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EMISSION OF POLLUTION THROUGH SHAFTS FROM FLØYFJELLSTUNNELEN, BERGEN

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EMISSION OF POLLUTION THROUGH SHAFTS FROM FLØYFJELLSTUNNELEN, BERGEN

1 INTRODUCTION

Hordaland road authorities have asked for an evaluation of the shaft emissions from Fløyfjellstunnelen in Bergen including a recommendation for emission conditions at different sites. The amount of ventilation air and the pollution concentrations to be considered have been specified in ref. 1.

2 METHODS OF EVALUATION

The report refer to wind measurements carried out near different sites in Bergen. Further reference is made to results of one tracer experiment recording the dispersion of SF_6 tracer gas around an existing shaft from "Løvstakktunnelen" in Bergen (2).

Different methods for dispersion calculations have been considered including

a) dispersion from a ground-level source
b) dispersion effect caused by the wake behind the shaft house
c) dispersion from an elevated source.

The results indicate the importance of high emission velocity in order to get an elevated plume.

In the following evaluation formulaes presented in (3) were found most applicable. These formulaes discribe our tracer experiment reasonably well. The methods separate between the stack aerodynamic effect and the momentum phase of dispersion being important for the problem to be considered.

3 EAST TUBE EMISSION

Two alternative emission sites are shown in Figure 3.1, marked alt. 1 and alt. 2. The site for the wind station is marked in the figure. The wind statistics of one year of hourly measurements are given in Appendix 1. The terrain profile of each site is given in Figure 3.2a and b.

3.1 Alternative 1

Due to distance and height of release above the building areas, the influence of pollution in this area will be negligible. This location is preferable to alternative 2.

3.2 Alternative 2

The horizontal distance from the shaft to the living areas is about 75 m and the height difference 30 m. A critical wind sector is marked on the figure. The windfrequencies for each season given in Appendix 1 show that at Sandviken the wind is blowing in the critical sector about 7-10% of the time during daytime (07-19) when emission occur. In summer a very small frequency of wind observation was recorded in the critical sector. On the other hand calm conditions are recorded 10-20% of the time when emission occur. When the wind is blowing in the critical sector, the wind speed is smaller than 2 m/s and the air mixing is poor.

4 WEST TUBE EMISSION

The emission site is shown in Figure 4.1, further the site of the wind station, and the critical wind sector for the shaft emission are marked on the map. The terrain profile is shown in Figure 4.2.

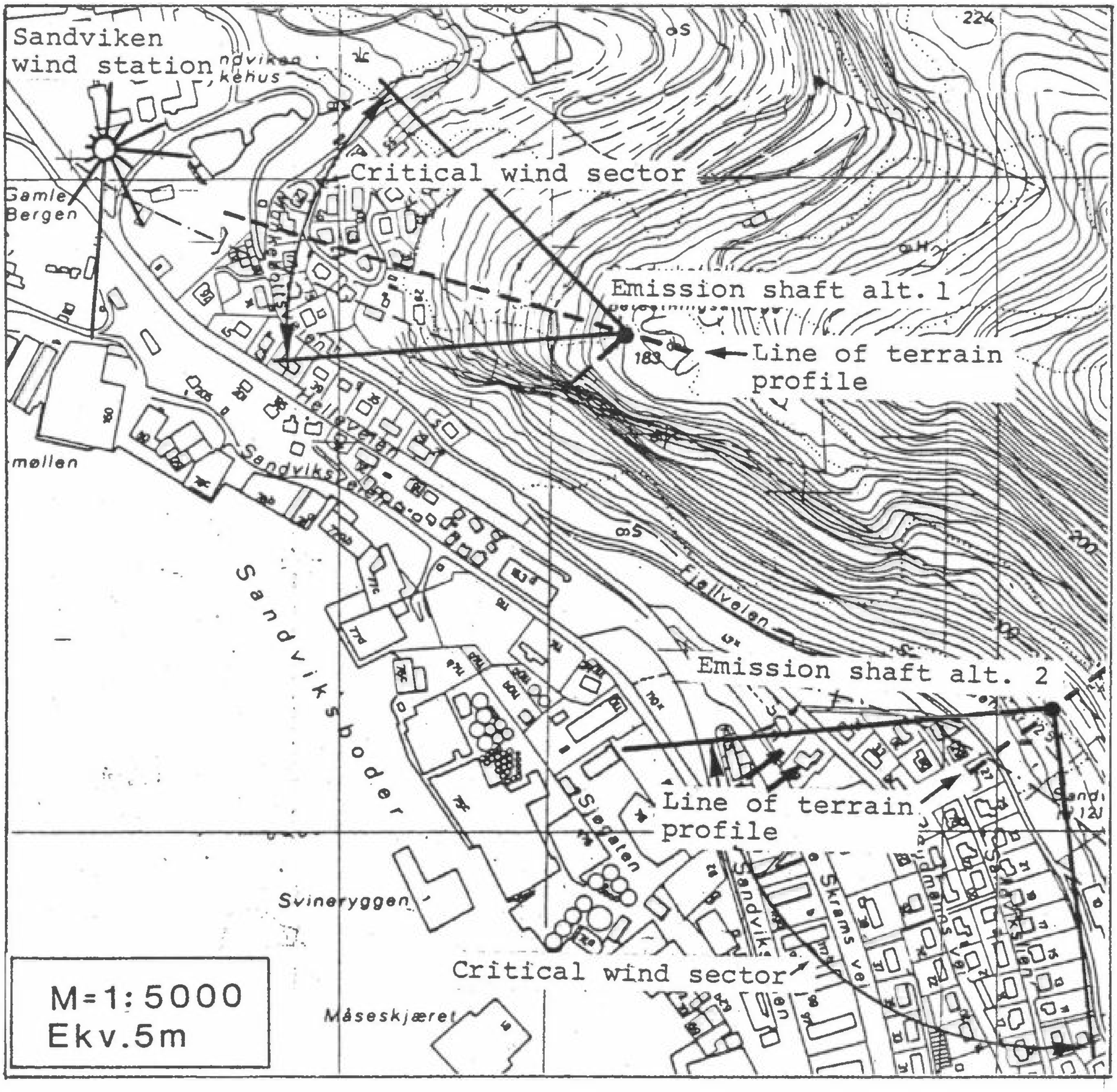

Figure 3.1: Alternative sites for the east tube emission.

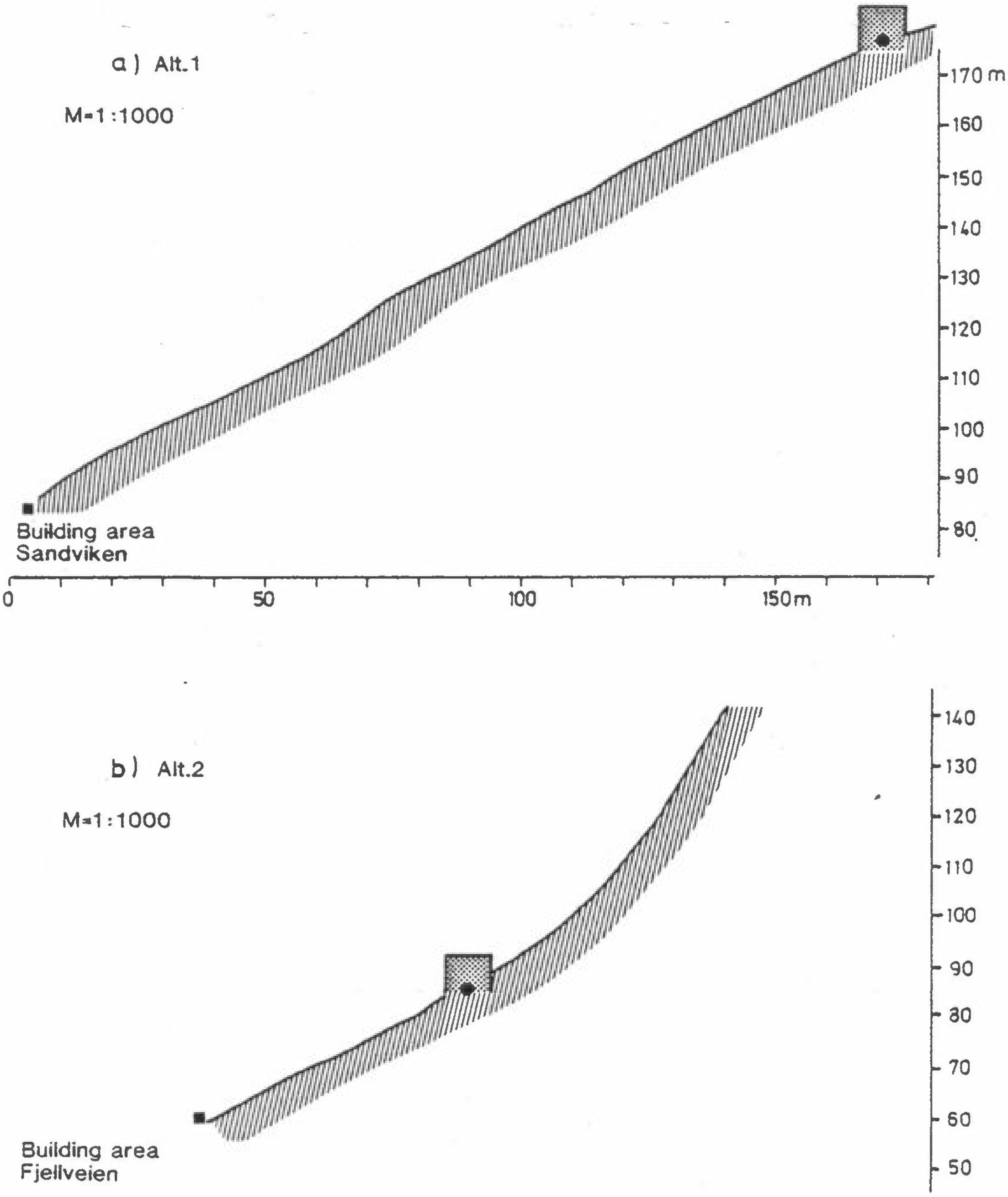

Figure 3.2: Terrain profiles with alternative shaft location for alternative 1.

Figure 4.2 show that the height difference between the ventilation shaft and Skansemyren building areas is close to 100 m and the effect of the emission will here be negligible.

The height difference between the ventilation shaft and Fløyen is about 30 m. The wind rose from Skansemyren show that (see Appendix 1) the wind is blowing in the critical sector more than 20% of the time in the afternoon. The distance between the emission shaft and Fløyen is about 75 m.

4.1 Dispersion calculations

Following the procedure of Briggs (3) the mean dilution factor over a 30 deg sector may be written

$$\frac{C}{C_T} = \frac{1.9\ F}{u\ x(h+R_z)} \tag{4.1}$$

x: distance from source
C: concentration at distance X
C_T: concentration in the ventilation air
F : flux of ventilation air (m^3/s)
u : windspeed m/s
h : effective emission height, m
R_z: vertical scale of the plume, m

$R_z = \alpha\ x \quad \alpha = 0.25$ strong atmospheric turbulence
$\qquad\qquad\quad = 0.1$ weak atmospheric turbulence

As a result of vertical momentum the effective height of emission will be

$$h = h_s + 2\left(\frac{V_s}{u} - 1.5\right)D \tag{4.2}$$

h_s: the height of the ventilation shaft (m)
V_s: emission velocity (m/s)
D : The diameter of the ventilation shaft (m)

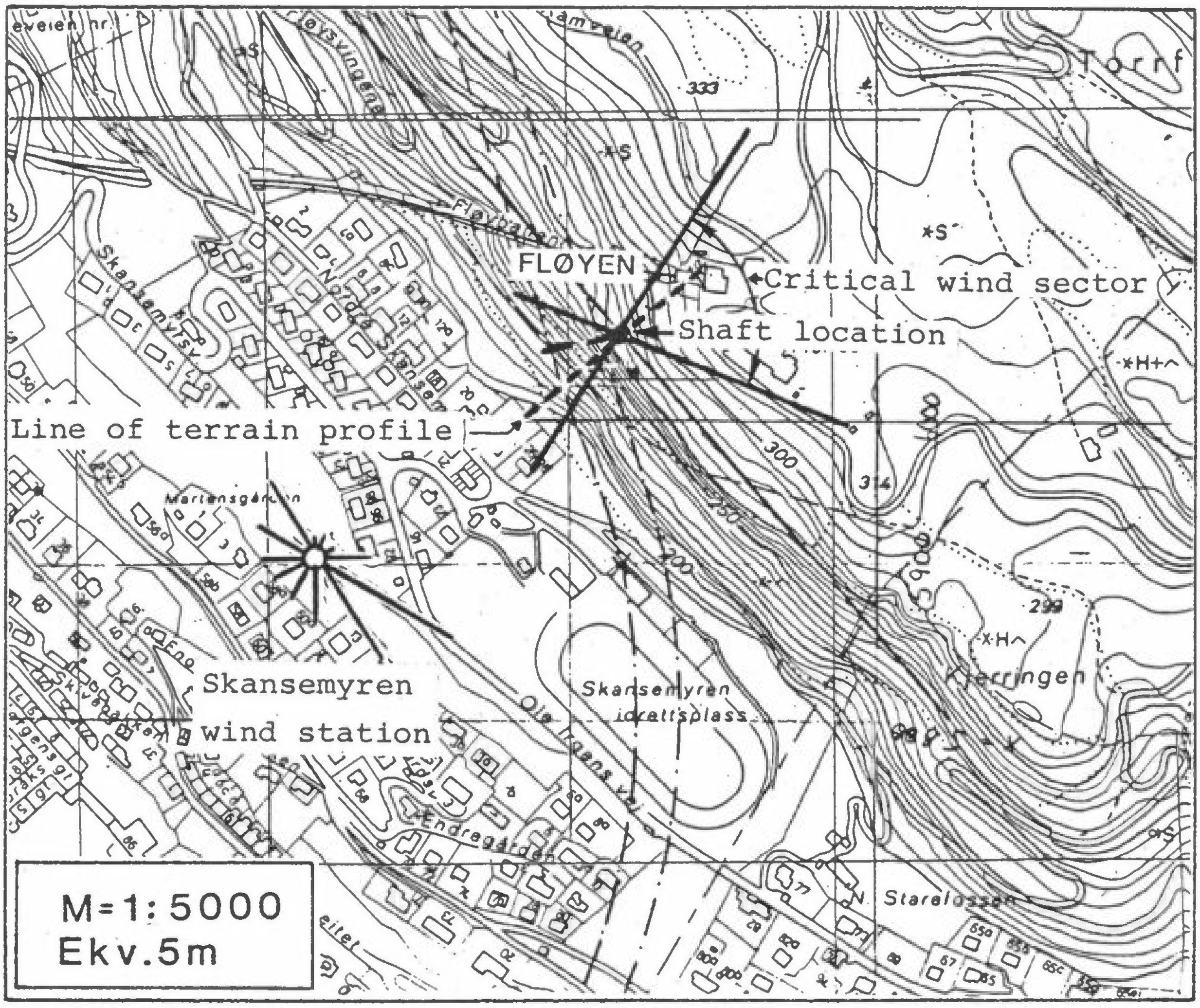

Figure 4.1: Location of the shaft for the west tube emission.

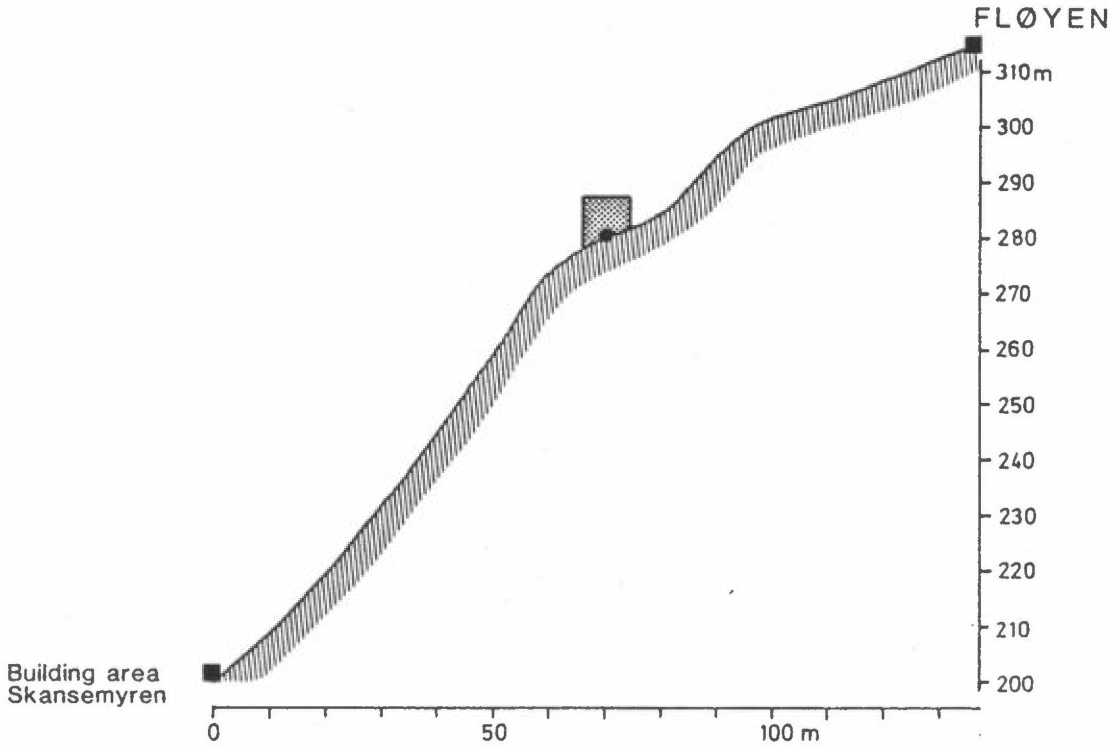

Figure 4.2: Terrain profile for shaft location near Fløyen.

4.2 Selection of emission conditions

Dispersion is improved and may be estimated by formular 4.1 when the ventilation air is lifted above the ground. For the ventilation air to avoid the wake behind the stack $\frac{V_s}{\bar{u}} > 1.5$

To take into account medium wind velocities

$$V_s \geq 10 \text{ m/s}$$

When F = 350 m^3/s we get $\underline{D \leq 6.7 \text{ m}}$

Further the dilution factor should be less than 0.1 to obtain satisfactory CO-concentrations. (The maximum CO-concentration in the tunnel will be 250 ppm).

When V_s = 10 m/s, u = 2 m/s and x = 75 m.

$$\frac{C}{C_T} = \frac{1.9 \cdot 350 \text{ m}^3/\text{s}}{2 \cdot 75 \cdot (10 + (\frac{10}{2} - 1.5) \cdot 6.7 + 75 \cdot 0.25) \text{ m}^3/\text{s}} = \underline{0.085}$$

Comparing the two additive terms in the denominator in equation 4.1 it is seen that the effective emission height is important for the dilution factor.

5 NEGATIVE BUOYANCY EFFECT ON DISPERSION NEAR HILLSIDES

In the afternoon during summer the ventilation air may be colder than the surrounding air. Measurements in the Løvstakk tunnel showed that in July the temperature difference may be 6°C or more about 30% of the days (see Appendix 1). The difference in density will influence dispersion when the windspeed u is small. Empirical data support the following expression given in reference 3 for this to occur

$$u < 0.22 \cdot \beta \cdot \sqrt{g \Delta D}$$

g = 10 m/s^2

Δ = $\frac{\Delta T}{T}$ the relative difference in density between the ventilation air and the atmosphere.

T = Temperature in (^oC)

D = Stack Diameter

β = Empirical factor.
For the emission sites in Bergen β = 5 during day time.

The dispersion is expected to be smaller than previously calculated when the windspeed u is smaller than

$$u < 0.22 \cdot 5 \cdot \sqrt{\frac{10 \cdot 6}{273} \cdot 6.7} \text{ m/s} \simeq 1 \text{ m/s}.$$

However, when the exit velocity exceeds 10 m/s this is not expected to be a problem. The difference in density will be reduced during the momentum phase of dispersion.

6 CONCLUSIONS

The emission through the shaft from east tube may effect Fløyen area at 75 m distance in a few afternoon hours about 20% of the days in the summer. If the emission velocity is higher than 10 m/s (stack diameter 6.7 m) and the emission height is 5-10 m, the concentrations are expected to be acceptable (not exceeding standards for outdoor air quality). Due to the height difference and the wind distribution the impact on the building areas near Skansemyren is expected to be negligible.

Two alternatives have been given for the location of the shaft from the east tube.
Alternative 1: From an air pollution point of view this location is recommended. Due to the height difference there will be negligible pollution in the building areas. If the emission conditions previously recommended are used, the polluted air will mainly remain

elevated in weak wind situations and the concentration in the close neighbourhood will also be small.

Alternative 2:
During calm wind conditions polluted ventilation air may drift towards the building areas. These conditions are expected to occur during the morning hours a few percent of the days.

The air turbulence (mixing) will be low in these situations. However, when the emission velocity is above 10 m/s, ground level concentrations is expected to be low in the weak wind situations.

7 REFERENCES

(1) P.R. Tharaldsen: Letter from Hordaland Vegkontor dated 2.12.82. Bergen 1982.

(2) Y. Gotaas: Spredning av sporstoff fra vegtunneler i Bergen. Lillestrøm 1981. (NILU OR 37/81.)

(3) G.A. Briggs: Diffusion estimation for small emissions. Oak Ridge, Tennessee 1973 (ATOL Contribution file no. 79).

APPENDIX I

Meteorological measurements

Wind data from Skansemyren, Table A1-A3.
Wind data from Sandviken, Table A4-A8.

The tables show frequences of wind observations in different wind sectors in percent. The frequency distributions are given for each 3 hour.
For each wind sector the frequency of observations in different wind speed classes is given.

Figure A1 shows monthly frequencies of observed temperature differencies between ventilation air from the Løvstakk tunnel and the ambient air at Gyllenpris.

Table A1: Skansemyren

VINDROSE FRA SKANSEMYREN
29/ 1-81 – 28/ 2-81 FRA TAPE 1

VINDROSE KL.

SEKTOR	1	4	7	10	13	16	19	22	DØGN
20– 40	0.0	3.2	3.2	0.0	0.0	0.0	6.5	0.0	1.5
50– 70	0.0	3.2	3.2	0.0	0.0	0.0	3.2	3.2	1.3
80–100	6.5	9.7	12.9	3.2	3.2	6.5	16.1	6.5	6.3
110–130	29.0	19.4	19.4	29.0	3.2	9.7	12.9	32.3	20.6
140–160	22.6	22.6	22.6	25.8	22.6	22.6	32.3	29.0	27.0
170–190	0.0	6.5	3.2	3.2	19.4	16.1	6.5	0.0	6.3
200–220	6.5	3.2	0.0	3.2	6.5	16.1	0.0	3.2	3.6
230–250	3.2	3.2	0.0	0.0	19.4	3.2	0.0	3.2	4.4
260–280	3.2	3.2	6.5	3.2	12.9	16.1	3.2	6.5	5.6
290–310	3.2	6.5	6.5	3.2	6.5	3.2	6.5	3.2	6.5
320–340	6.5	9.7	12.9	25.8	6.5	6.5	9.7	6.5	9.8
350– 10	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.0	.7
STILLE	19.4	9.7	6.5	3.2	0.0	0.0	3.2	6.5	6.3
ANT. OBS.	31	31	31	31	31	31	31	31	744
MIDL. VIND	3.5	3.3	3.4	3.4	3.8	3.9	3.5	3.5	3.5

VINDANALYSE

DØGNMIDDEL	30	60	90	120	150	180	210	240	270	300	330	360	TOTAL
STILLE													6.3
.6– 2.0 M/S	1.1	.9	4.4	9.9	3.5	1.2	1.6	1.9	2.7	1.6	4.6	.5	34.0
2.1– 4.0 M/S	.4	.3	1.1	9.7	6.6	2.2	1.3	.3	1.1	.8	2.7	.1	26.5
4.1– 6.0 M/S	0.0	.1	.5	.9	7.0	1.1	.3	.5	.8	1.2	.9	0.0	13.4
OVER 6.0 M/S	0.0	0.0	.3	0.0	9.9	1.9	.4	1.7	1.1	2.8	1.6	0.0	19.8
TOTAL	1.5	1.3	6.3	20.6	27.0	6.3	3.6	4.4	5.6	6.5	9.8	.7	100.0
MIDL. VIND M/S	1.4	1.9	2.0	2.2	5.3	4.4	2.7	4.6	3.4	5.5	3.4	1.5	3.5
ANT OBS.	11	10	47	153	201	47	27	33	42	48	73	5	744

MIDLERE VINDSTYRKE FOR HELE DATASETTET ER 3.5 M/S, BASERT PÅ 744 OBSERVASJONER

Table A2: Skansemyren

VINDROSE FRA SKANSEMYREN
1/ 3-81 - 31/ 5-81 FRA TAPE 1

VINDROSE KL.

SEKTOR	1	4	7	10	13	16	19	22	DØGN
20- 40	3.3	2.2	1.1	0.0	0.0	0.0	2.2	10.1	3.1
50- 70	2.2	1.1	2.2	0.0	0.0	0.0	2.2	2.2	1.6
80-100	2.2	4.5	4.5	0.0	0.0	3.3	1.1	3.4	2.4
110-130	13.2	16.9	11.2	6.7	1.1	3.3	10.9	13.0	10.4
140-160	18.7	24.7	28.1	21.1	17.4	17.8	16.3	22.5	20.1
170-190	8.8	14.6	12.4	16.7	20.7	16.7	13.0	6.7	13.0
200-220	3.3	0.0	0.0	11.1	7.6	4.4	3.3	1.1	4.7
230-250	1.1	0.0	0.0	1.1	3.3	3.3	1.1	0.0	1.3
260-280	1.1	2.2	3.4	7.8	7.6	3.3	0.0	0.0	2.4
290-310	1.1	1.1	1.1	7.8	9.8	15.6	3.3	0.0	5.1
320-340	7.7	7.9	6.7	18.9	25.0	30.0	32.6	5.6	16.4
350- 10	15.4	9.0	7.9	4.4	6.5	0.0	8.7	18.0	3.6
STILLE	22.0	15.7	21.3	4.4	1.1	2.2	5.4	12.4	10.9
ANT. OBS.	91	89	89	90	92	90	92	89	2169
MIDL. VIND	2.2	2.4	2.6	3.2	3.9	4.0	3.3	2.8	3.0

VINDANALYSE

DØGNMIDDEL	30	60	90	120	150	180	210	240	270	300	330	360	TOTAL
STILLE													10.9
.6- 2.0 M/S	2.5	1.2	1.7	4.8	4.6	2.3	1.4	.8	1.9	2.4	6.1	3.6	33.3
2.1- 4.0 M/S	.6	.3	.5	3.6	7.1	3.0	2.1	.5	.2	2.0	6.4	2.9	29.0
4.1- 6.0 M/S	.0	.1	.1	1.2	3.3	3.8	.9	.0	.2	.3	2.2	1.2	13.5
OVER 6.0 M/S	0.0	.0	.1	.8	5.1	4.0	.3	0.0	.0	.4	1.7	.8	13.2
TOTAL.	3.1	1.6	2.4	10.4	20.1	13.0	4.7	1.3	2.4	5.1	16.4	8.6	100.0
MIDL. VIND M/S	1.4	1.6	2.1	2.8	4.3	4.8	3.1	1.9	1.8	2.6	3.1	2.9	3.0
ANT. OBS.	67	35	52	275	435	283	102	29	53	110	355	186	2169

MIDLERE VINDSTYRKE FOR HELE DATASETTET ER 3.0 M/S, BASERT PÅ 2206 OBSERVASJONER

Table A3: Skansemyren

VINDROSE FRA SKANSEMYREN
1/ 6-81 - 31/ 8-81 FRA TAPE 1

VINDROSE KL.

SEKTOR	1	4	7	10	13	16	19	22	DØGN
20- 40	8.2	6.8	4.1	0.0	0.0	0.0	2.8	15.3	4.9
50- 70	2.7	1.4	0.0	0.0	0.0	0.0	0.0	1.4	.6
80-100	1.4	1.4	1.4	0.0	0.0	0.0	1.4	0.0	.7
110-130	5.5	9.6	0.0	0.0	0.0	0.0	0.0	8.3	3.6
140-160	21.9	27.4	28.8	13.9	5.6	6.9	4.2	23.6	15.5
170-190	21.9	15.1	26.0	22.2	16.7	19.4	23.6	20.8	20.5
200-220	4.1	5.5	5.5	13.9	19.4	16.7	18.1	2.8	11.4
230-250	0.0	0.0	1.4	6.9	4.2	4.2	1.4	0.0	2.1
260-280	2.7	1.4	2.7	5.6	15.3	4.2	4.2	0.0	3.8
290-310	0.0	2.7	4.1	8.3	16.7	15.3	4.2	1.4	7.0
320-340	11.0	12.3	11.0	25.0	18.1	30.6	38.9	16.7	20.8
350- 10	11.0	8.2	5.5	2.8	2.8	1.4	1.4	6.9	4.6
STILLE	9.6	8.2	9.6	1.4	1.4	1.4	0.0	2.8	4.4
ANT. OBS.	73	73	73	72	72	72	72	72	1733
MIDL. VIND	2.6	2.4	2.4	2.8	3.3	3.7	3.1	2.7	2.9

VINDANALYSE

DØGNMIDDEL	30	60	90	120	150	180	210	240	270	300	330	360	TOTAL
STILLE													4.4
.6- 2.0 M/S	3.5	.6	.7	2.9	5.6	2.5	2.2	1.0	2.8	2.4	9.3	2.2	35.6
2.1- 4.0 M/S	1.4	0.0	0.0	.7	6.9	6.5	4.1	1.2	1.0	4.5	8.4	2.1	36.8
4.1- 6.0 M/S	.1	0.0	0.0	0.0	2.4	6.4	3.7	0.0	0.0	.2	2.0	.3	15.0
OVER 6.0 M/S	0.0	0.0	0.0	0.0	.6	5.2	1.3	0.0	0.0	0.0	1.2	0.0	8.3
TOTAL.	4.9	.6	.7	3.6	15.5	20.5	11.4	2.1	3.8	7.0	20.3	4.6	100.0
MIDL. VIND M/S	1.6	.7	.8	1.3	2.8	4.5	3.8	1.9	1.6	2.4	2.6	2.3	2.9
ANT. OBS.	85	11	12	62	270	357	198	37	66	122	362	80	1738

MIDLERE VINDSTYRKE FOR HELE DATASETTET ER 2.9 M/S, BASERT PÅ 1738 OBSERVASJONER

Table A4: Sandviken

VINDROSE FRA SANDVIKEN
10/ 7-80 - 31/ 8-80 FRA TAPE 1

VINDROSE KL.

SEKTOR	1	4	7	10	13	16	19	22	DOGN
20- 40	0.0	0.0	0.0	2.6	4.9	7.3	5.4	7.7	2.1
50- 70	15.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	2.7
80-100	35.0	35.0	7.7	7.7	2.4	4.9	0.0	25.6	13.1
110-130	0.0	2.5	2.6	2.6	0.0	2.4	5.4	10.3	3.3
140-160	10.0	17.5	28.2	43.6	36.6	9.8	10.8	7.7	20.4
170-190	5.0	2.5	5.1	2.6	14.6	17.1	0.0	5.1	7.3
200-220	2.5	0.0	0.0	2.6	14.6	9.8	8.1	2.6	5.1
230-250	2.5	2.5	0.0	0.0	0.0	0.0	0.0	0.0	.4
260-280	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
290-310	0.0	0.0	0.0	0.0	4.9	2.4	2.7	0.0	1.0
320-340	7.5	7.5	10.3	15.4	12.2	26.8	27.0	7.7	14.4
350- 10	10.0	7.5	10.3	12.8	7.3	12.2	13.5	7.7	10.5
STILLE	12.5	22.5	35.9	10.3	2.4	7.3	27.0	25.6	19.7
ANT. OBS	40	40	39	39	41	41	37	39	936
MIDL VIND	1.1	1.1	1.3	1.3	1.4	1.4	1.2	1.0	1.2

VINDANALYSE

DØGNMIDDEL	30	60	90	120	150	180	210	240	270	300	330	360	TOTAL
STILLE													19.7
.6- 2.0 M/S	2.1	2.7	13.0	3.2	16.7	5.3	4.0	.4	0.0	.4	8.4	6.6	62.9
2.1- 4.0 M/S	0.0	0.0	.1	.1	3.7	1.6	1.2	0.0	0.0	.5	6.0	3.3	16.6
4.1- 6.0 M/S	0.0	0.0	0.0	0.0	0.0	.3	0.0	0.0	0.0	0.0	0.0	.4	.7
OVER 6.0 M/S	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.1
TOTAL	2.1	2.7	13.1	3.3	20.4	7.3	5.1	.4	0.0	1.0	14.4	10.5	100.0
MIDL. VIND M/S	.8	.3	.8	1.0	1.4	1.7	1.4	1.1	0.0	2.2	1.9	1.3	1.2
ANT. OBS.	20	25	123	31	191	63	43	4	0	9	105	98	936

MIDLERE VINDSTYRKE FOR HELE DATASETTET ER 1.2 M/S. BASERT PÅ 939 OBSERVASJONER

Table A5: Sandviken

VINDROSE FRA SANDVIKEN
1/ 9-80 - 30/11-80 FRA TAPE 1

VINDROSE KL.

SEKTOR	1	4	7	10	13	16	19	22	DOGN
20- 40	9.4	7.1	8.2	3.5	3.6	11.9	12.0	11.9	8.0
50- 70	12.9	16.5	15.3	5.9	2.4	6.0	8.4	10.7	9.6
80-100	9.4	9.4	8.2	9.4	2.4	4.8	13.3	19.0	10.4
110-130	4.7	1.2	5.9	3.5	2.4	4.8	7.2	3.6	3.8
140-160	11.8	15.3	15.3	16.5	21.4	20.2	16.9	19.0	17.8
170-190	21.2	20.0	15.3	22.4	23.8	21.4	20.5	19.0	20.0
200-220	9.4	3.5	4.7	2.4	6.0	4.8	4.8	4.8	5.2
230-250	0.0	1.2	0.0	1.2	1.2	0.0	0.0	0.0	.3
260-280	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	.1
290-310	0.0	0.0	0.0	1.2	2.4	1.2	0.0	0.0	.6
320-340	1.2	1.2	0.0	3.5	6.0	2.4	0.0	0.0	1.8
350- 10	4.7	7.1	8.2	10.6	9.5	10.7	6.0	4.8	7.9
STILLE	15.3	17.6	18.8	20.0	17.9	11.9	10.8	7.1	14.4
ANT. OBS.	85	85	85	85	84	84	83	84	2026
MIDL. VIND	1.6	1.6	1.5	1.6	1.9	1.8	1.6	1.7	1.7

VINDANALYSE

DØGNMIDDEL	30	60	90	120	150	180	210	240	270	300	330	360	TOTAL
STILLE													14.4
.6- 2.0 M/S	7.2	9.3	10.2	2.5	10.9	6.3	2.7	.2	.1	.3	.7	4.2	54.7
2.1- 4.0 M/S	.8	.3	.0	.9	6.1	11.0	2.0	.0	0.0	.2	1.0	3.1	25.6
4.1- 6.0 M/S	0.0	0.0	.1	.2	.8	2.5	.5	0.0	0.0	0.0	.1	.6	4.9
OVER 6.0 M/S	0.0	0.0	0.0	.2	0.0	.2	0.0	0.0	0.0	0.0	0.0	0.0	.4
TOTAL	8.0	9.6	10.4	3.8	17.8	20.0	5.2	.3	.1	.6	1.8	7.9	100.0
MIDL. VIND M/S	1.3	1.0	.8	2.0	1.9	2.7	2.3	1.3	.7	1.8	2.4	2.1	1.7
ANT. OBS	163	194	210	78	380	406	105	6	2	12	37	161	2026

MIDLERE VINDSTYRKE FOR HELE DATASETTET ER 1.6 M/S. BASERT PÅ 2040 OBSERVASJONER
2 3 1 0 3 2.00 4.00 6.00 0.00 0.00 0.00 .50
BOTANIEN 12 1 1 0 0 0 0.00

Table A6: Sandviken

VINDROSE FRA SANDVIKEN
1/12-80 - 28/ 2-81 FRA TAPE 1

VINDROSE KL.

SEKTOR	1	4	7	10	13	16	19	22	DOGN
20- 40	2.3	4.5	4 5	4.5	1.1	1.1	4.5	3.4	3.9
50- 70	13.8	13.6	8.0	4.5	6.8	8.0	10.2	11.5	9.1
80-100	12.6	12.5	19.3	14.8	4.5	10.3	19.3	17.2	12.9
110-130	3.4	4.5	4.5	2.3	1.1	2.3	4.5	0.0	3.2
140-160	11.5	12.5	8.0	13.6	12.5	13.8	12.5	10.3	12.2
170-190	28.7	22 7	29.5	22.7	30.7	31.0	22.7	27.6	27.4
200-220	11.5	9.1	6.8	9.1	8.0	10.3	8.0	12.6	8.7
230-250	0.0	0.0	0.0	0.0	1.1	0.0	3.4	0.0	.4
260-280	0.0	0.0	0.0	0.0	2.3	1.1	0.0	2.3	.7
290-310	0.0	1.1	0.0	0.0	2.3	0.0	1.1	0.0	.5
320-340	2.3	2 3	0.0	1.1	3.4	2 3	1.1	1.1	2.0
350- 10	5.7	5 7	11.4	10.2	10.2	11.5	10.2	6.9	9.5
STILLE	8 0	11.4	8.0	17.0	15.9	8.0	2 3	6.9	9.5
ANT. OBS	87	88	88	88	88	87	88	87	2102
MIDL. VIND	2.1	2.1	1.9	2.0	1.8	1.9	1.9	2 1	2.0

VINDANALYSE

DOGNMIDDEL	30	60	90	120	150	180	210	240	270	300	330	360	TOTAL
STILLE													9.5
.6- 2.0 M/S	3.7	7.8	11.0	2.0	8.1	8.9	2 5	.3	.4	.1	.6	5.3	50.9
2.1- 4.0 M/S	.2	.9	1.4	.9	3.2	13.7	4.5	.1	.3	.4	.8	2.7	29.1
4.1- 6.0 M/S	0.0	.4	.5	.2	.8	4.0	1.5	0.0	0.0	0.0	.4	.9	8.8
OVER 6.0 M/S	0 0	0.0	0.0	0.0	.1	.8	.2	0.0	0.0	0.0	.1	.6	1.8
TOTAL	3.9	9.1	12.9	3.2	12.2	27.4	8.7	.4	.7	.5	2.0	9.5	100.0
MIDL. VIND M/S	1.0	1.3	1.3	1.8	1.9	2.8	2.9	1.9	1.5	2 5	3.2	2.4	2.0
ANT. OBS.	83	192	272	67	257	575	183	8	14	11	41	199	2102

MIDLERE VINDSTYRKE FOR HELE DATASETTET ER 2.0 M/S, BASERT PÅ 2104 OBSERVASJONER

Table A7: Sandviken

VINDROSE FRA SANDVIKEN
1/ 3-81 - 31/ 5-81 FRA TAPE 1

VINDROSE KL.

SEKTOR	1	4	7	10	13	16	19	22	DOGN
20- 40	3.4	8.1	3.5	0.0	3.3	0.0	3.3	7.7	3.8
50- 70	13.4	20.9	10.6	3.4	2.2	3.3	10.9	14.3	10.8
80-100	16.1	10.5	16.5	3.4	2.2	5.6	5.4	16.5	8.7
110-130	1.1	2.3	1.2	2.3	2.2	1.1	0.0	0.0	1.9
140-160	6.9	8.1	9.4	10.3	8.8	12.2	6.5	12.1	8.3
170-190	12.6	9.3	14.1	16.1	18.7	14.4	15.2	7.7	14.4
200-270	1.1	7.0	5.9	16.1	19.8	12.2	6.5	6.6	8.5
230-250	0.0	0.0	0.0	2.3	6.6	3.3	1.1	0.0	2.5
260-280	0.0	0.0	0.0	6.9	5.5	7.8	0.0	1.1	2.1
290-310	0.0	0.0	0.0	6.9	8.8	10.0	7.6	2.2	5.0
320-340	4.6	10.5	10.6	9.2	15.4	22.2	20.7	6.6	11.9
350- 10	9.2	1.2	0.0	0:0	1.1	0.0	3.3	5.5	2.7
STILLE	26.4	22.1	28.2	23.0	5.5	7.8	19.6	19.8	19.5
ANT. OBS.	87	86	85	87	91	90	92	91	2124
MIDL. VIND	1.1	1.2	1.3	1.6	2.0	2.1	1.7	1.3	1.5

VINDANALYSE

DØGNMIDDEL.	30	60	90	120	150	180	210	240	270	300	330	360	TOTAL
STILLE													19.5
.6- 2.0 M/S	3.4	9.5	6.4	1.6	5.3	6.2	6.2	2.4	2.0	2.9	4.3	2.4	52.6
2.1- 4.0 M/S	.4	1.2	1.9	.3	2.1	6.3	2.2	.1	.0	1.6	5.6	.3	22.0
4.1- 6.0 M/S	0.0	.0	.3	0.0	1.0	1.6	.1	0.0	0.0	.5	1.8	0.0	5.4
OVER 6.0 M/S	0.0	0.0	0.0	0.0	0.0	.3	0.0	0.0	0.0	0.0	.2	0.0	.5
TOTAL	3.8	10.8	8.7	1.9	8.3	14.4	8.5	2.5	2.1	5.0	11.9	2.7	100.0
MIDL. VIND M/S	1.1	1.1	1.5	1.1	2.0	2.5	1.7	1.0	1.2	2.1	2.6	1.2	1.5
ANT. OBS.	80	229	184	41	177	306	180	53	44	106	252	58	2124

MIDLFRE VINDSTYRKE FOR HELE DATASETTET ER 1.5 M/S. BASERT PÅ 2198 OBSERVASJONER

Table A8: Sandviken

VINDROSE FRA SANDVIKEN
1/ 6-81 - 31/ 8-81 FRA TAPE 1

VINDROSE KL.

SEKTOR	1	4	7	10	13	16	19	22	DØGN
20- 40	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.3
50- 70	8.3	6.6	0.0	0.0	0.0	0.0	0.0	3.4	2.6
80-100	3.3	3.3	0.0	0.0	0.0	0.0	0.0	3.4	1.9
110-130	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	.5
140-160	6.7	9.8	11.1	6.6	4.9	1.6	1.7	8.6	6.8
170-190	16.7	4.9	15.9	13.1	11.5	6.5	11.9	12.1	12.1
200-220	6.7	11.5	9.5	21.3	23.0	22.6	15.3	12.1	14.9
230-250	0.0	1.6	0.0	4.9	13.1	6.5	3.4	0.0	4.0
260-280	6.7	4.9	4.8	9.8	9.8	14.5	5.1	6.9	7.7
290-310	5.0	1.6	14.3	14.8	19.7	17.7	8.5	1.7	11.0
320-340	13.3	9.3	11.1	11.5	6.6	19.4	30.5	25.9	15.8
350- 10	0.0	0.0	1.6	0.0	0.0	0.0	1.7	3.4	1.0
STILLE	30.0	45.9	30.2	18.0	11.5	11.3	22.0	22.4	21.5
ANT. OBS.	60	61	63	61	61	62	59	58	1459
MIDL. VIND	1.0	.8	1.1	1.3	1.5	1.6	1.6	1.5	1.3

VINDANALYSE

DØGNMIDDEL.	30	60	90	120	150	180	210	240	270	300	330	360	TOTAL
STILLE													21.5
.6- 2.0 M/S	.3	2.6	1.9	.5	5.8	9.4	12.3	3.9	6.8	6.2	11.5	1.0	62.2
2.1- 4.0 M/S	0.0	0.0	0.0	0.0.	.9	2.4	2.3	.1	1.0	4.5	3.2	0.0	14.2
4.1- 6.0 M/S	0.0	0.0	0.0	0.0	0.0	0.0	.1	0.0	0.0	.3	1.1	0.0	1.5
OVER 6.0 M/S	0.0	0.0	0.0	0.0	.1	.3	.2	.1	0.0	0.0	0.0	0.0	.7
TOTAL	.3	2.6	1.9	.5	6.8	12.1	14.9	4.0	7.7	11.0	15.3	1.0	100.0
MIDL. VIND M/S	.7	.7	.7	.8	1.8	1.8	1.6	1.2	1.4	1.9	1.7	.8	1.3
ANT. OBS.	5	33	27	8	99	176	217	59	113	160	230	14	1452

MIDLERE VINDSTYRKE FOR HELE DATASETTET ER 1.3 M/S. BASERT PÅ 1523 OBSERVASJONER

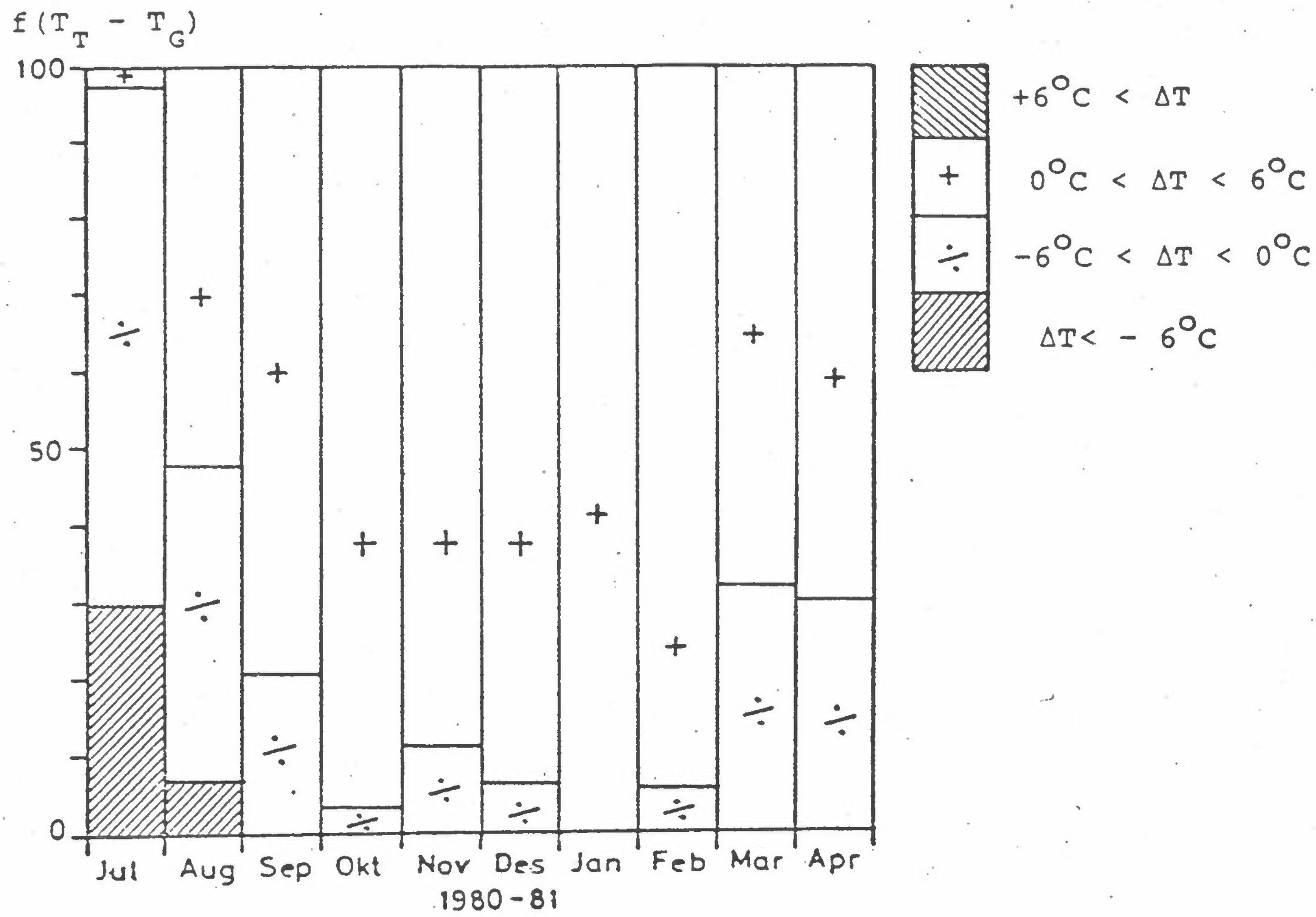

Figure A1: Frequency of observed differences in temperature, the Løvstakk tunnel - Gyllenpris.

NORSK INSTITUTT FOR LUFTFORSKNING

NILU

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Oppdragsrapport	OR 3/83	
DATO: JANUARY 1983	ANSV.SIGN.: B.Ottar	ANT. SIDER: 19
TITTEL: Emission of pollution through shafts from Fløyfjellstunnelen, Bergen		PROSJEKTLEDER: K.E.Grønskei
		NILU PROSJEKT NR.: 07931
FORFATTER(E): Knut Erik Grønskei		TILGJENGELIGHET**:
		OPPDRAGSGIVERS REF.:
OPPDRAGSGIVER: Hordaland Vegkontor		
3 STIKKORD (á maks. 20 anslag)		
Bergen	Tunnelventilasjon	Luftforurensninger

REFERAT (maks. 300 anslag, 5-10 linjer)

Utbredelsen av forurenset ventilasjonsluft fra Fløyfjellstunnelen er vurdert. Den vertikale utslippshastigheten i sjakter bør være over ca 10 m/s for å oppnå tilfredsstillende spredning.

TITLE Emission of pollution through shafts from Fløyfjellstunnelen, Bergen

ABSTRACT (max. 300 characters, 5-10 lines.

The dispersion of polluted ventilation air from Fløyfjellstunnelen is evaluated. The vertical emission velocity should be more than about 10 m/s to achieve a good air quality in the surroundings.

**Kategorier:	Åpen - kan bestilles fra NILU	A
	Må bestilles gjennom oppdragsgiver	B
	Kan ikke utleveres	C