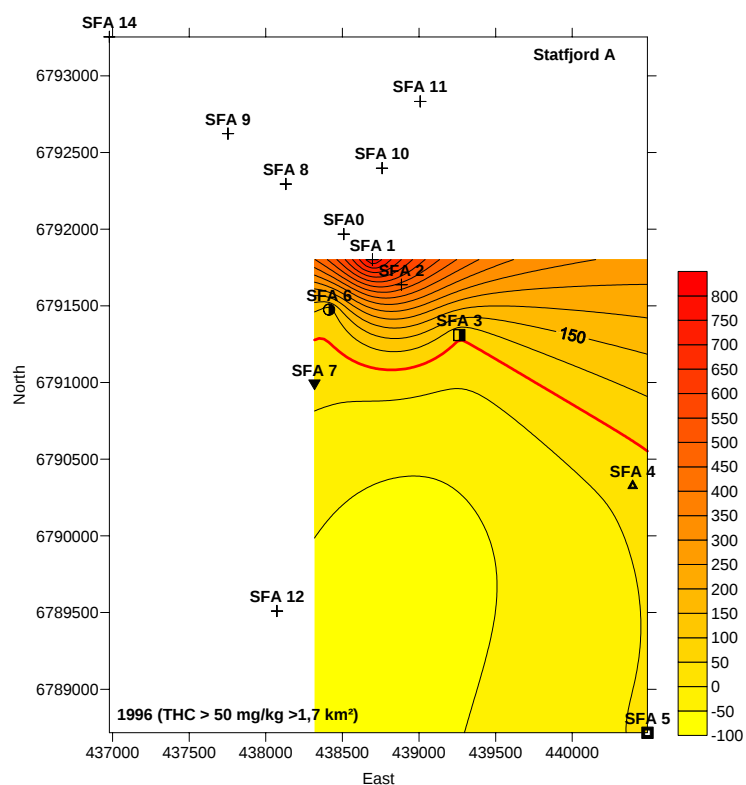
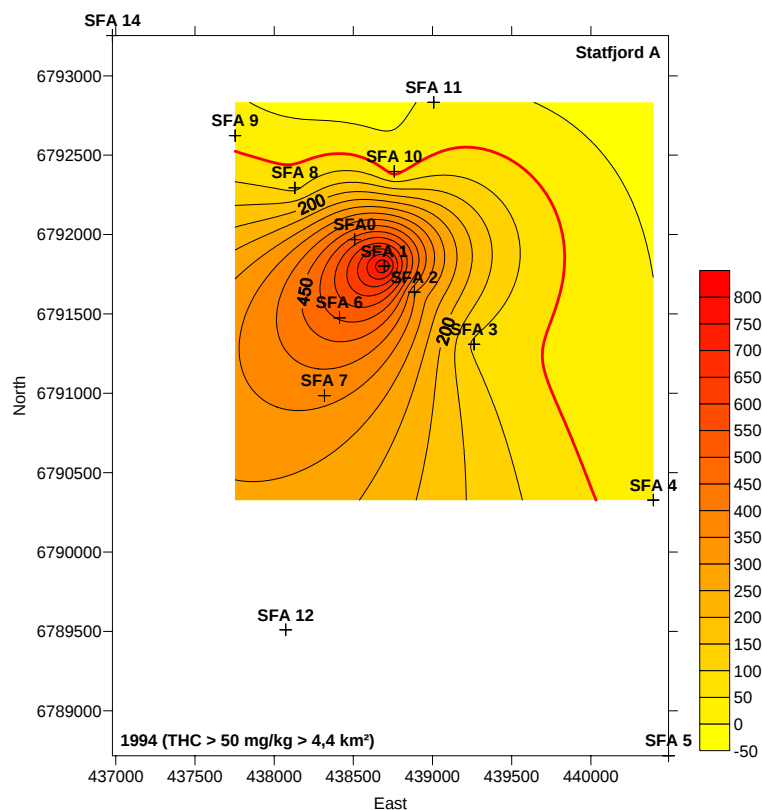
Appendix B. 1.1. Contour plot from Statfjord A.



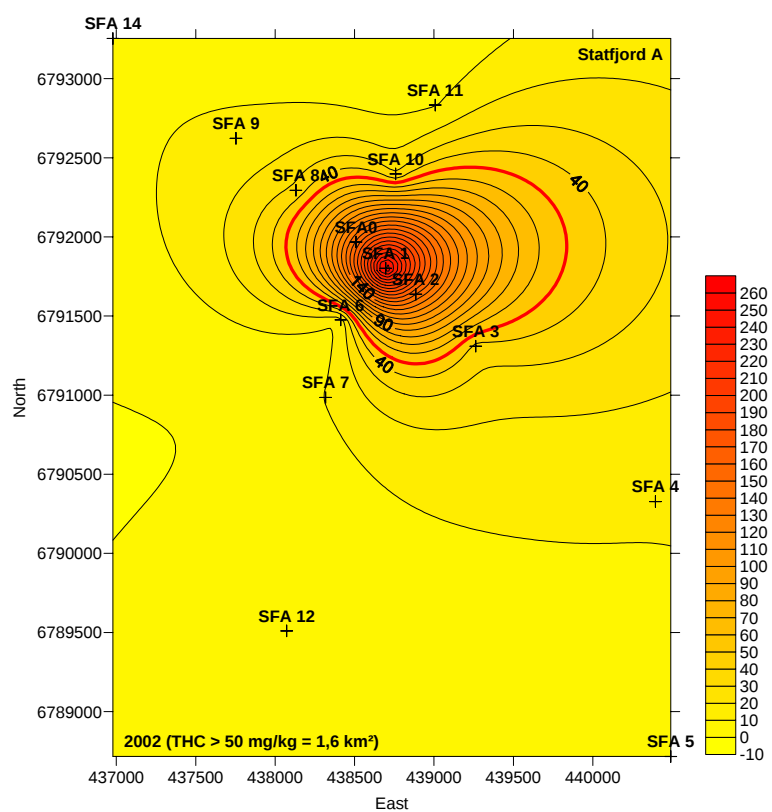
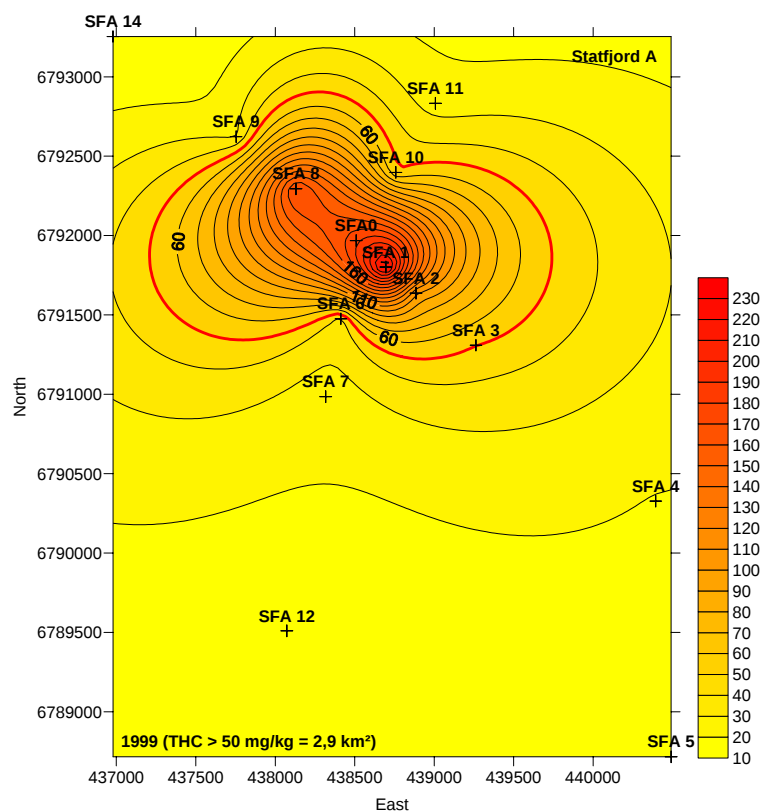
Appendix B. 1.2. Contour plot from Statfjord A.



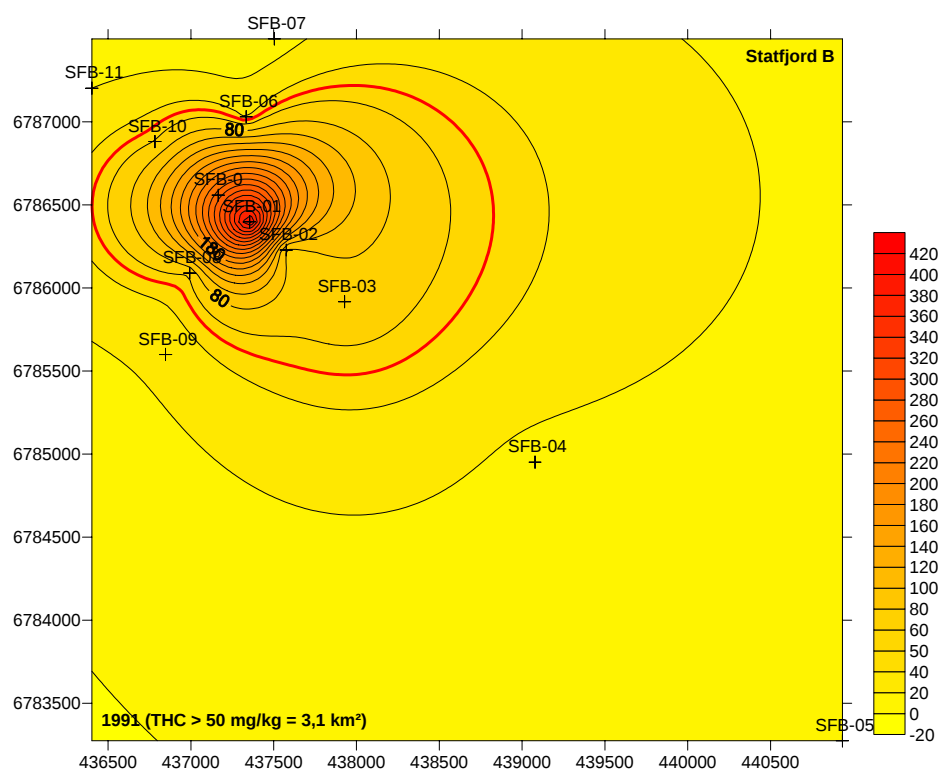
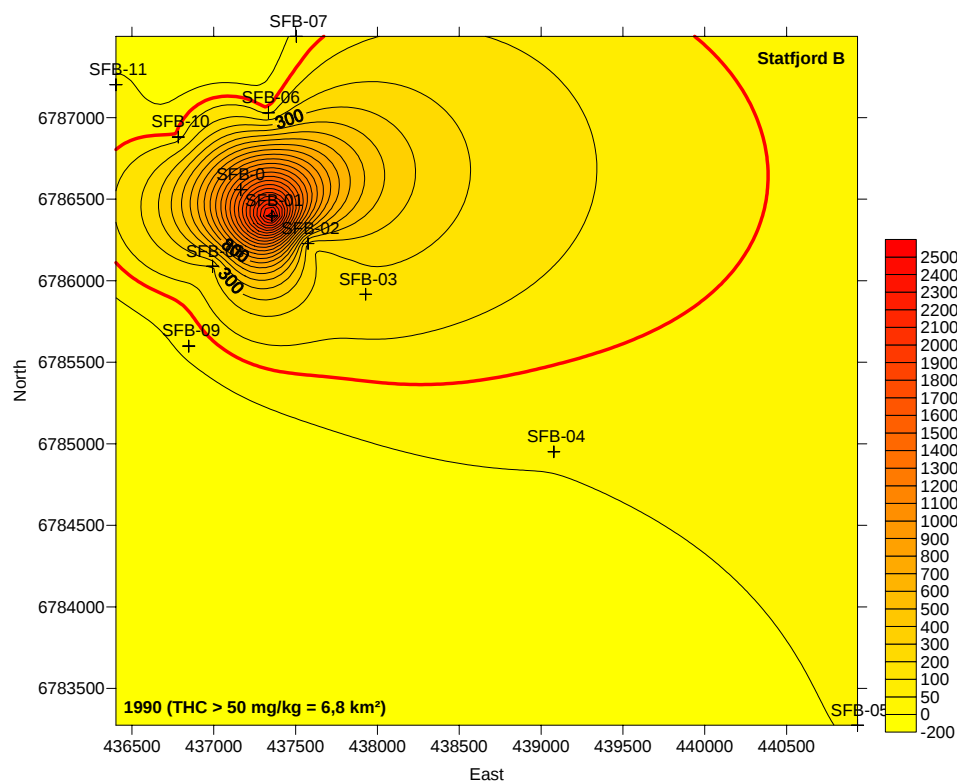
Appendix B.13. Contour plot from Statfjord A.



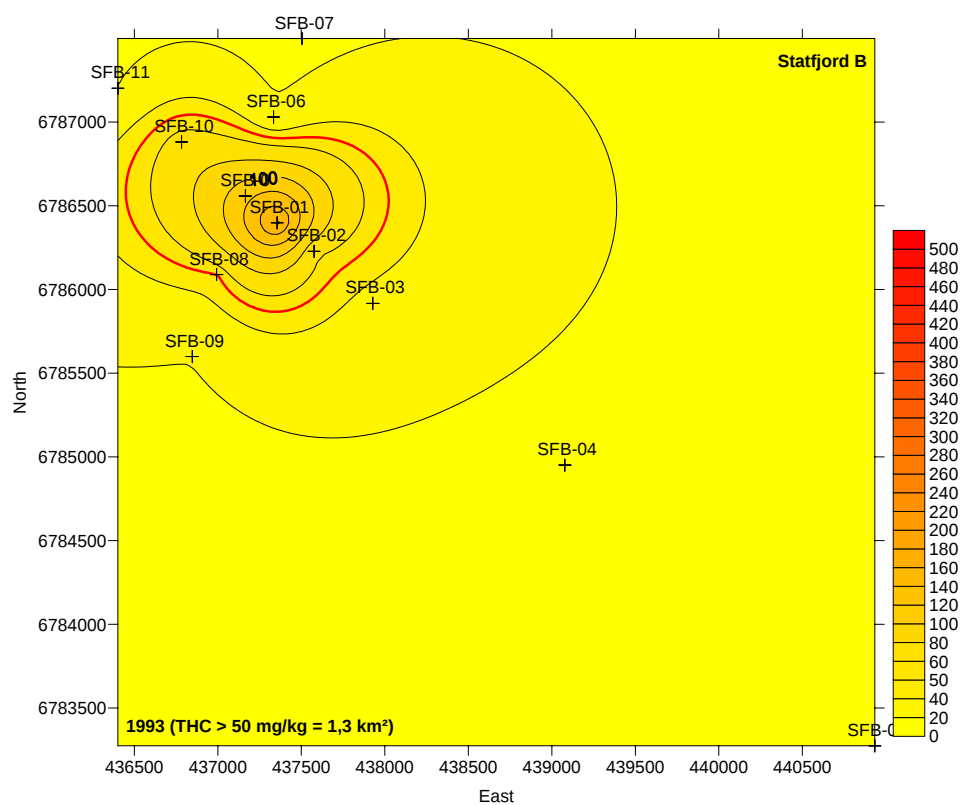
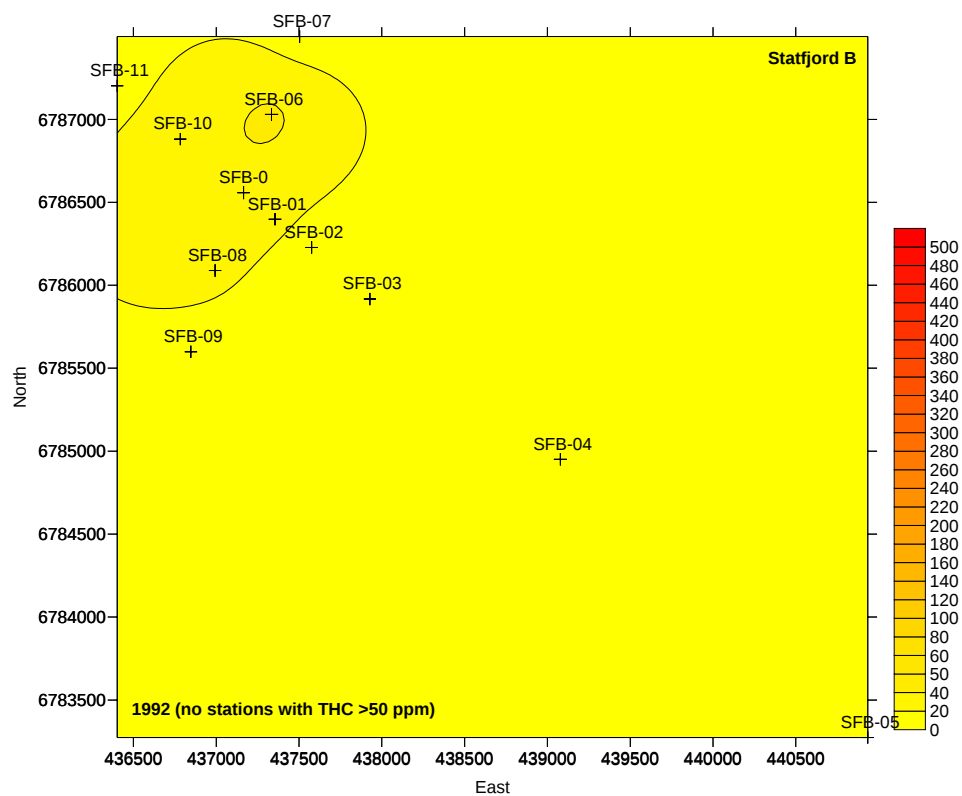
Appendix B.1. 4. Contour plot from Statfjord A.



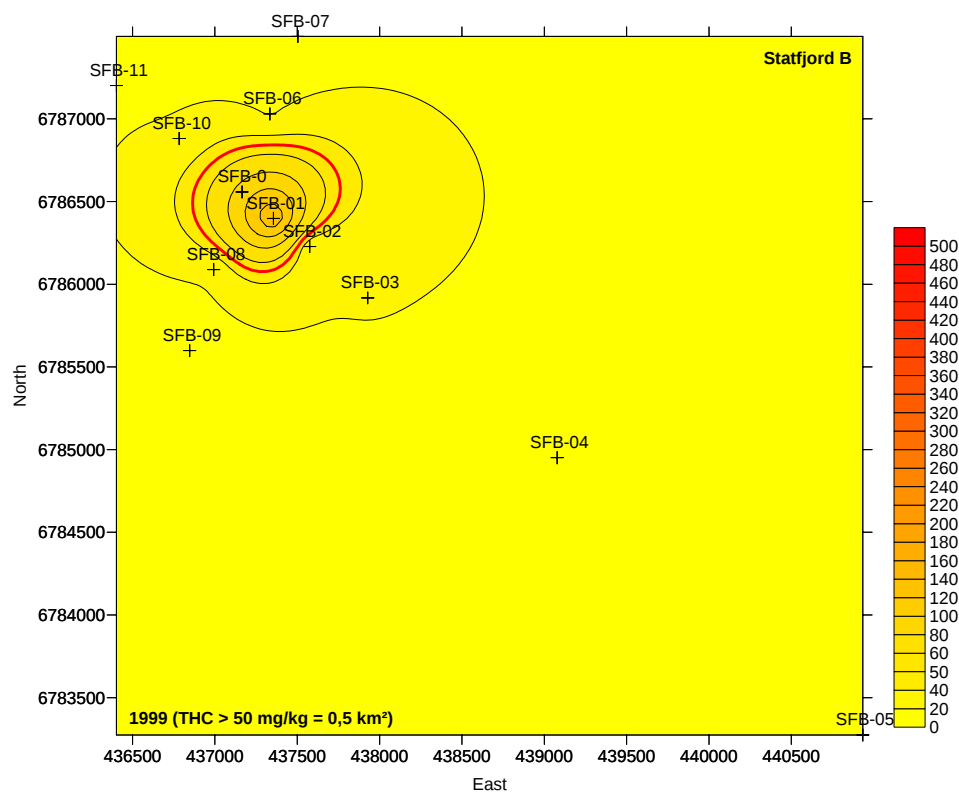
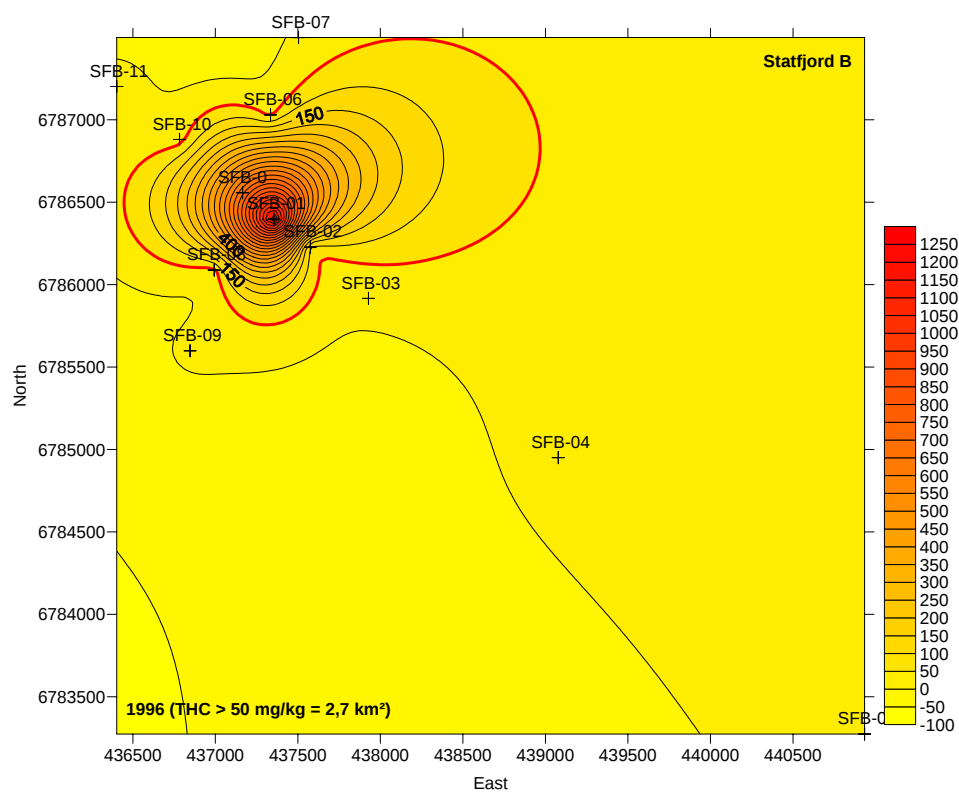
Appendix B.2. 1. Contour plot from Statfjord B.



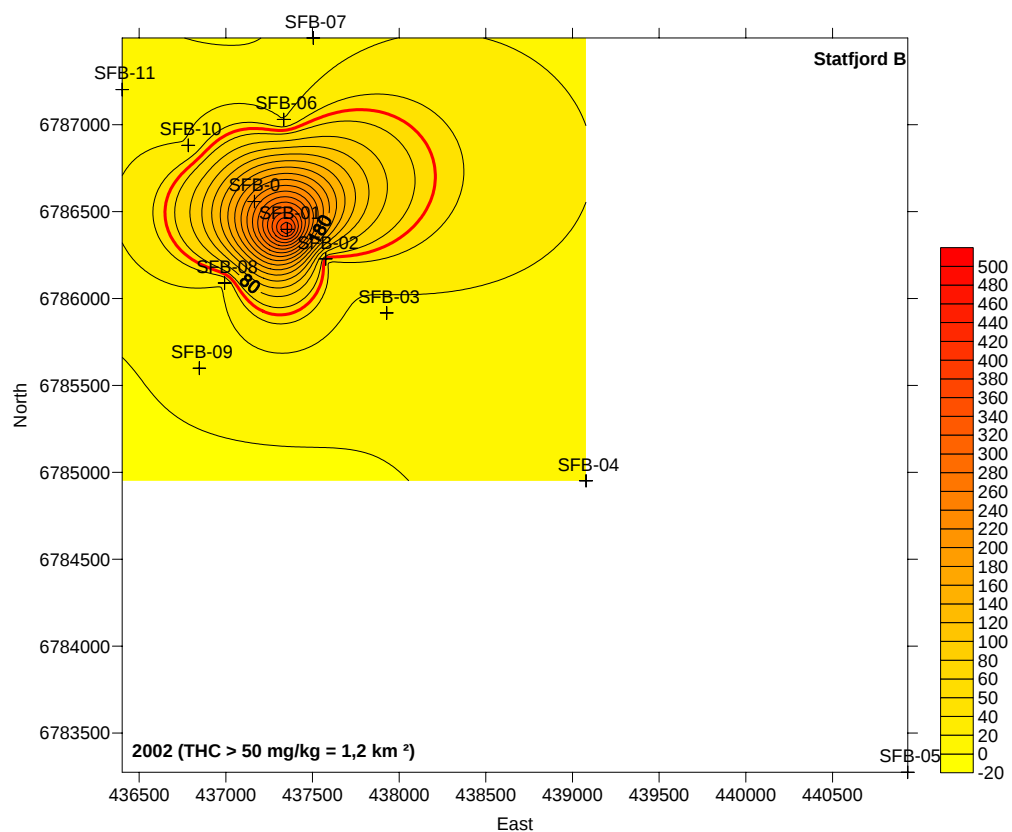
Appendix B.2. 2. Contour plot from Statfjord B.



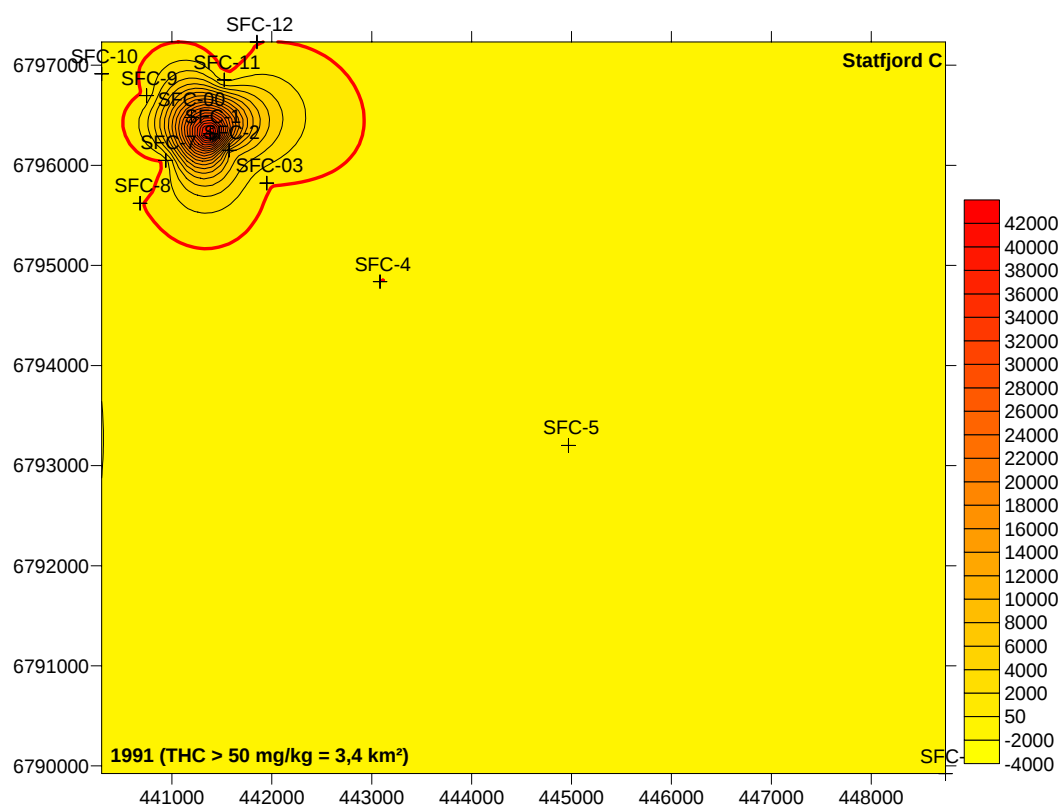
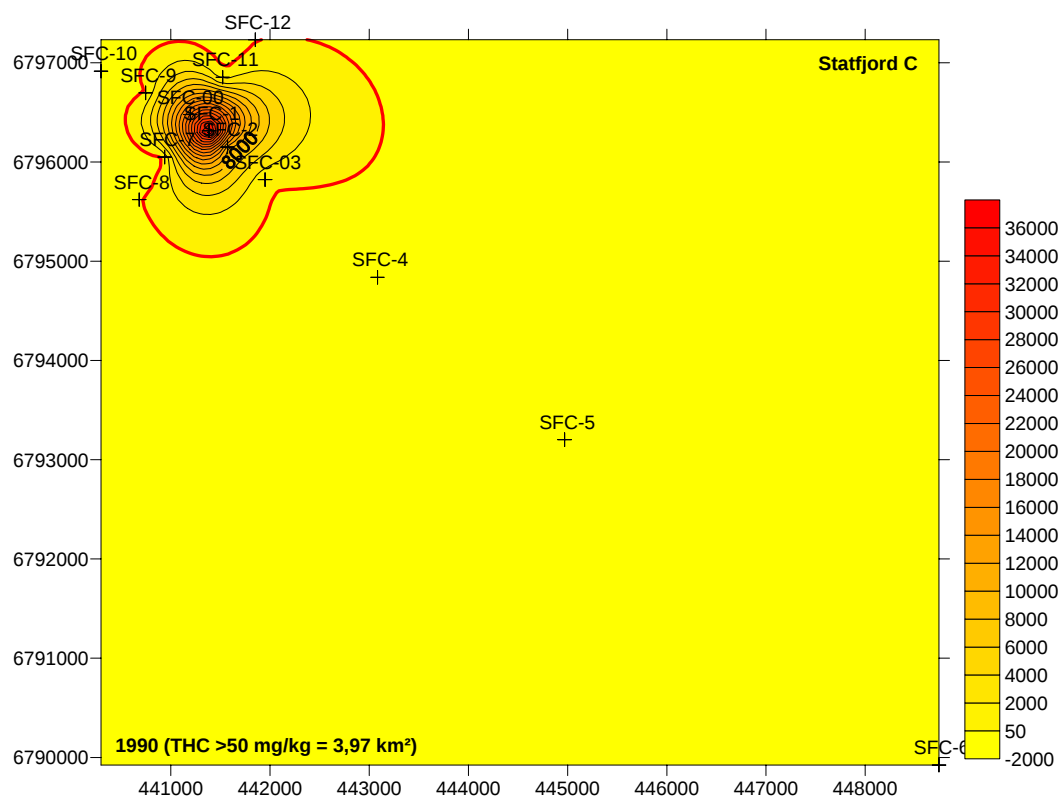
Appendix B.2. 3. Contour plot from Statfjord B.



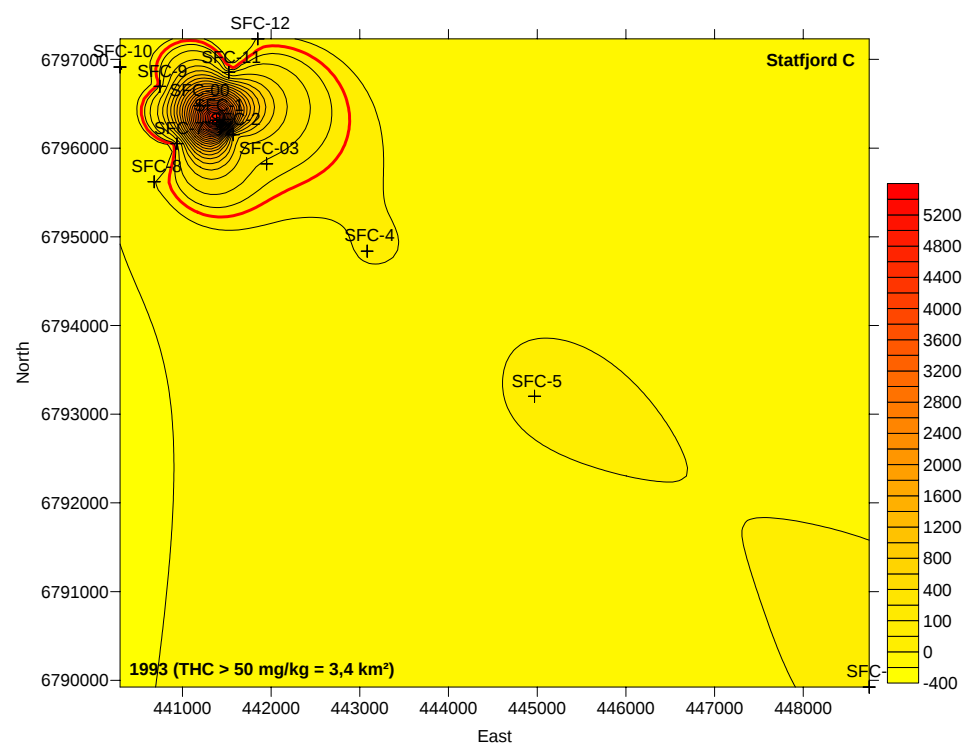
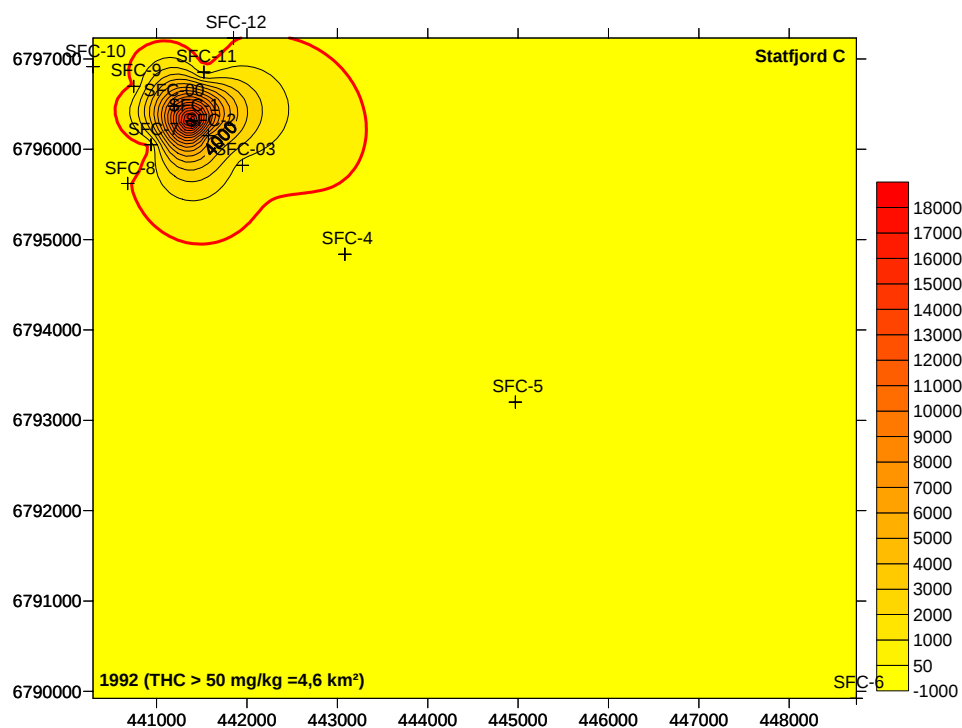
Appendix B.2. 4. Contour plot from Statfjord B.



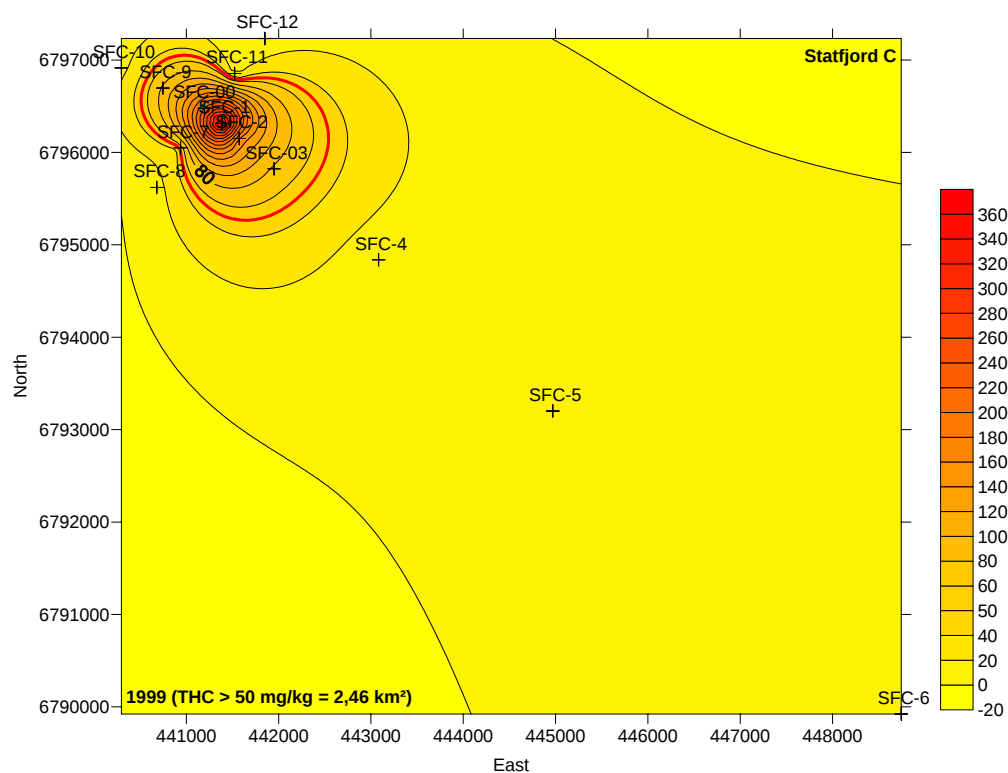
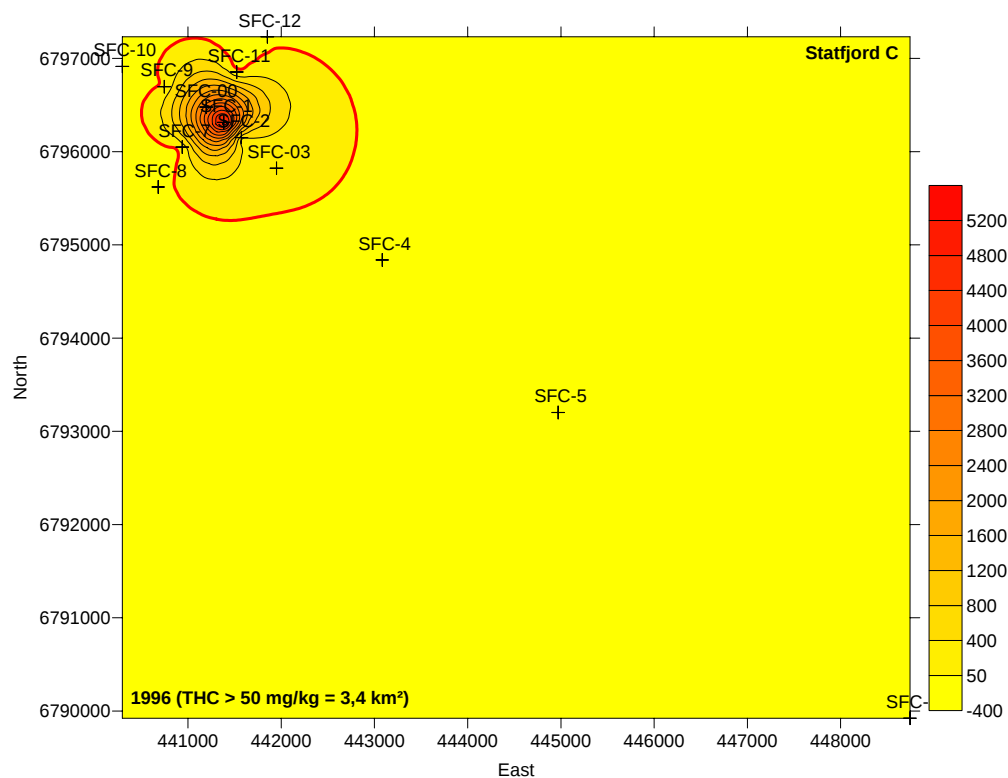
Appendix B.3. 1. Contour plot from Statfjord C.



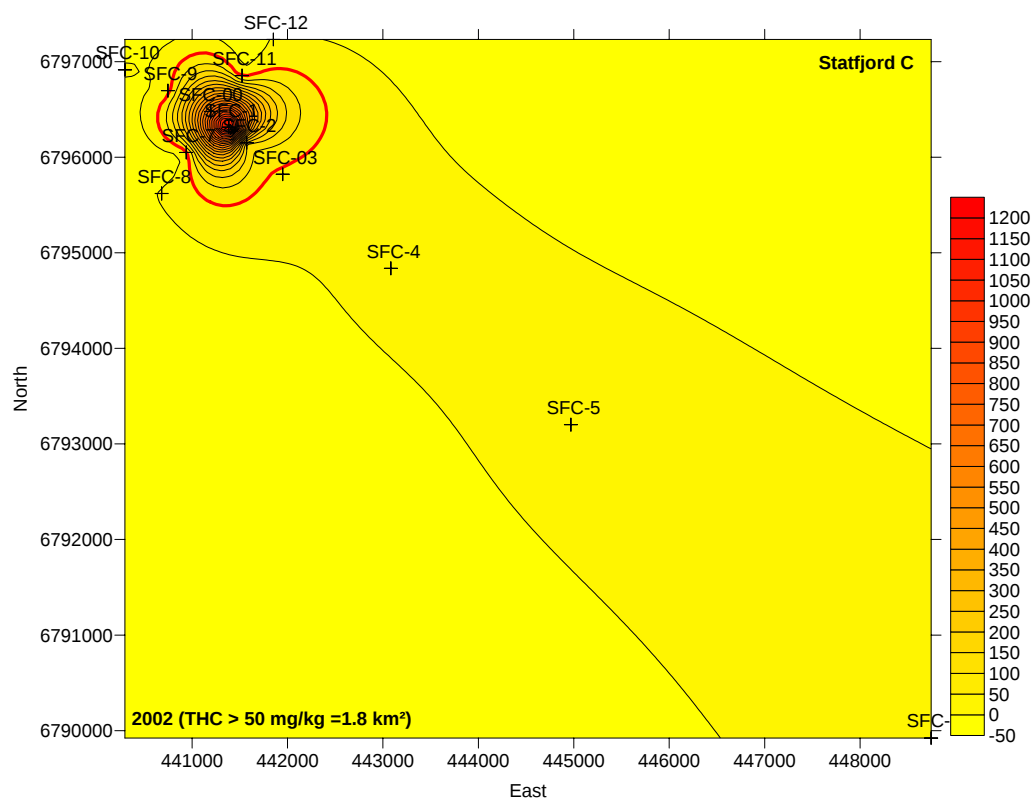
Appendix B.3. 2. Contour plot from Statfjord C.



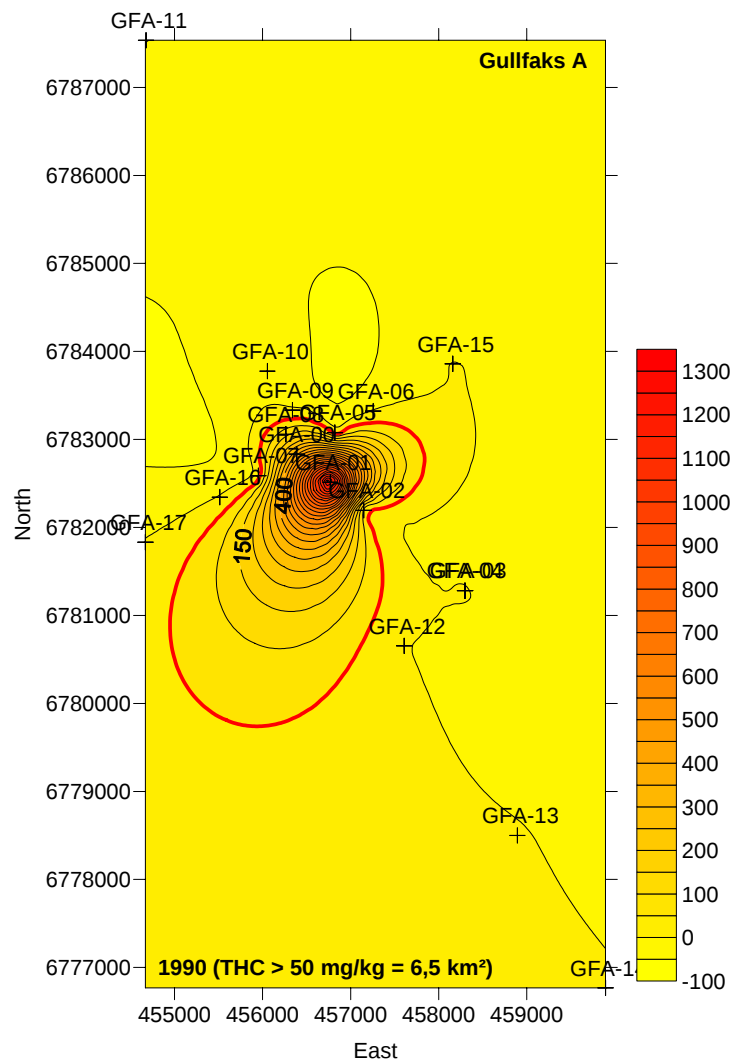
Appendix B.3. 2. Contour plot from Statfjord C.



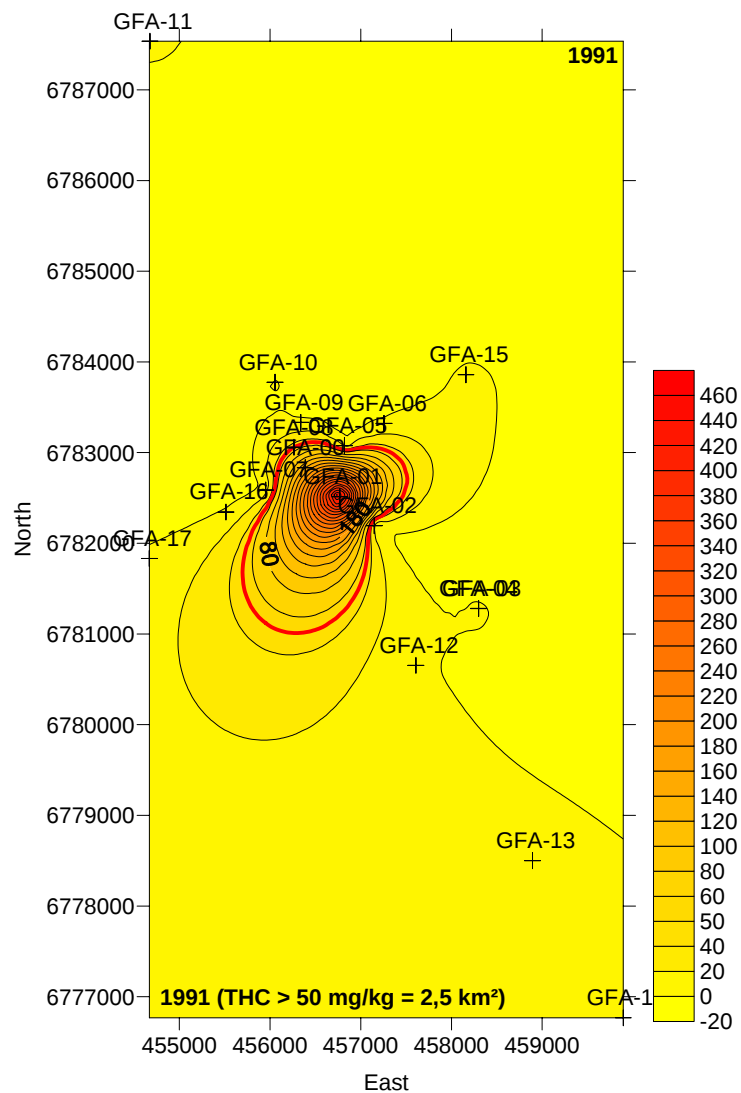
Appendix B.3. 4. Contour plot from Statfjord C.



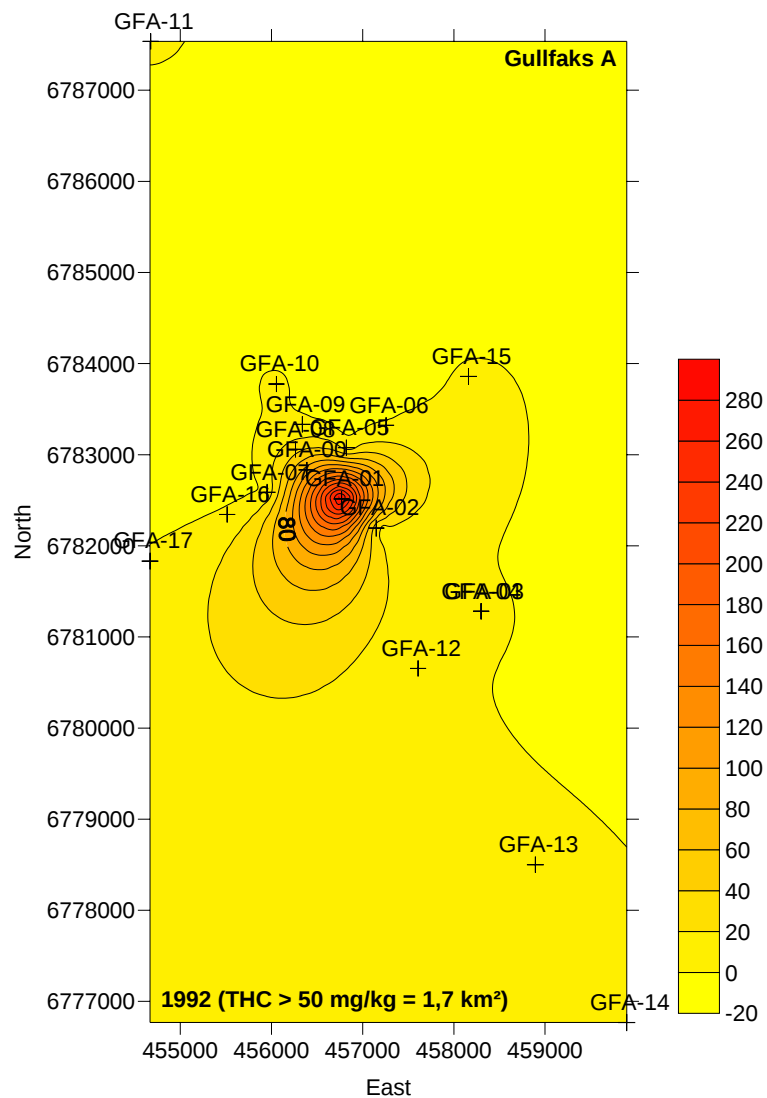
Appendix B.4.1. Contour plot from Gullfaks A.

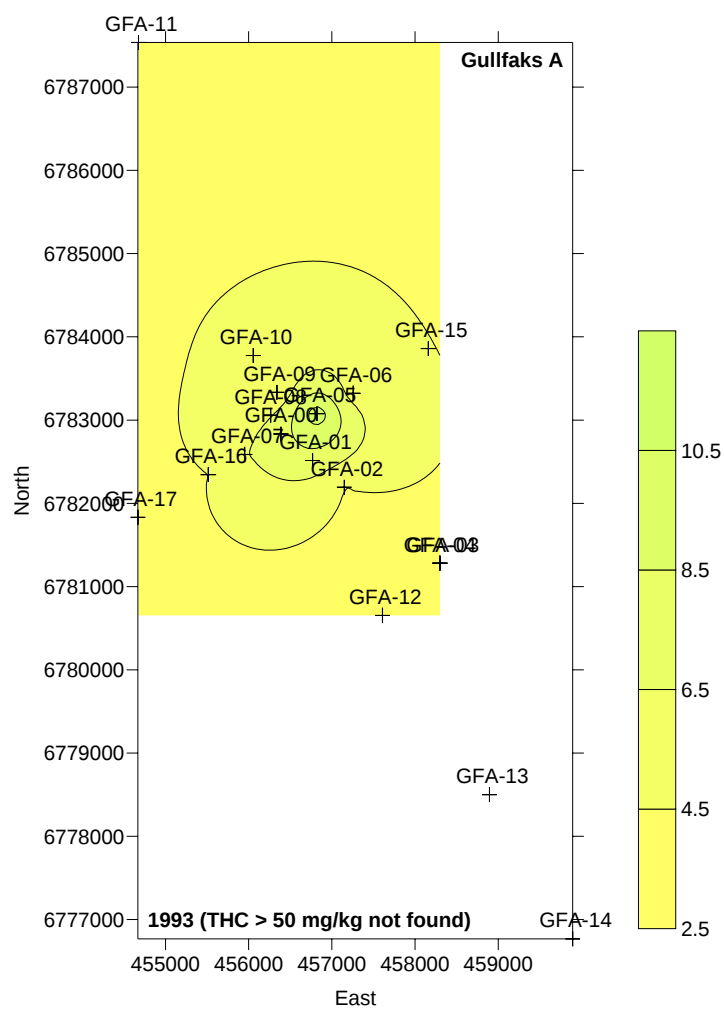


Appendix B.4. 2. Contour plot from Gullfaks A.

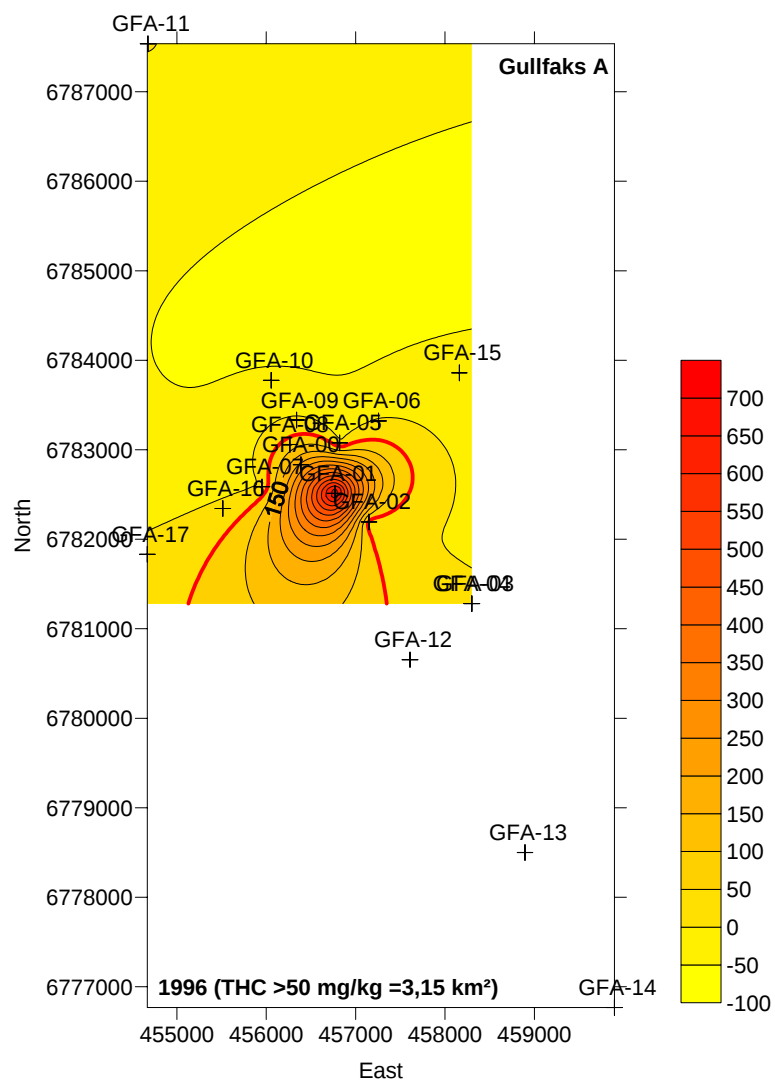


Appendix B.4. 3. Contour plot from Gullfaks A.

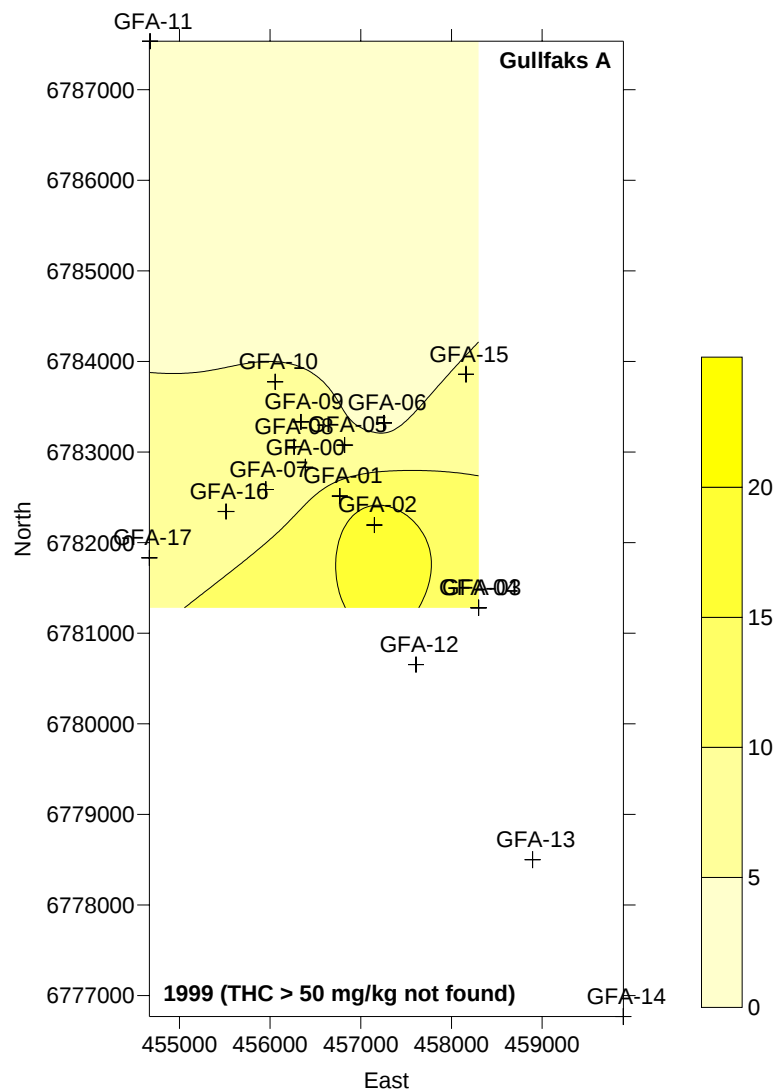


Appendix B.4. 4. Contour plot from Gullfaks A.

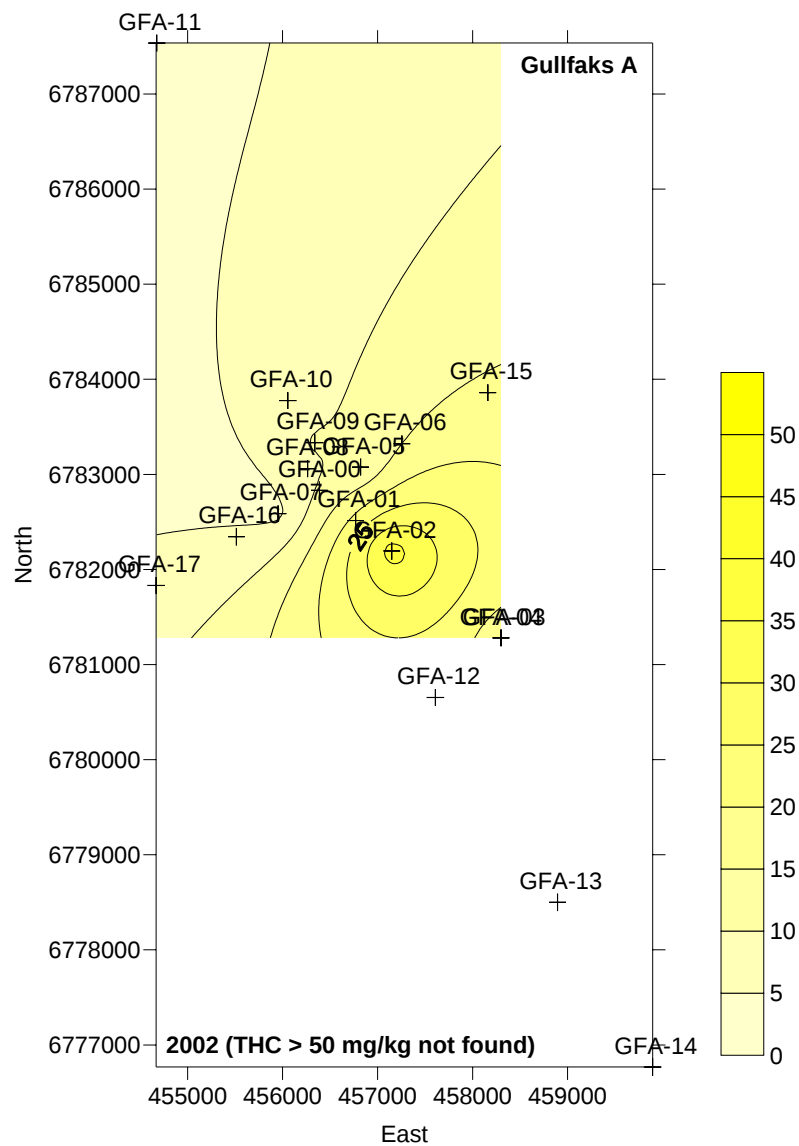
Appendix B.4. 5. Contour plot from Gullfaks A.



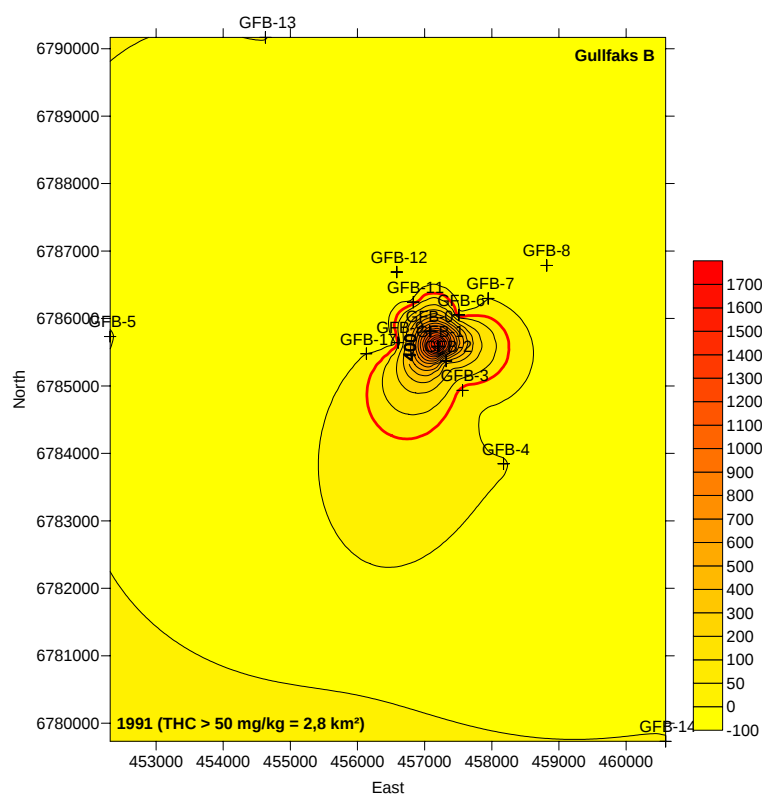
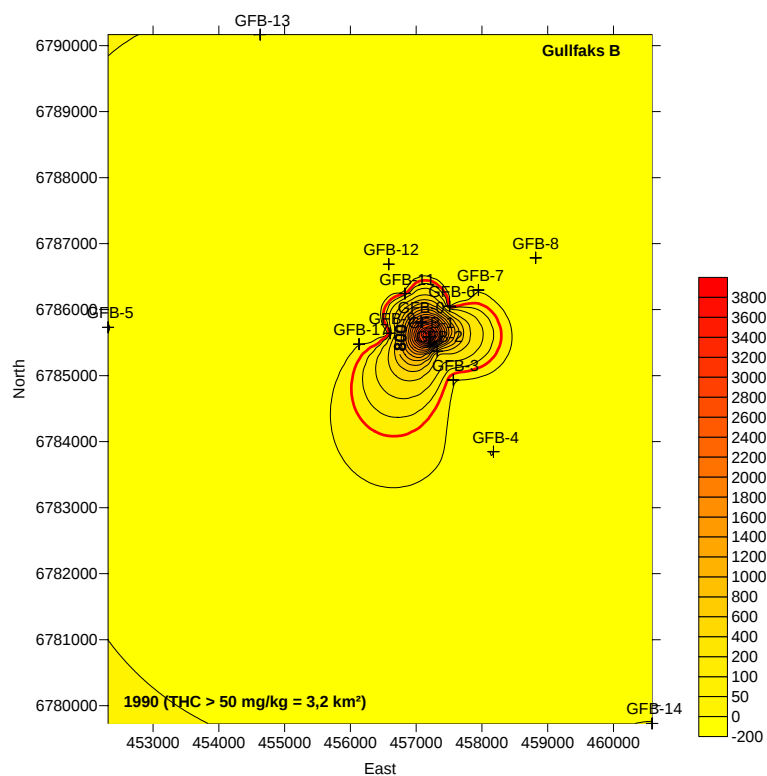
Appendix B.4. 6. Contour plot from Gullfaks A.



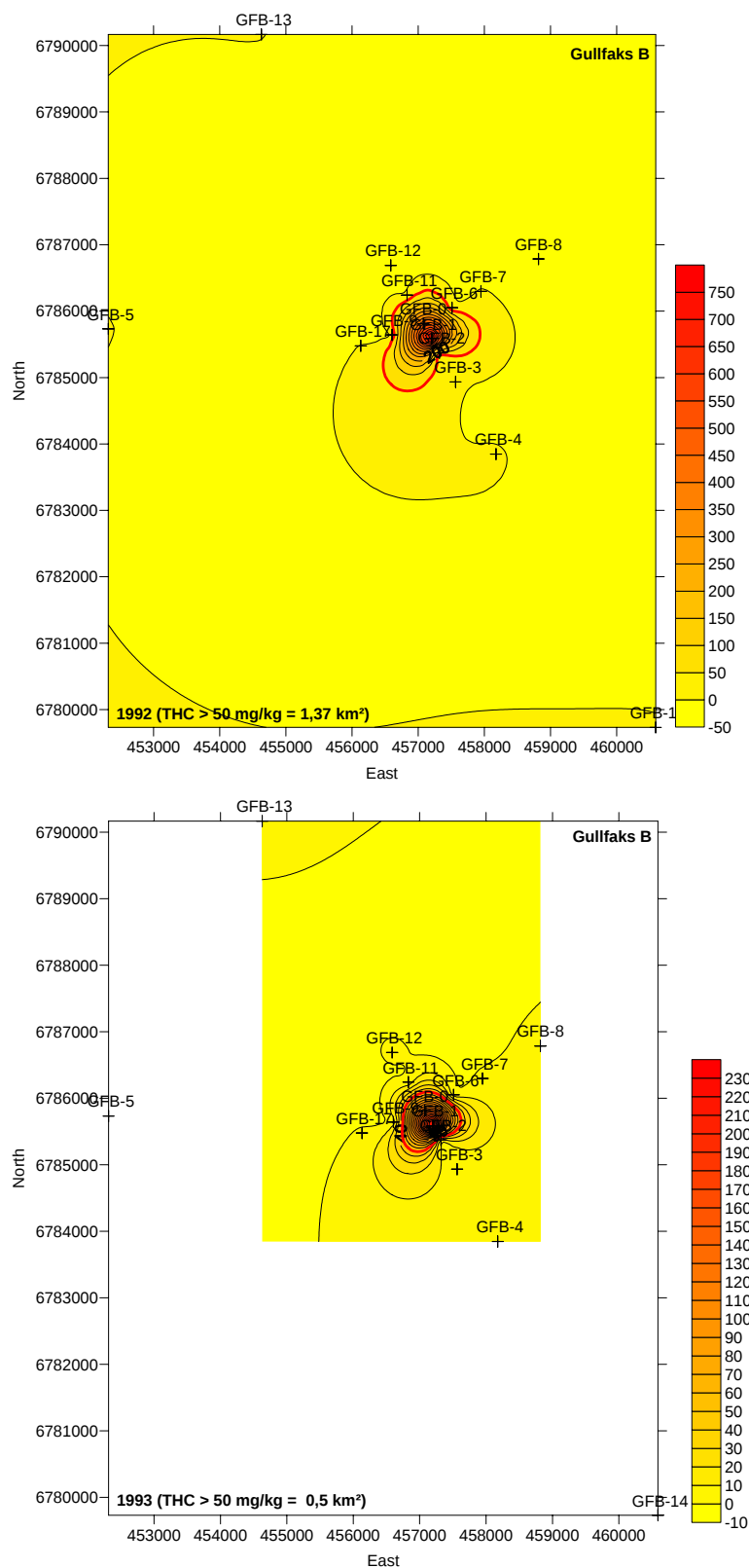
Appendix B.4.8. Contour plot from Gullfaks A.



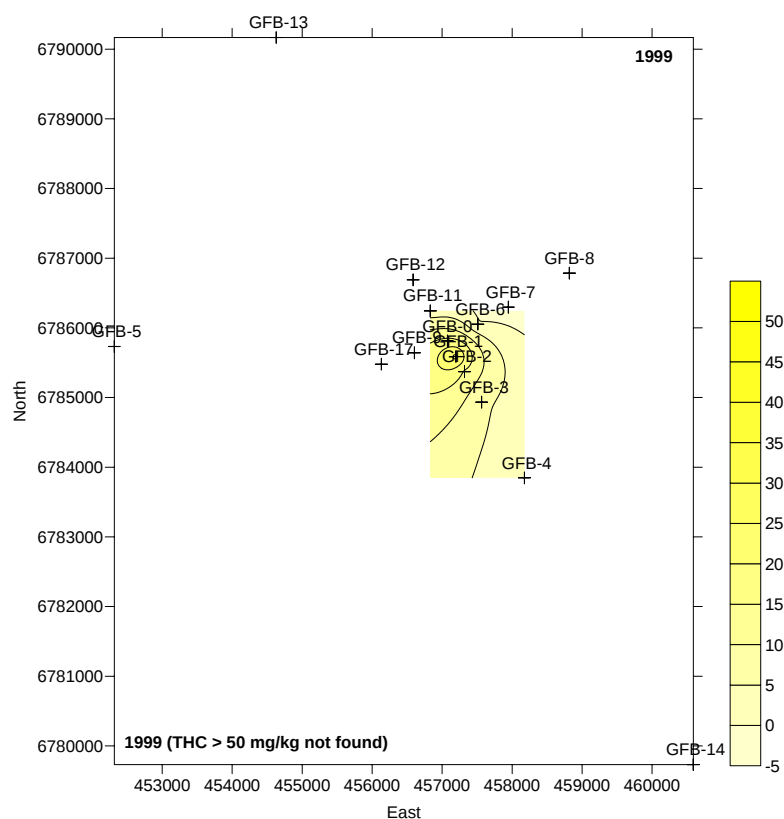
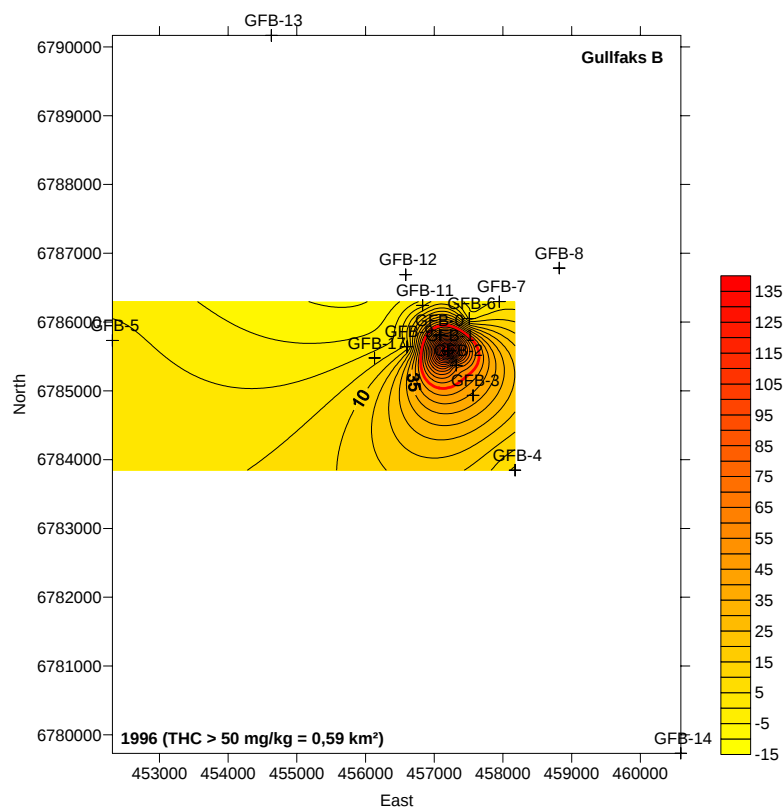
Appendix B.5.1. Contour plot from Gullfaks B.



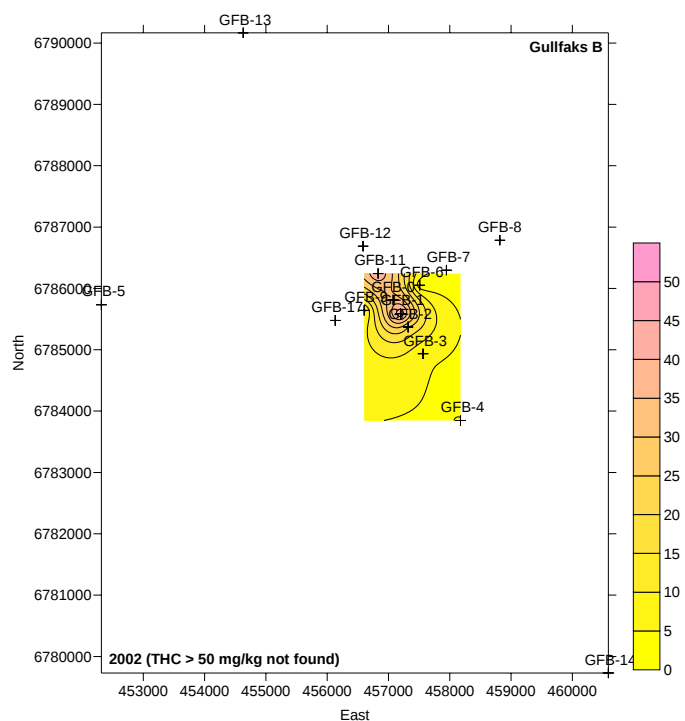
Appendix B.5.2. Contour plot from Gullfaks B.



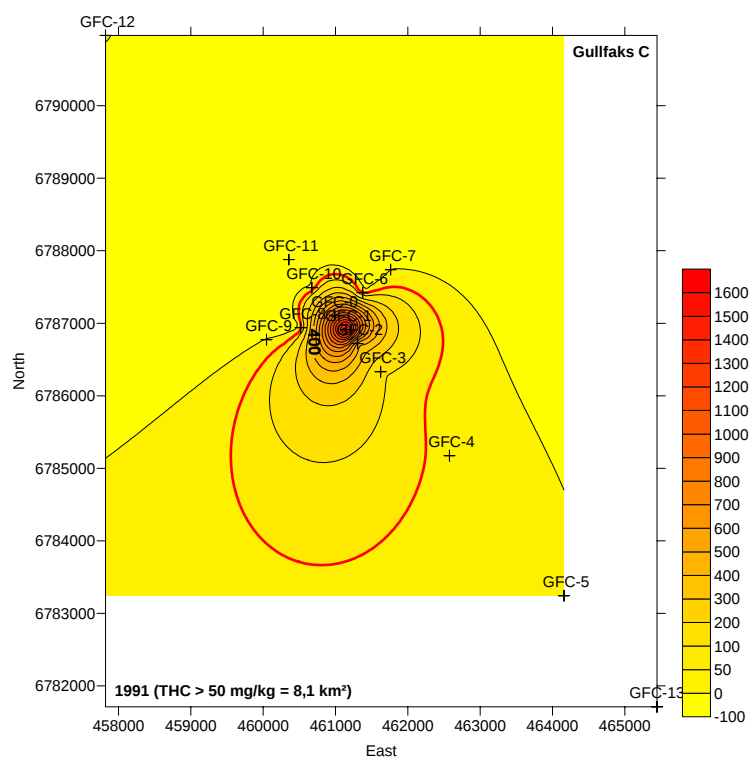
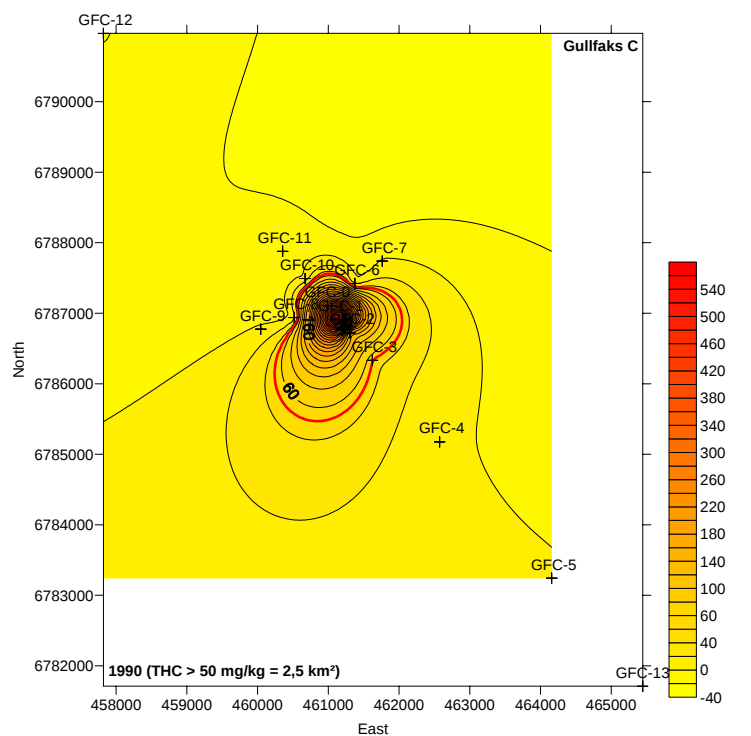
Appendix B.5. 3. Contour plot from Gullfaks B.



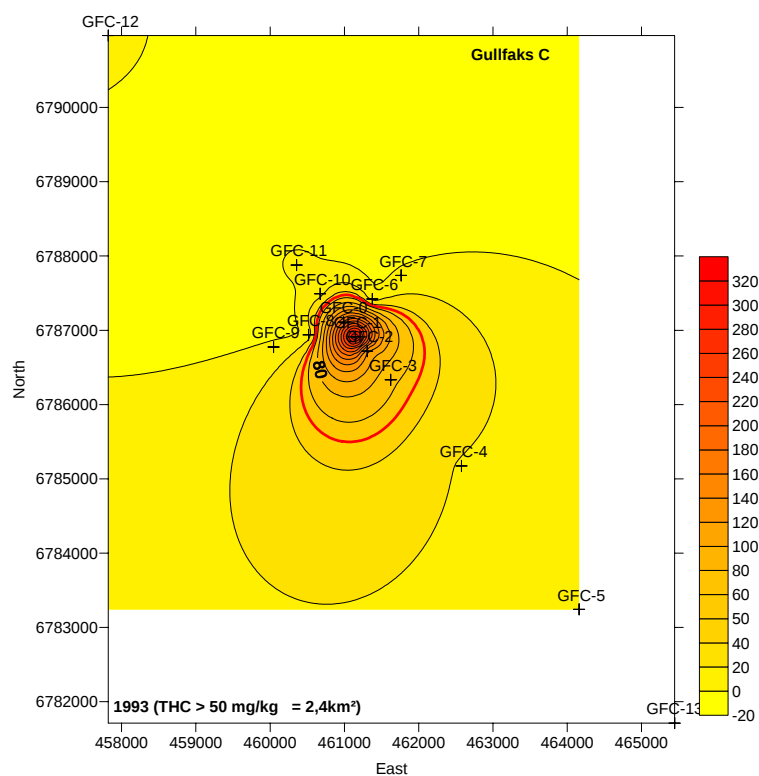
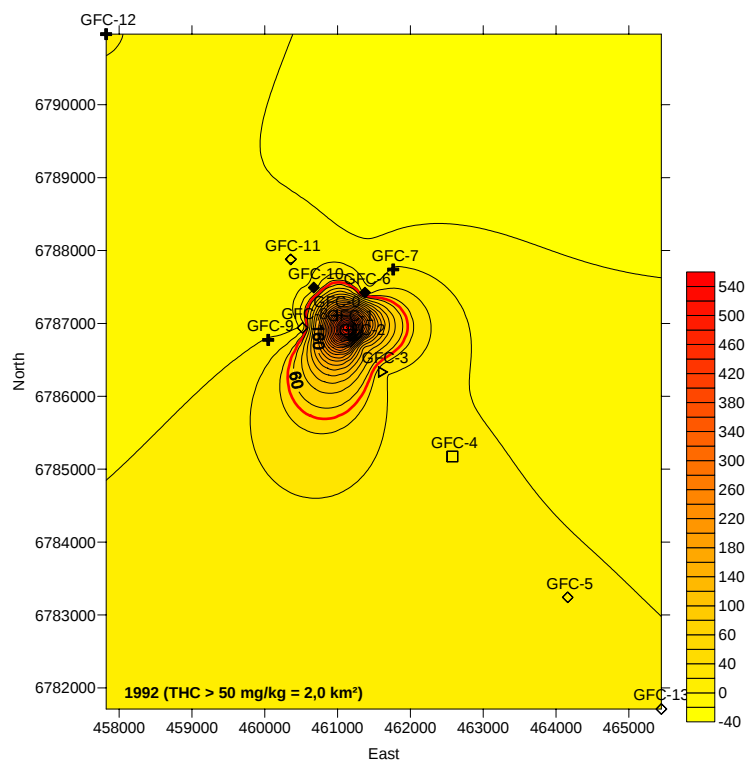
Appendix B.5. 4. Contour plot from Gullfaks B.



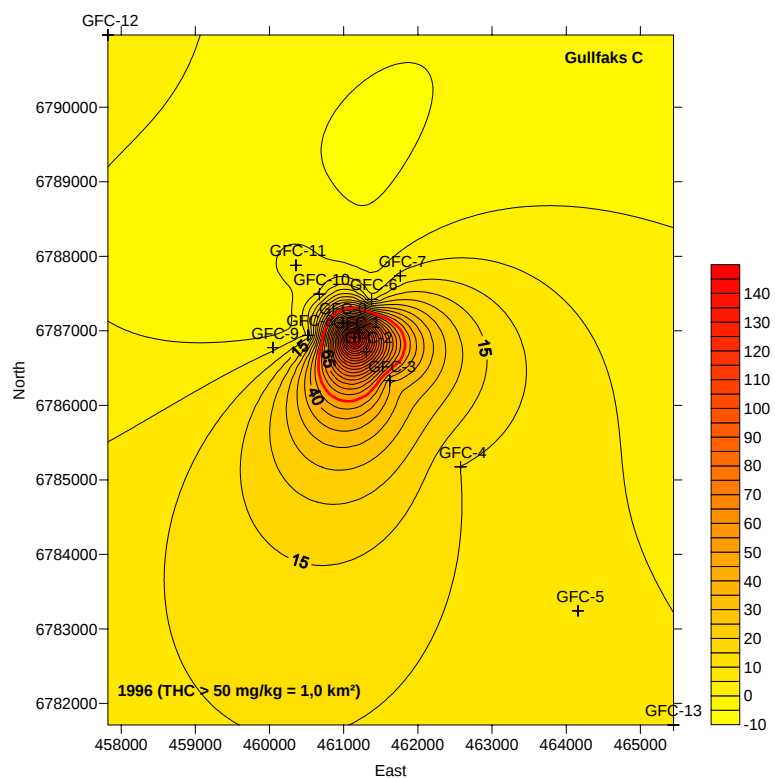
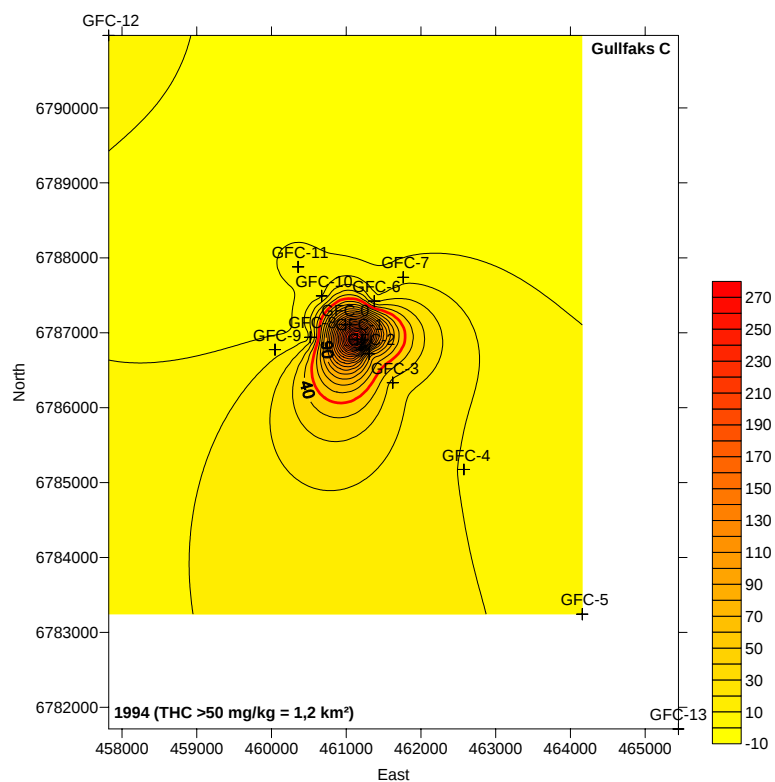
Appendix B.6. 1. Contour plot from Gullfaks C.



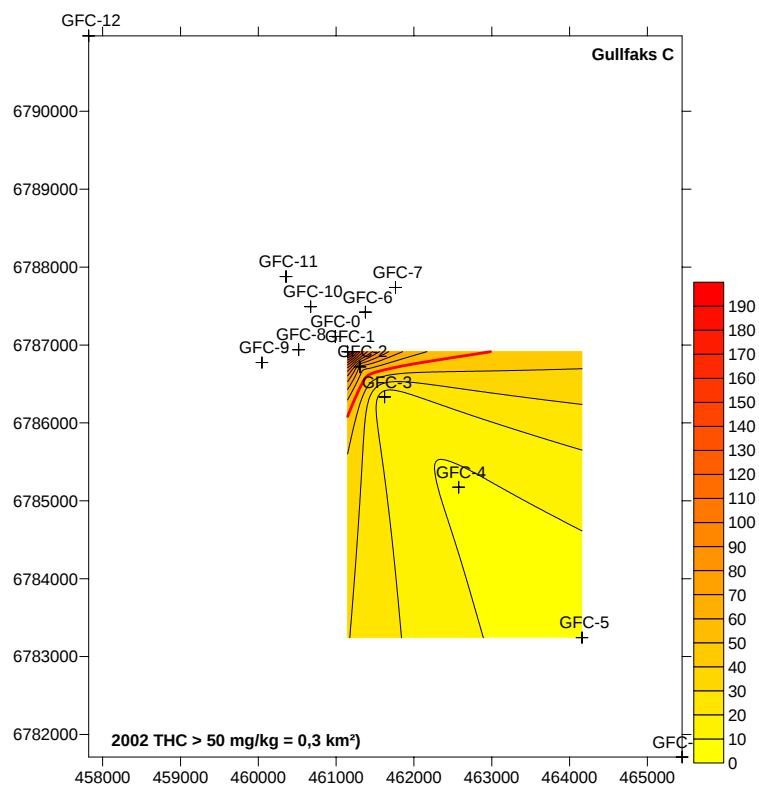
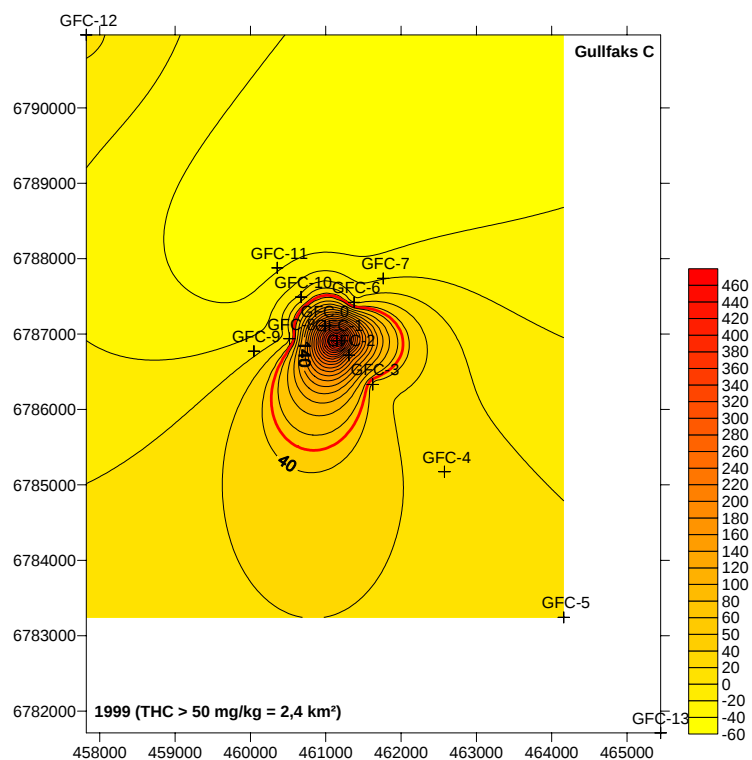
Appendix B.6. 2. Contour plot from Gullfaks C.



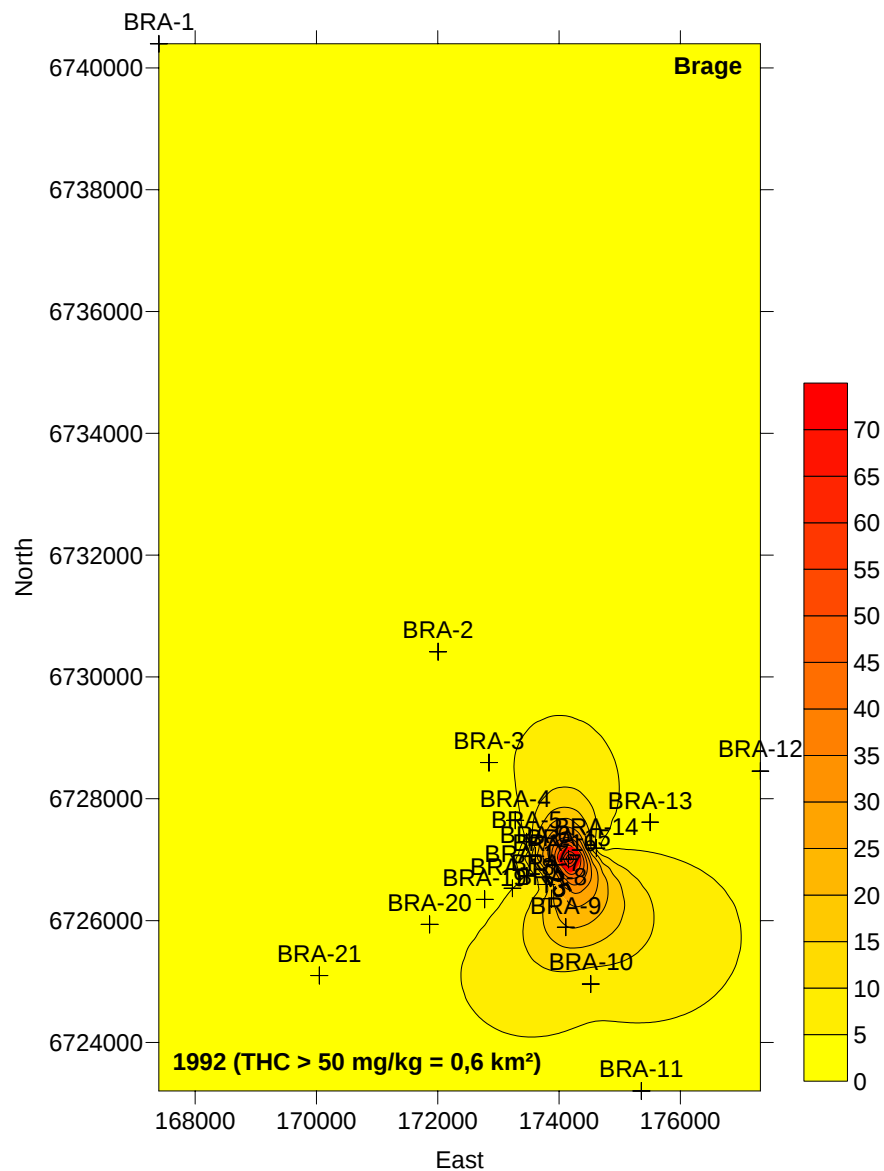
Appendix B.6. 3. Contour plot from Gullfaks C.



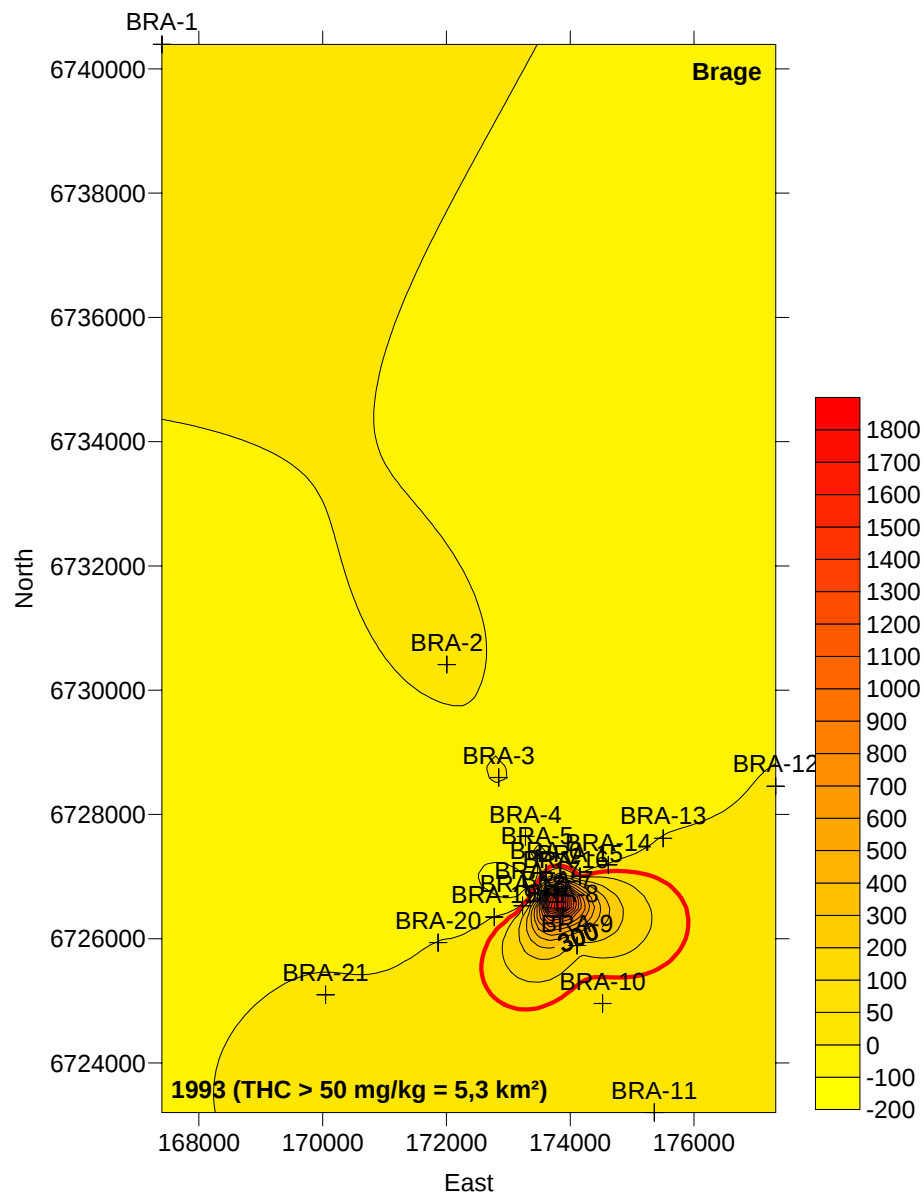
Appendix B.6. 4. Contour plot from Gullfaks C.



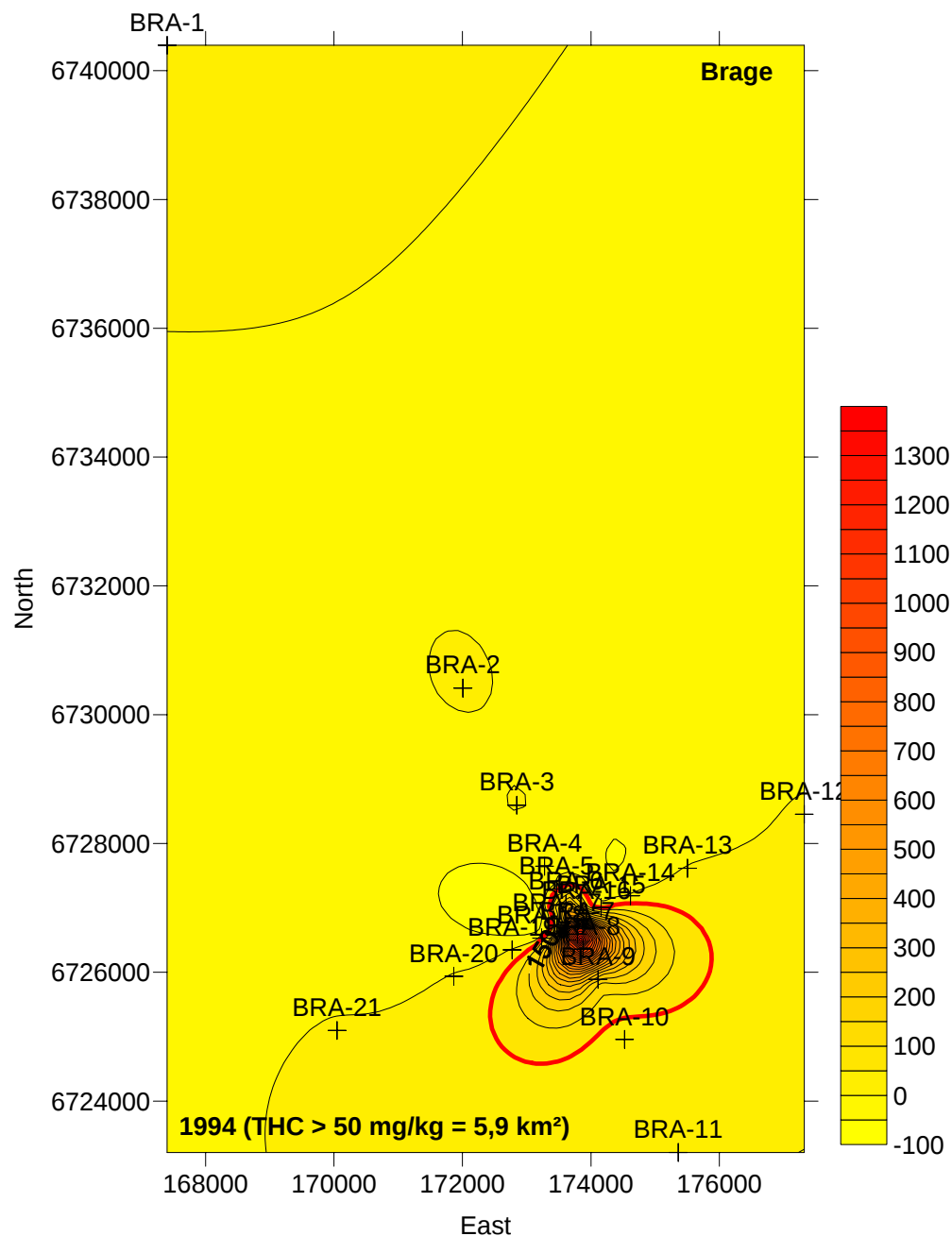
Appendix B.7. 1. Contour plot from Brage.



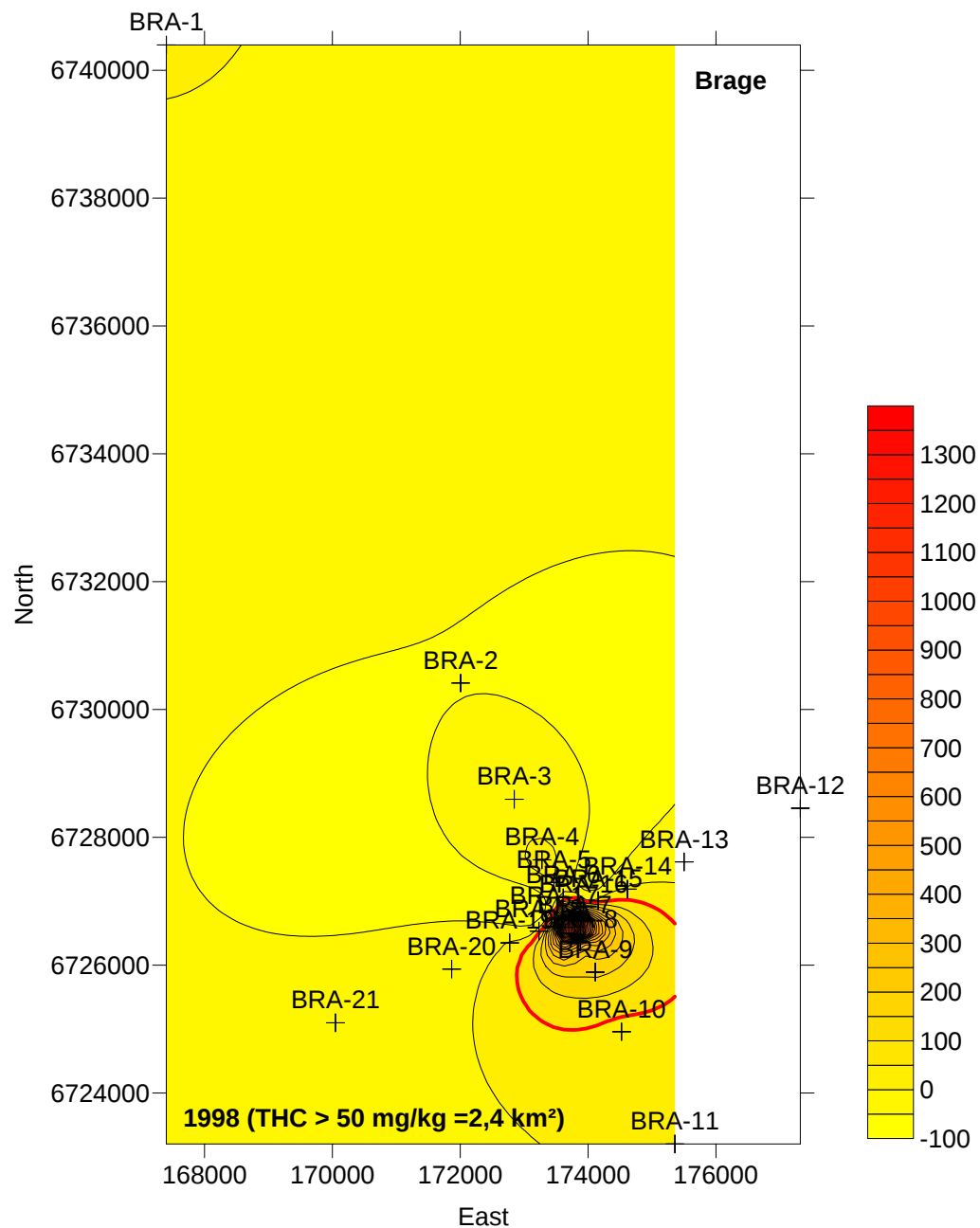
Appendix B.7. 2. Contour plot from Brage.



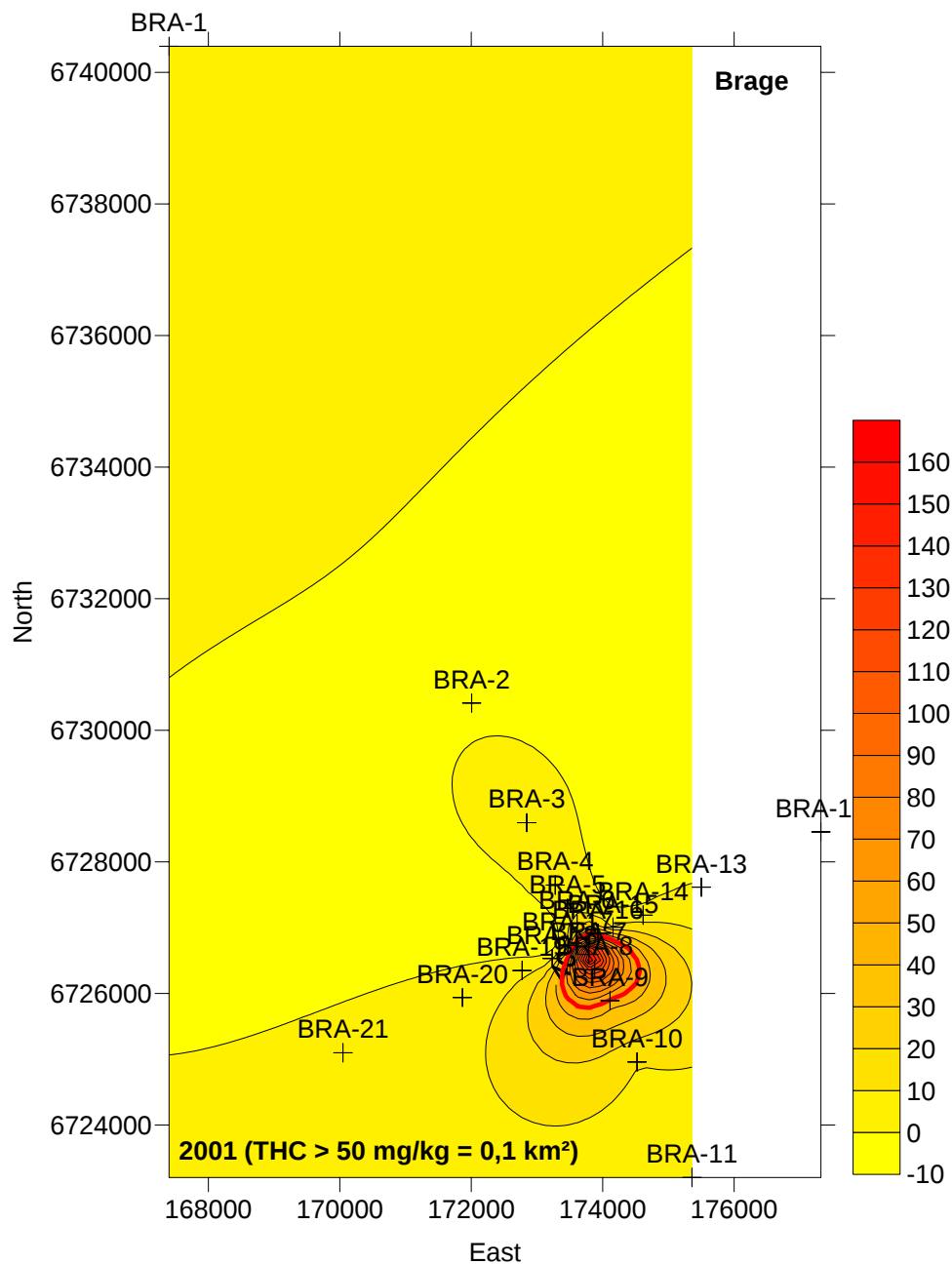
Appendix B.7. 1. Contour plot from Brage.



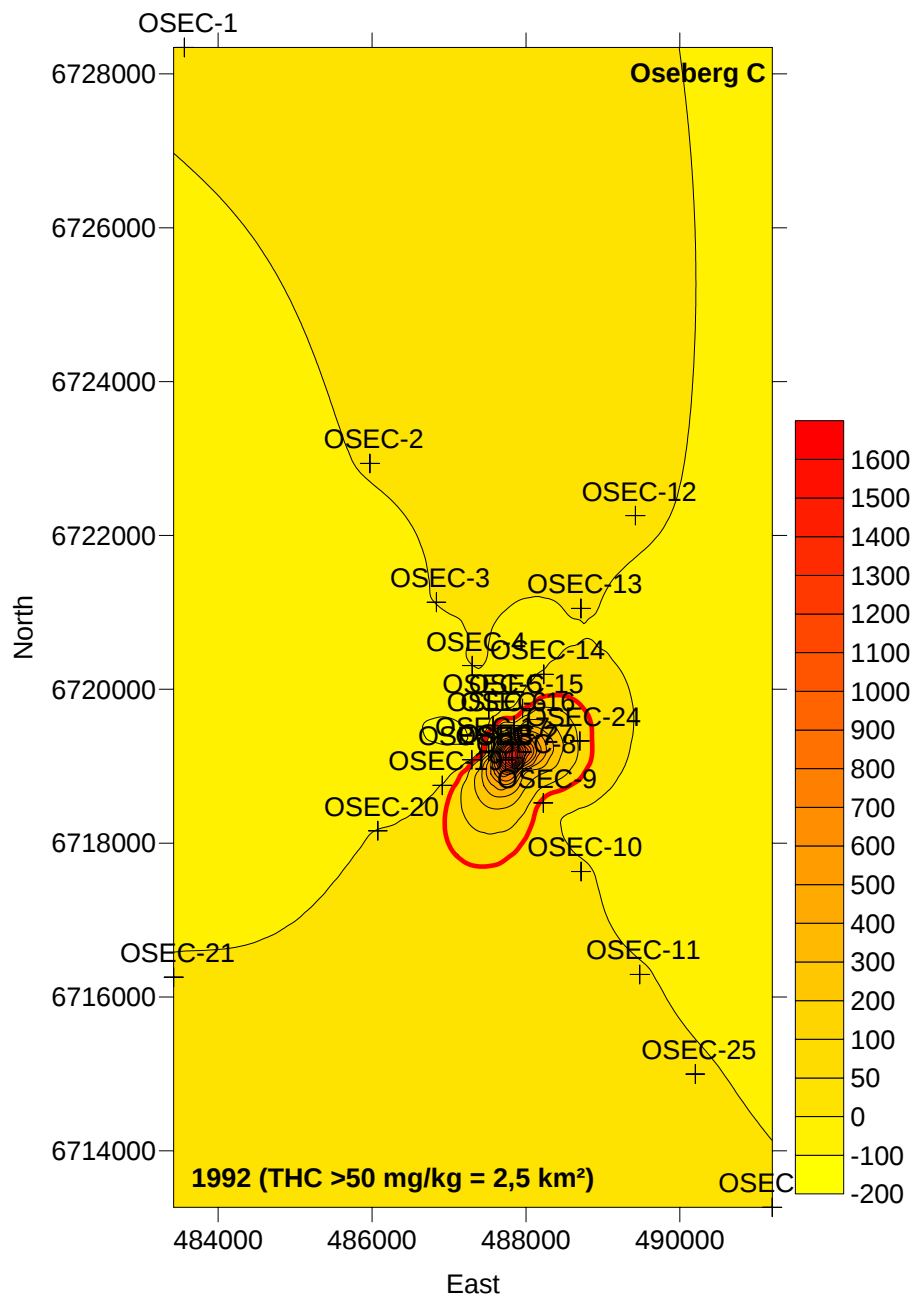
Appendix B.7. 1. Contour plot from Brage.

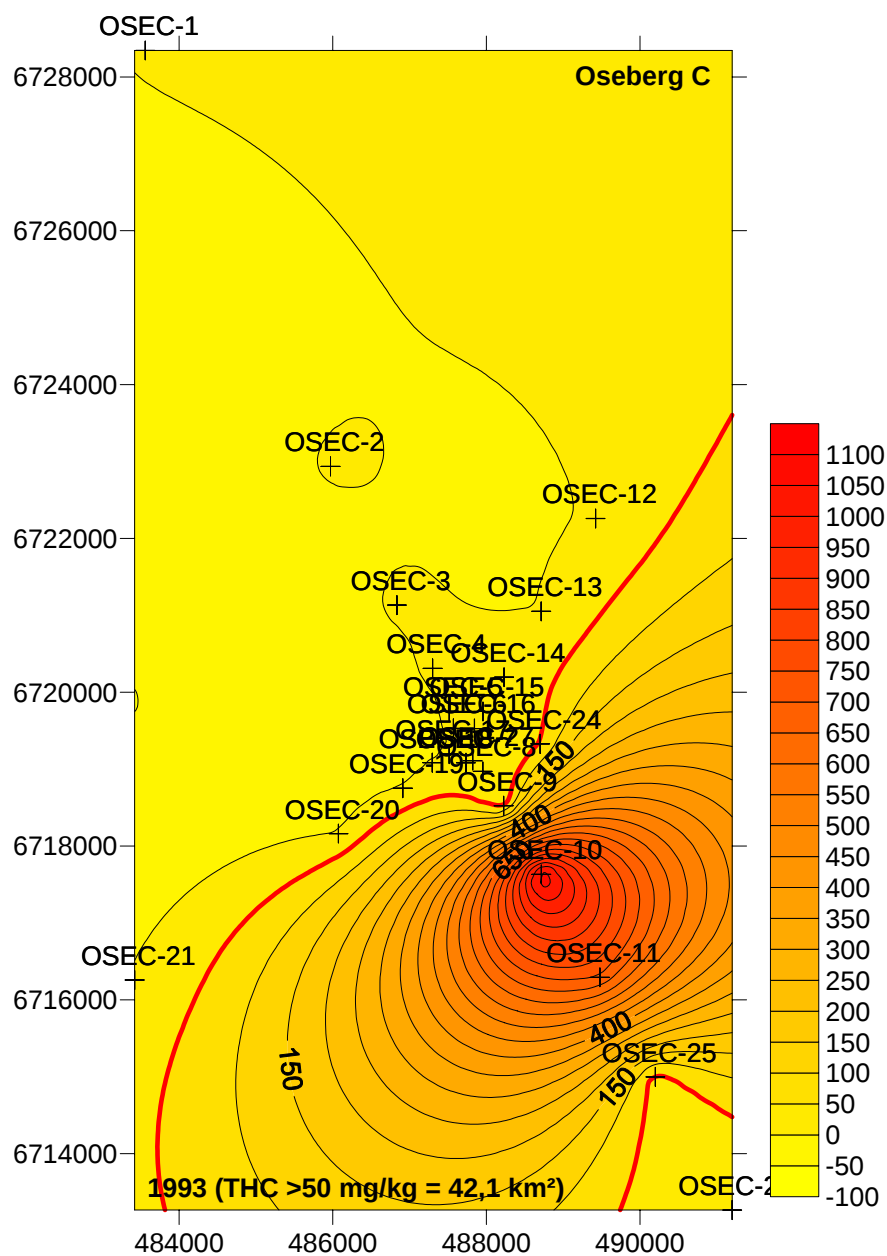


Appendix B.7. 1. Contour plot from Brage.

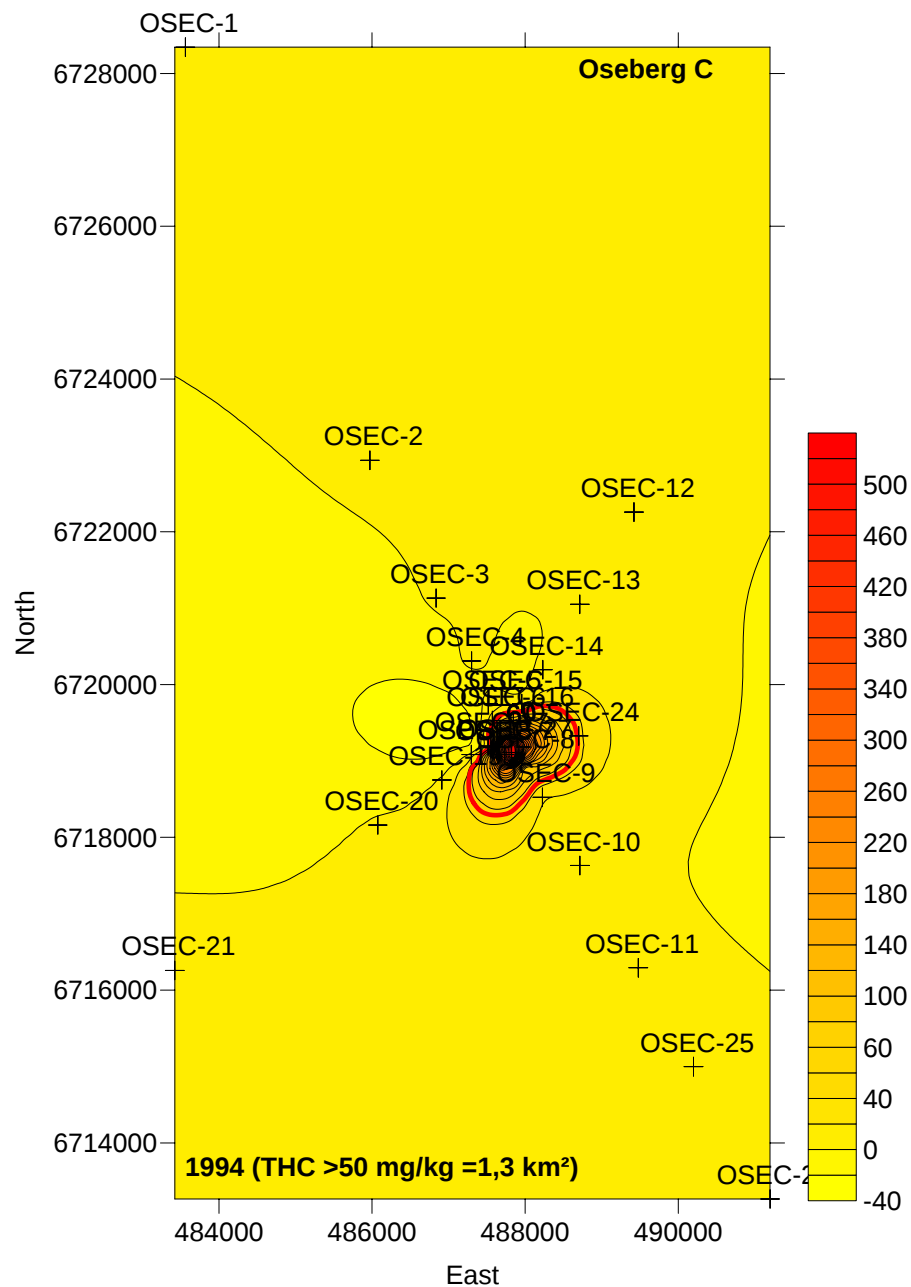


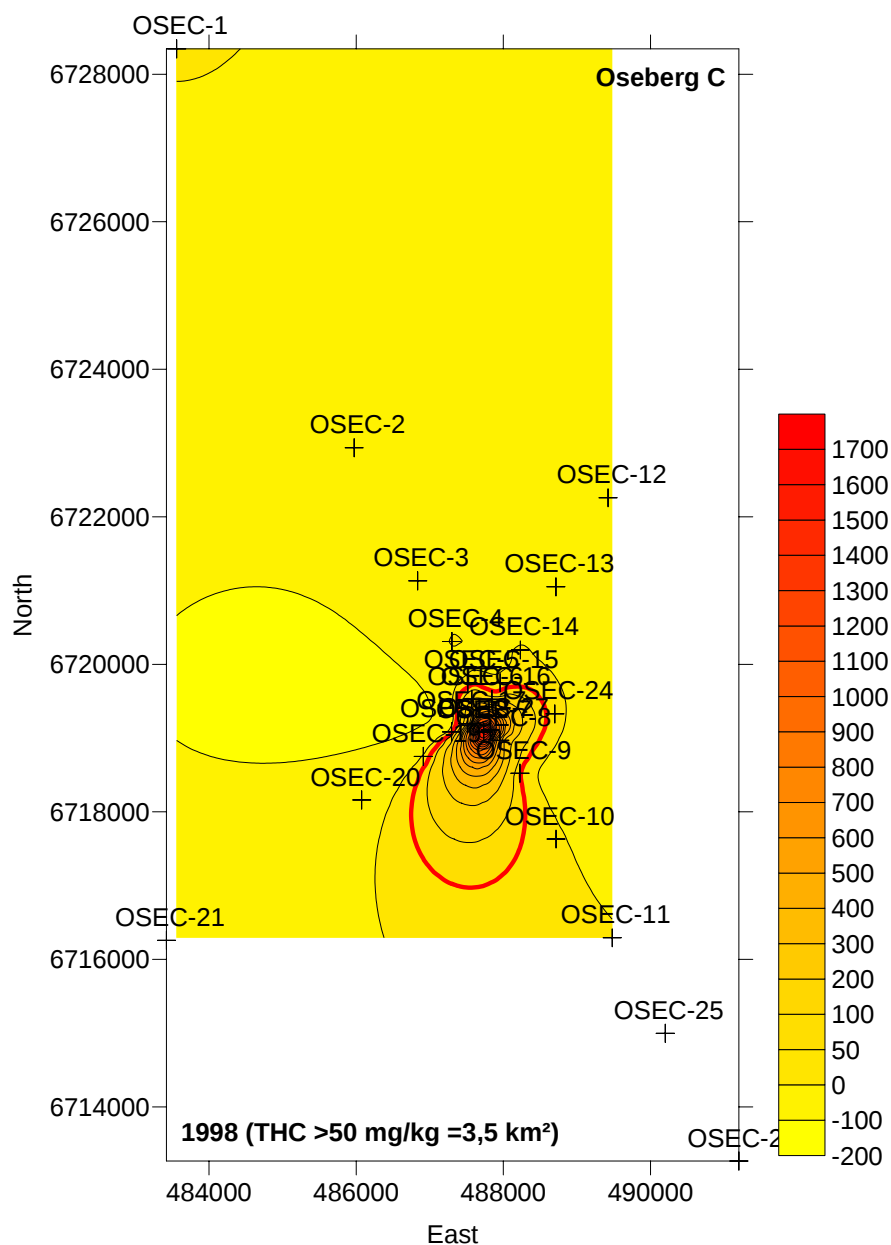
Appendix B.7. 1. Contour plot from Brage.



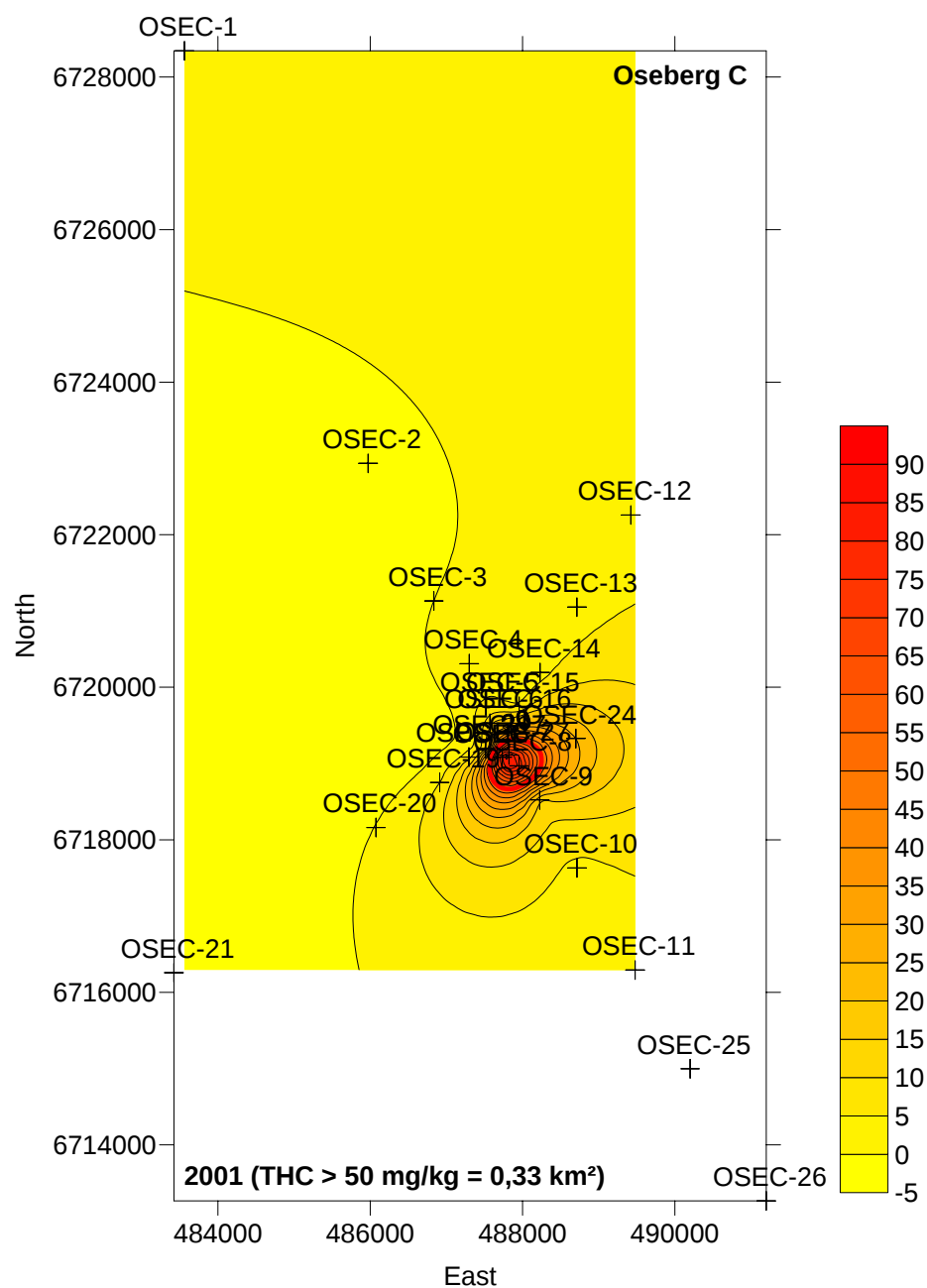
Appendix B.7. 1. Contour plot from Brage.

Appendix B.7. 1. Contour plot from Brage.

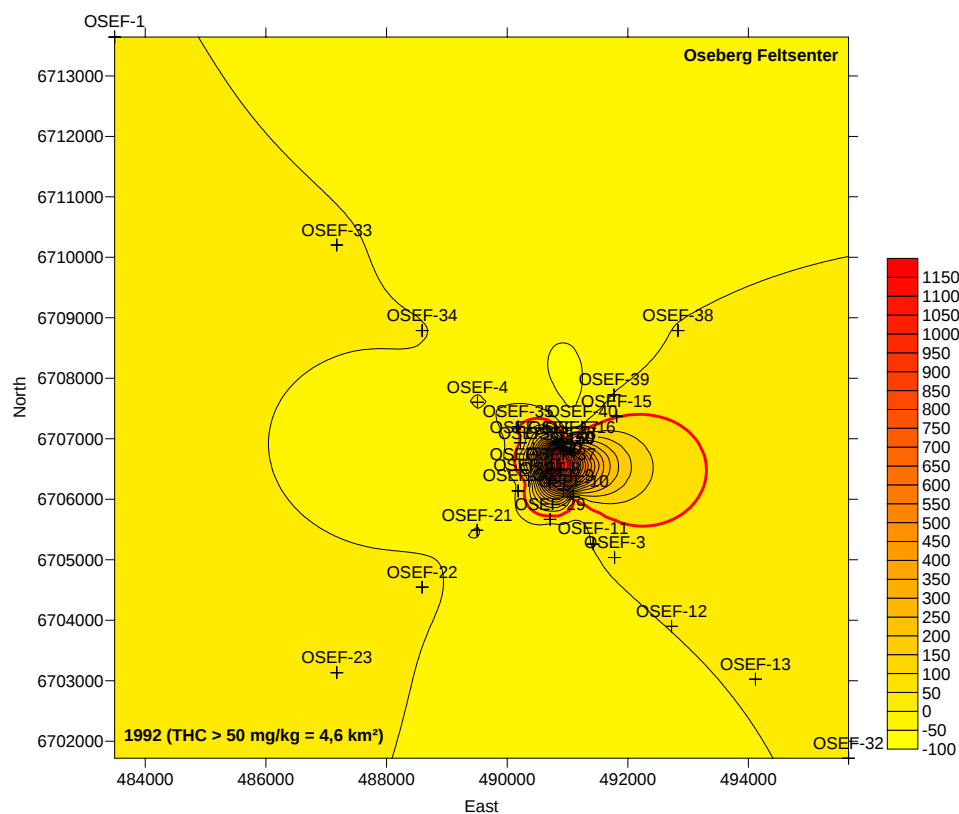
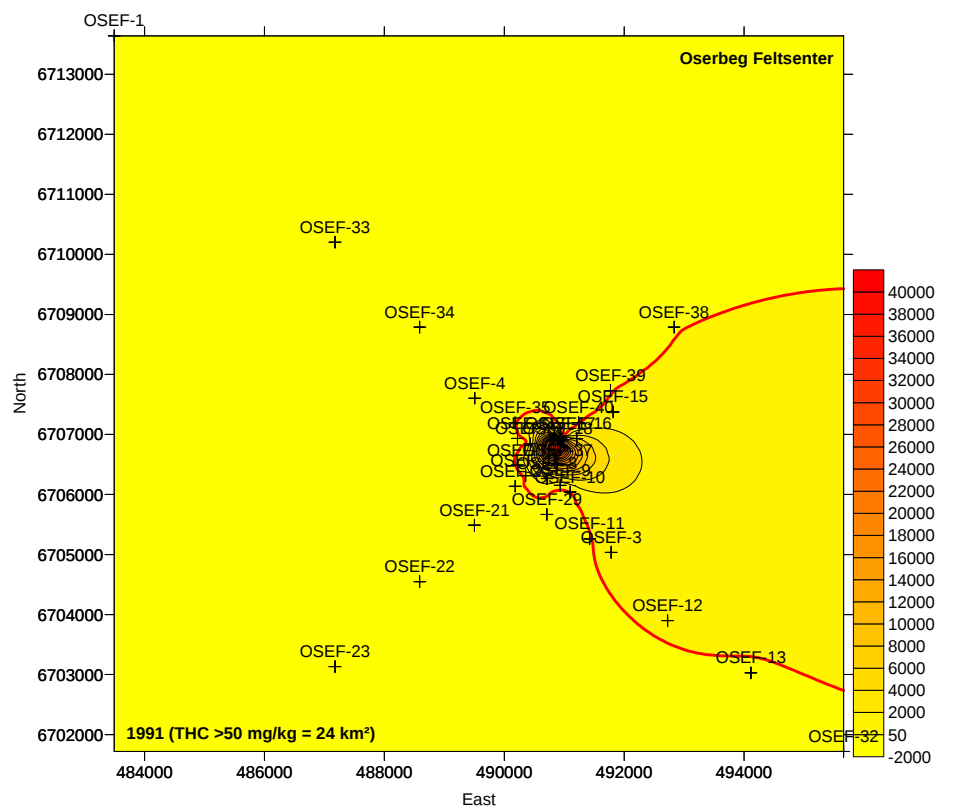


Appendix B.7. 1. Contour plot from Brage.

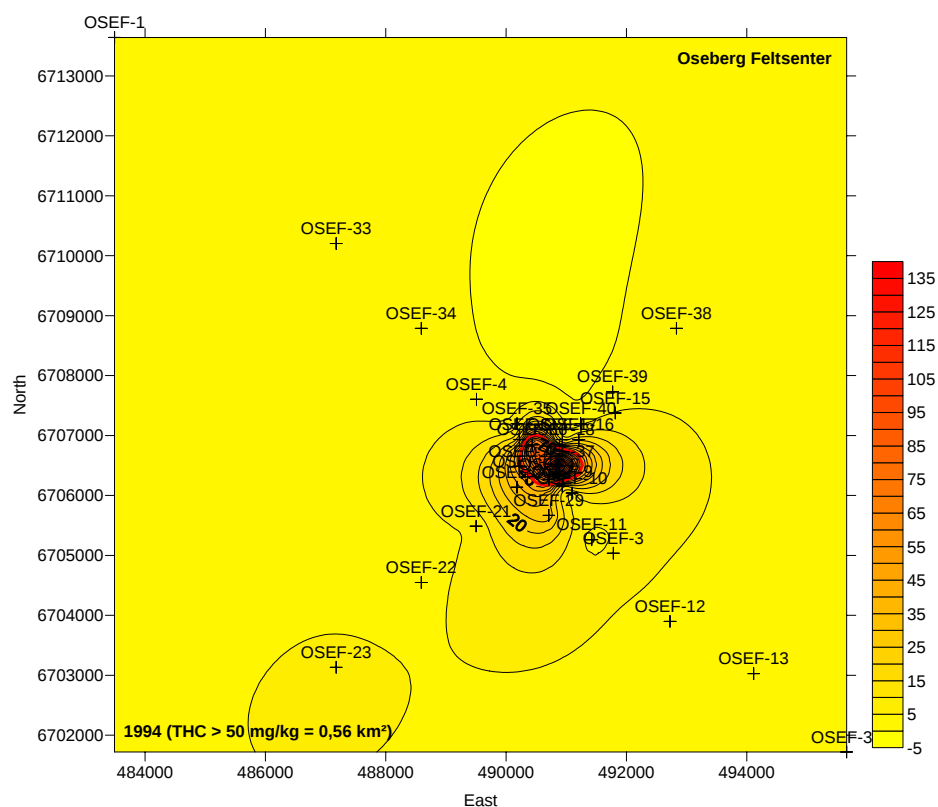
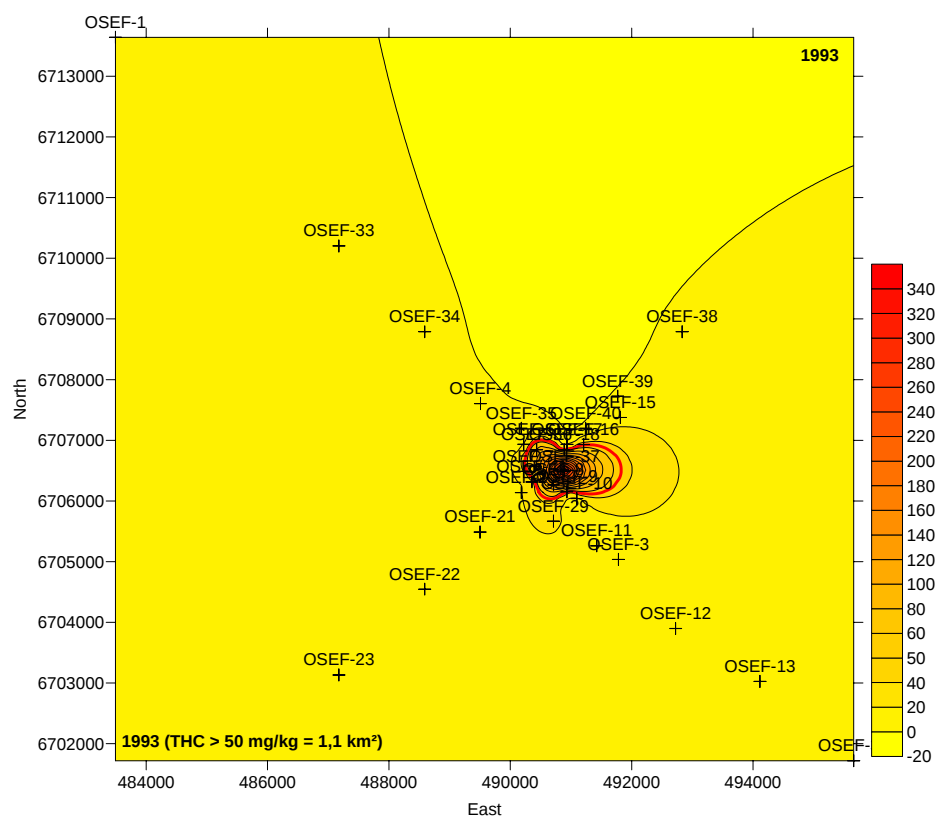
Appendix B.7. 1. Contour plot from Brage.



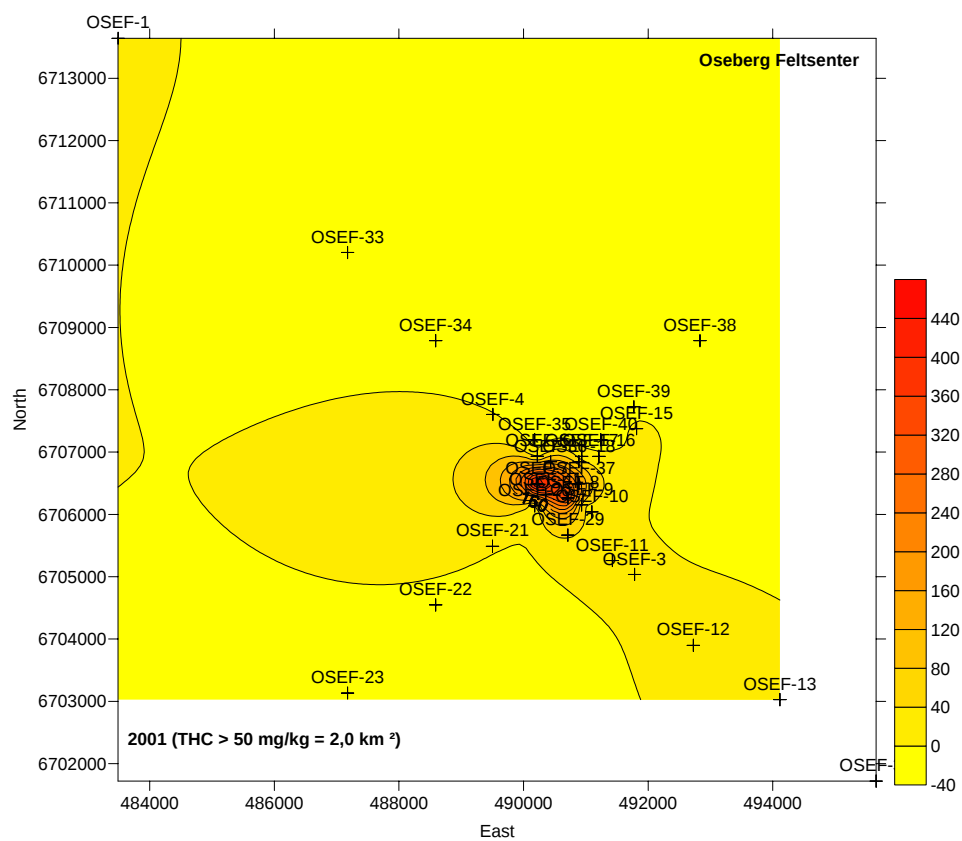
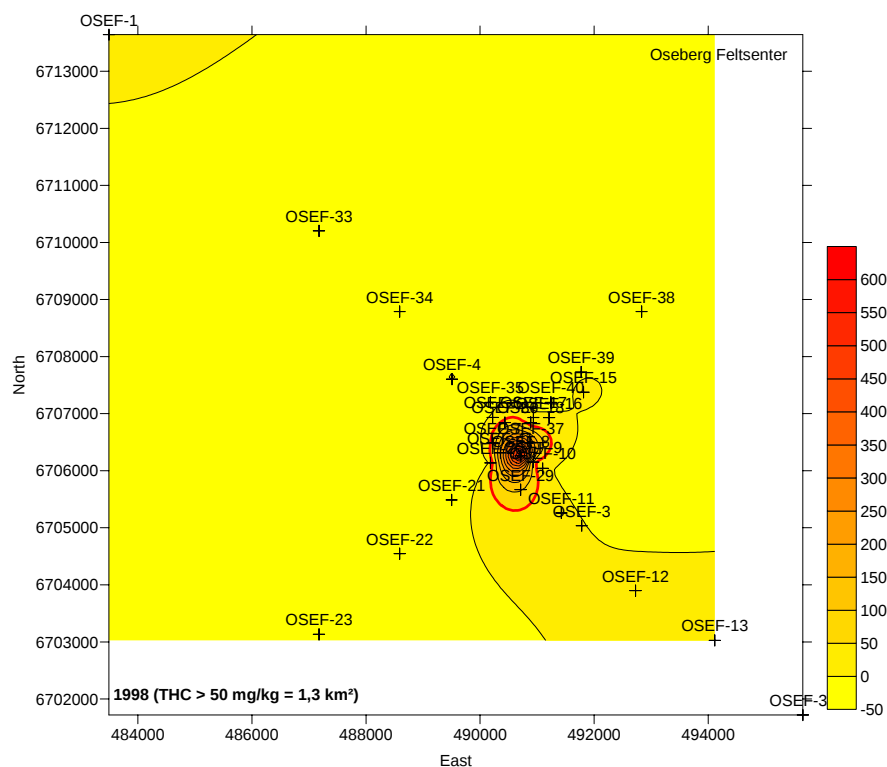
Appendix B.8. 1. Contour plot from Oseberg Feltcenter



Appendix B.8. 2. Contour plot from Oseberg Feltsenter



Appendix B.8.3. Contour plot from Oseberg Feltcenter



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