SKB

TECHNICAL REPORT 91-36

Tentative outline and siting of a repository for spent nuclear fuel at the Finnsjön site. SKB 91 reference concept

Lars Ageskog, Kjell Sjödin

VBB VIAK

September 1991

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This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the author(s) and do not necessarily coincide with those of the client.

Information on SKB technical reports from 1977-1978 (TR 121), 1979 (TR 79-28), 1980 (TR 80-26), 1981 (TR 81-17), 1982 (TR 82-28), 1983 (TR 83-77), 1984 (TR 85-01), 1985 (TR 85-20), 1986 (TR 86-31), 1987 (TR 87-33), 1988 (TR 88-32), 1989 (TR 89-40) and 1990 (TR 90-46) is available through SKB.

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SKB91 Reference Concept

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ABSTRACT

A site in northern Uppland has been selected for a safety assessment of a generic repository for spent nuclear fuel. The site chosen has been thoroughly investigated and documented in previous reports. The repository studied is of the KBS-3 type consisting of a number of deposition drifts with the canisters deployed in holes drilled in the drift floor.

The major fracture zones in the host rock were entered into a 3-dimensional CAD model in which the repository was placed. Two alternative layouts were studied: one with deposition drifts oriented approximately parallel with the hydraulic gradient, the other with drifts perpendicular to the gradient.

The report includes appendices with coordinates for the fracture zones as well as coordinates describing the endpoints of the deposition drifts.

1. INTRODUCTION

The Finnsjön site in northern Uppland has been selected for a safety assessment of a generic repository for spent nuclear fuel. The study, named SKB-91, is carried out within the current R&D-programme of SKB.

The Finnsjön site has been thoroughly investigated at a number of occasions since 1977. In connection with the SKB-91 study, the findings have been summarized in the SKB Technical Report 91-08 /1/ and also used as a basis for identifying a generic host rock, see Work Report 91-15 /2/.

This report illustrates possible ways of having a repository according to the KBS-3 concept fit into a suitable rock mass within the frame of the investigated area at Finnsjön, considering various design criteria and the number and spacing of waste canisters. For the location of access shafts, the ground surface conditions have been considered as well.

2. GENERAL DESIGN PRINCIPLES

The type of repository used in the SKB-91 study is taken from the KBS-3 report /4/, consisting of a number of deposition drifts in which the canisters are deployed in holes drilled in the bottoms of the drifts. An overview of the principle is shown in Figure 1. The deposition depth in KBS-3 is assumed typically 500 m below ground.

The adaptation to the generic site at Finnsjön has been based on the following principles and design criteria:

- The number of canisters to be deployed is 5 300. Allowances should be made for sections where crossings of minor fissure zones will prohibit actual canister deposition. An addition of 10% to the total length of deposition drifts has been deemed appropriate for that purpose. Thus a total of 5 830 canister positions have been considered.

- The spacing of canisters and deposition drifts has been studied earlier with respect to the thermal load on the buffer and the rock /3/. The result of that study indicates that, under certain assumptions regarding canister and canister content, the spacing of canisters could be chosen out of practical reasons rather than based on thermal constraints. Thus the spacing of canisters in deposition drifts has been set to 6.0 m and the distance between two adjacent drifts to 25 m.

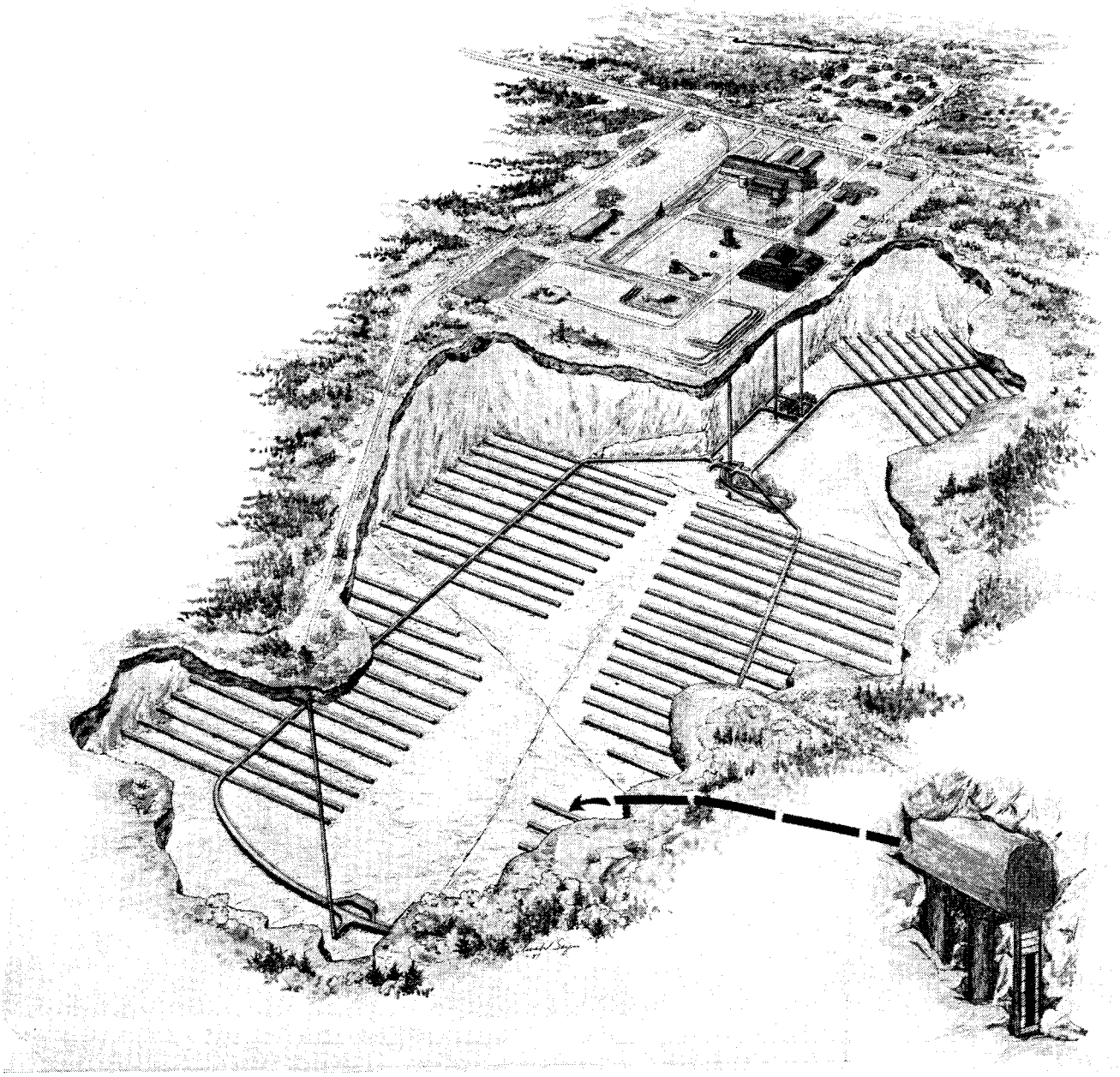

Figure 1 Final repository for spent fuel according to the KBS-3 concept.

- The repository has been located at the level -600 m in the RAK coordinate system. The level of -500 m typically chosen in KBS-3 has been avoided at this site due to the difficulty in finding a large area undisturbed by fracture zones at this level. It should be pointed out that the deposition panels will be excavated

sloping slightly upwards (1:100) in order to facilitate the dewatering but that the differences in depth for various parts of the repository, as a consequence of this, are not regarded in this study.

- The respect distance to major fracture zones (first order and to some extent second order zones according to /1/) should be 100 m for areas intended for canister deposition. Other fracture zones should not be considered in other ways than by the overall addition of 10% to the length of deposition drifts. The repository area should preferably be confined to the so called northern block of the investigated area /1/.

- Access shafts should be located outside the rock mass intended for deposition, defined by the major fracture zones mentioned above.

- An orientation at an angel of at least 15° to joints of third through fifth order has been deemed appropriate in order to minimize the adverse influence from the disturbed zone and to avoid excessive stability problems and overbreak in the rock cavities.

- The layout study included two cases regarding the orientation of the deposition drifts:

  North/south

  The drifts are oriented perpendicularly to the hydraulic gradient.

  East/west

  The drifts are oriented approximately along the hydraulic gradient.

- The length of the deposition drifts (blind drifts) should be limited to some 250 m with respect to labour safety factors such as ventilation, fire protection, escape routes etc.

3. HOST ROCK AND SITE CHARACTERISTICS

The major fracture zones within the investigated area, earlier defined by means of equations derived from core loggings etc., see Appendix 1, were entered into a 3-dimensional CAD file. Figures 4 and 5 include printouts of the fracture pattern at repository level.

The deposition area restriction, indicated by a dotted border line in Figures 4 and 5, was measured with a 100 m respect distance to fracture zones no. 1, 2, 4 and 12. Zone no. 2, sloping slightly southwest relative the horizontal plane and located above the repository, is not penetrating the area shown in the figures (the repository level), but effects the southwest border of the restricted area. Because of the particular characteristics of zone 2, it was possible to expand the restricted area simply by placing the repository at the -600 m level instead of the typical -500 m level.

The predominant direction of fissure zones and joints of the fifth order is shown in Figure 2 as a fracture pole diagram. It could be assumed that the situation indicated in Figure 2 is representative also for fissures of third and fourth order.

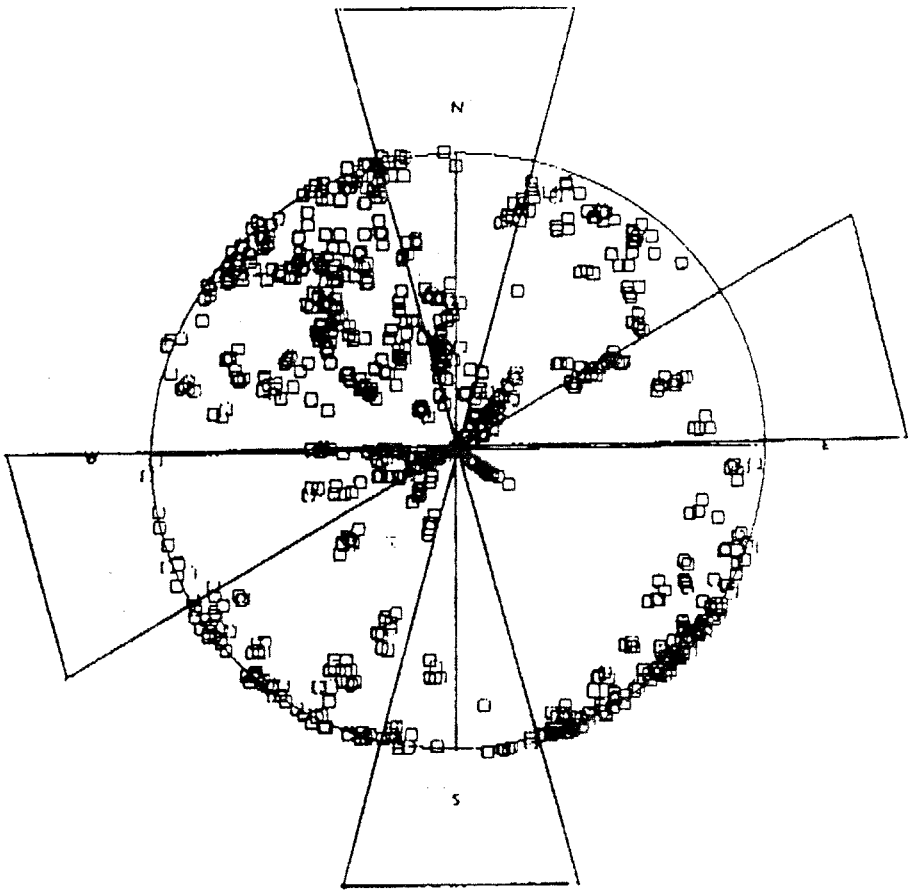

Figure 2 Fracture pole diagram for the fifth order fissures with indication of sectors within 15° from the chosen alternative orientations of deposition drifts.
(Conterra AB)

The diagram in Figure 2 demonstrates that the precise east/west orientation of the deposition drifts, i.e. approximately parallel with the hydraulic gradient, should be acceptable with respect to the required deviation from a dominant fissure direction, as mentioned above. The north/south orientation, however, has to be adjusted somewhat and an orientation approximately parallel with the zone 3 direction has been deemed appropriate.

4. ALTERNATIVE REPOSITORY CONFIGURATIONS

Figures 4 and 5 below show the two alternative repository layouts which have been studied: the north/south and the east/west orientation respectively. Figure 3 is a key plan based on figure 8 in /1/.

It should be noted that the access shafts have been located not only outside the repository area, but separated from it by fracture zones 1 and 4. Avoiding direct vertical pathways between the repository area and the ground surface in this way will, however, have an adverse effect on the length of central tunnels and the need for plugging of fracture zone crossings. Further, site-specific considerations during site selection will have to show whether this type of arrangement is justified with respect to what can be gained in the matter of long term safety.

5. SITING OF SURFACE FACILITIES

The location of the surface facilities, have been determined on the basis of the following early stage principles:

- Shaft openings, except for one peripheral ventilation shaft, shall be located within the fenced site area. The location of shafts in relation to the deposition area below ground is to some extent free, see above.

- Topographical conditions should be considered. Elevated areas, assumed to contain rock near the surface, should be favoured with respect to shaft connections.

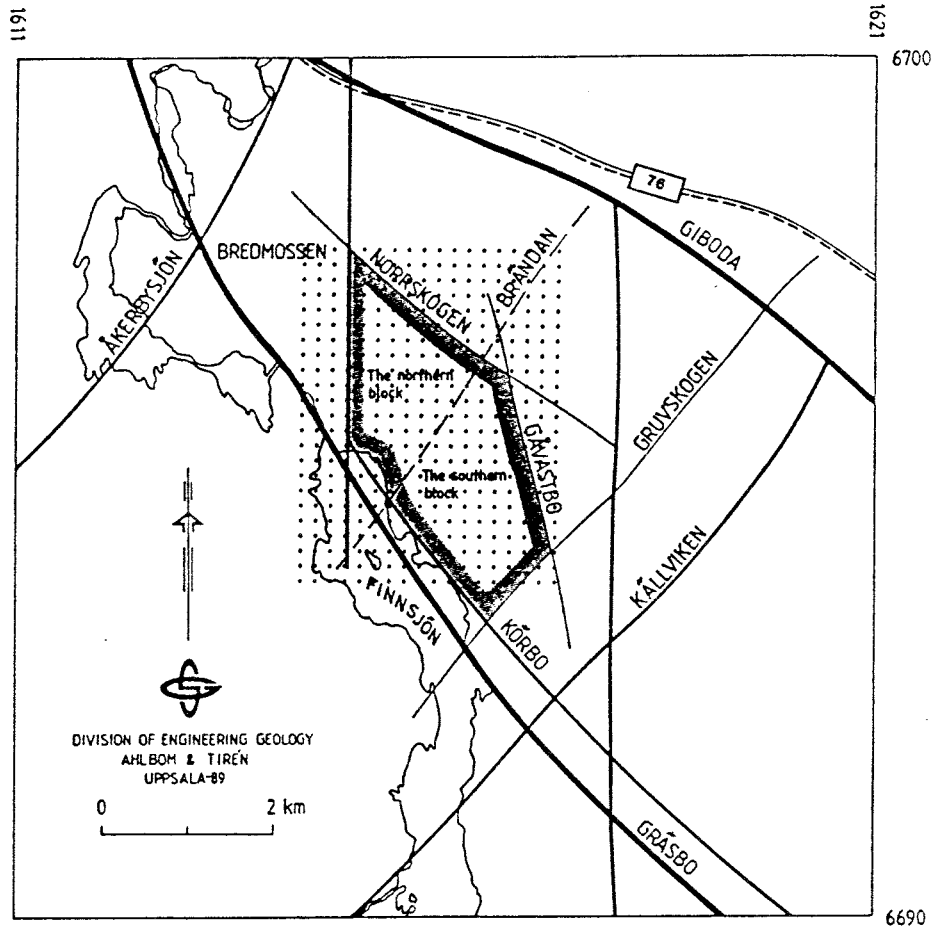

Figure 3 Key plan for the printouts in Figures 4 and 5.

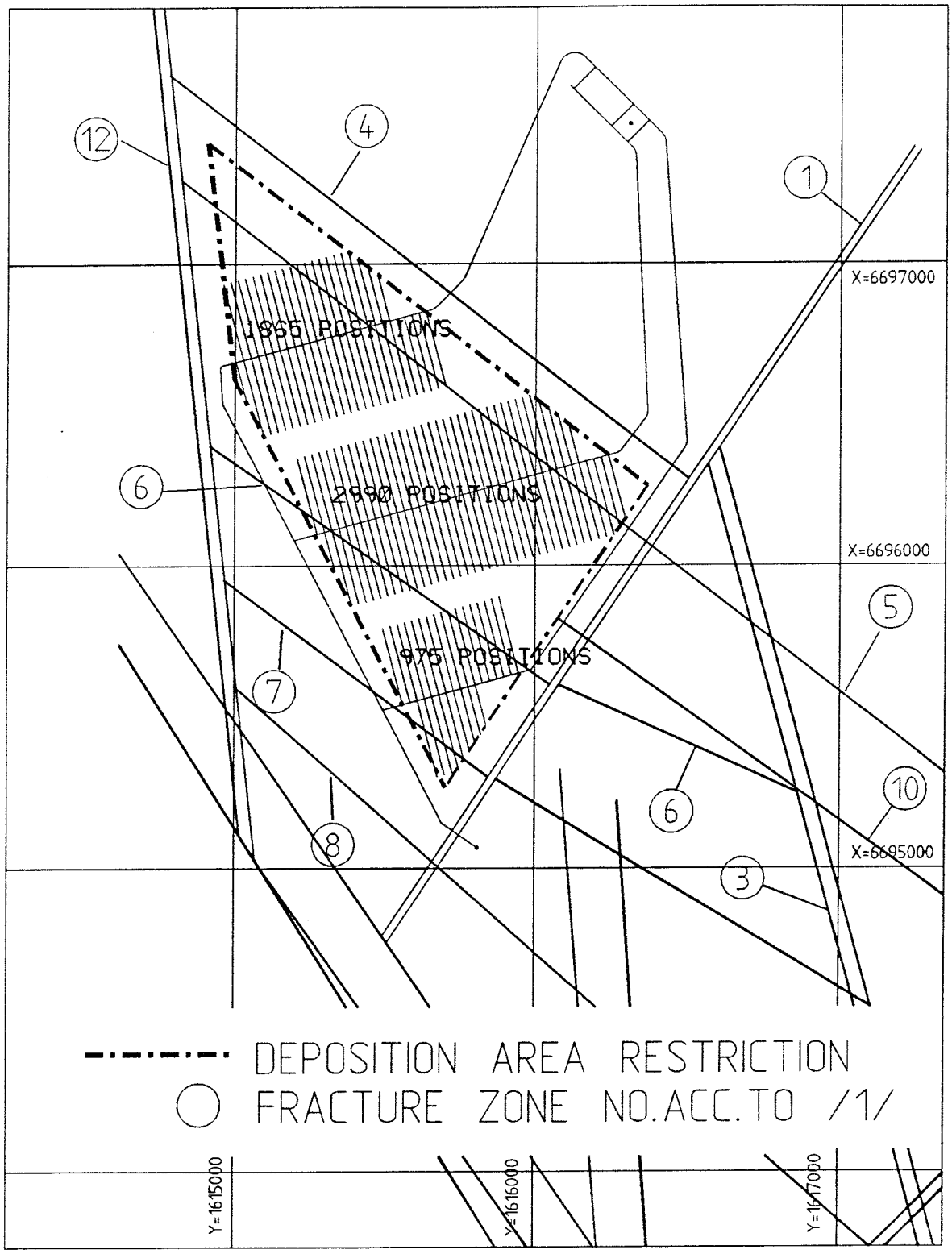

Figure 4 Repository layout with north/south orientation of deposition drifts. Level -600 m.

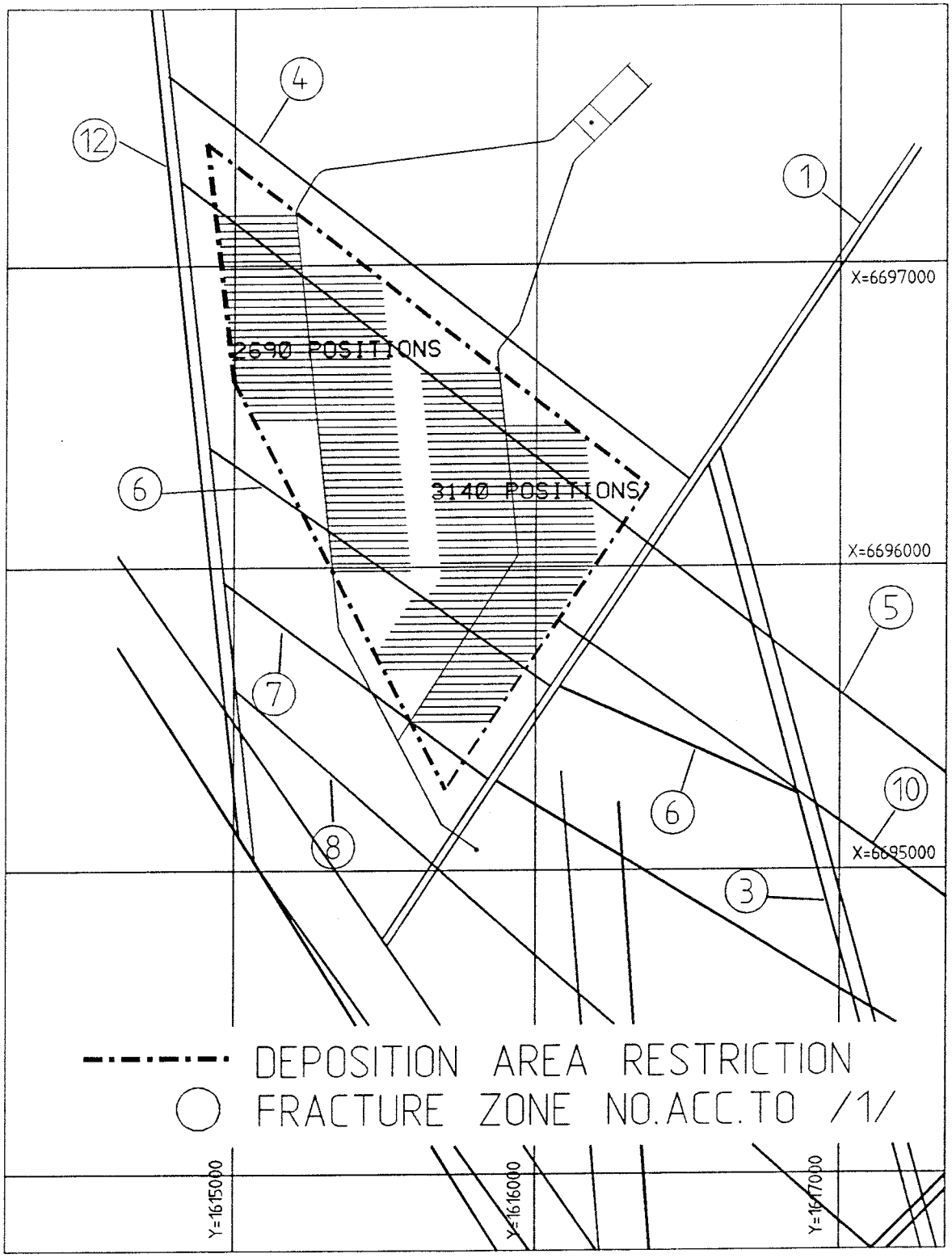

Figure 5 Repository layout with east/west orientation of deposition drifts. Level -600 m.

6. REFERENCES

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Appendix 1: Coordinates for upper and lower surfaces of fracture zones at the Finnsjön site

Appendix 2: Coordinates for deposition drifts for the alternative with east/west orientation

Appendix 3: Coordinates for deposition drifts for the alternative with north/south orientation

Appendix 1

Coordinates for upper and lower surfaces of fracture zones at the Finnsjön site

Coordinates on pages 2-4 according to Swedish Geological Co.

Coordinates for upper and lower surfaces of fracture zones at the Finnsjön site.

The coordinates are given in the RAK coordinate system with offset in the point Y = 1600000, X = 6600000

Zone	Surface	Intersection	X	Y	Z
1	Upper	Zone 14	94903	15405	30
			94659	15573	-1000
		N Boundary	97444	17105	30
			97329	17361	-1000
	Lower	Zone 14	94925	15389	30
			94681	15558	-1000
		N Boundary	97455	17082	30
			97340	17338	-1000
2	North				
	Upper	Zones 4 and 1	96747	16611	24
		Zones 6 and 1	95844	16087	-224
		Zones 4 and 12	97931	14752	-286
		Zones 6 and 12	96525	14906	-431
	Lower	Zones 4 and 1	96660	16591	-96
		Zones 6 and 1	95777	16079	-339
		Zones 4 and 12	97808	14766	-403
		Zones 6 and 12	96439	14915	-544
	South				
	Upper	Zones 6 and 1	95927	16100	30
		Zones 14 and 1	94824	15460	-398
		Zones 12 and 14	95458	15022	-425
		Zones 12 and 6	96621	14895	-305
	Lower		Not interpreted		
3	Upper	Zone 1	96673	16589	30
			96120	16552	-1000
		S Boundary	93140	17549	30
			93140	17361	-1000
	Lower	Zone 1	96728	16626	30
			96175	16588	-1000
		S/E Boundary	93292	17560	30
			93140	17413	-1000
4		Zone 1	96755	16614	30
			95989	16433	-1000
		Zone 12	98232	14719	30
			97242	14826	-1000
5		Zone 12	97886	14756	30
			96893	14866	-1000
		E Boundary	95701	17560	30
			94794	17560	-1000
6	West	Zone 1	96005	16112	30
			95353	16008	-1000
		Zone 12	96877	14868	30
			96091	14953	-1000
	East	Zone 1	95983	16128	30
			95366	16047	-1000
		Zone 3	95644	16869	30
			94996	16587	-1000

Zone	Surface	Intersection	X	Y	Z
7	West	Zone 1	95704	15910	30
			95043	15801	-1000
		Zone 12	96446	14914	30
			95638	15002	-1000
	East	Zone 1	95685	15928	30
			95047	15833	-1000
		E Boundary	94691	17560	30
			93995	17560	-1000
8		Zone 12	95596	15007	30
			95596	15007	-1000
		Zone 13	93864	16975	30
			93676	17188	-1000
9	Upper	Zone 7	95899	15646	30
		Zones 7 and 12	96289	14932	-169
		N Boundary	98214	15390	30
		N Boundary/Z 12	98530	14687	-169
	Lower	Zones 7 and 12	96263	14934	-203
		Zone 1	95786	15966	30
		Zones 1 and 7	95691	15908	10
		N Boundary	98214	15390	30
		N Boundary/Z 12	98530	14687	-130
10	West	Zone 1	95883	16030	30
		Zones 1 and 6	95815	16082	-270
		Zone 12	96666	14890	30
		Zones 12 and 6	96629	14894	-295
	East	Zone 1	95864	16048	30
		Zone 1 and 6	95793	16103	-1000
		E Boundary	94850	17560	30
			94742	17560	-1000
11	Upper	Zone 1	97085	16865	30
		SE Boundary	94204	15589	-1000
		S Boundary	93140	17136	30
			93140	16260	-582
	Lower	Zone 1	97330	17029	30
		SE Boundary	93883	15791	-1000
		S Boundary	93140	17317	30
			93140	16260	-709
12	East	N Boundary	98529	14687	30
			98529	14687	-1000
		S Boundary	95026	15069	30
			95026	15069	-1000
	West	N Boundary	98546	14650	30
			98546	14650	-1000
		S Boundary	95109	15017	30
			95109	15017	-1000
13	Upper	Zone 14	93140	16306	30
			93140	16706	-1000
		E Boundary	94403	17560	30
			94000	17560	-1000
	Lower	Zone 14	93143	16258	30
			93143	16656	-1000
		E Boundary	94453	17560	30
			94050	17560	-1000

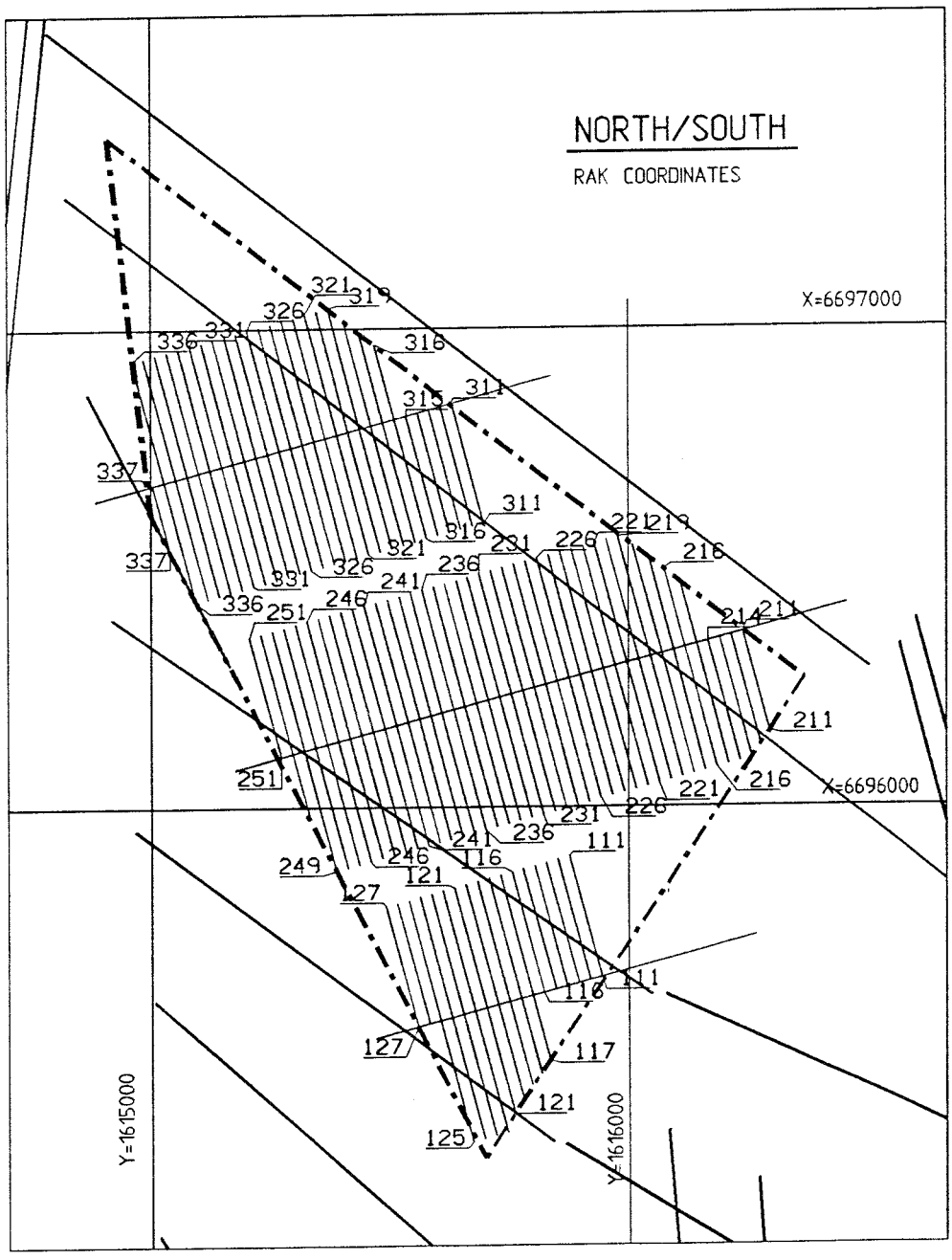
Zone	Surface	Intersection	X	Y	Z
14	North-east	W Boundary	96041	14620	30
			96041	14620	-1000
		S Boundary	93140	16620	30
			93140	16620	-1000
	South-west	W Boundary	95740	14620	30
			95740	14620	-1000
		S Boundary	93140	16260	30
			93140	16260	-1000

Boundary Surfaces	X	Y	Z
South	93140	16260	30
	93140	16260	-1000
	93140	17560	30
	93140	17560	-1000
East	93140	17560	30
	93140	17560	-1000
	97240	17560	30
	97240	17560	-1000
North	97240	17560	30
	97240	17560	-1000
	98560	14620	30
	98560	14620	-1000
West	98560	14620	30
	98560	14620	-1000
	95740	14620	30
	95740	14620	-1000
Southwest	95740	14620	30
	95740	14620	-1000
	93140	16260	30
	93140	16260	-1000

Appendix 2

Coordinates for deposition drifts for the alternative with north/south orientation

Coordinates, x and y in the RAK system, are given for the endpoints of centre lines at bottom of drifts. Drifts are labelled according to key plan below.



NORTH/SOUTH

ADDITION OF X:6690000 AND Y:1610000 GIVES RAK COORD.

UNIT: METERS

TUNNEL NO	ENDPOINT 1		ENDPOINT 2	
	X-COORD	Y-COORD	X-COORD	Y-COORD
111	5643.87	5945.32	5896.34	5877.67
112	5637.40	5921.17	5889.87	5853.52
113	5630.93	5897.02	5883.40	5829.37
114	5624.46	5872.87	5876.93	5805.22
115	5617.99	5848.72	5870.46	5781.07
116	5611.51	5824.58	5863.99	5756.93
117	5468.64	5836.98	5857.52	5732.78
118	5441.41	5818.39	5851.05	5708.63
119	5417.84	5798.82	5844.58	5684.48
120	5385.80	5781.53	5838.11	5660.33
121	5358.37	5762.99	5831.64	5636.18
122	5320.22	5747.34	5825.17	5612.04
123	5313.75	5723.19	5818.69	5587.89
124	5307.28	5699.04	5812.22	5563.74
125	5300.81	5674.89	5805.75	5539.59
126	5546.81	5583.09	5799.28	5515.44
127	5540.34	5558.95	5792.81	5491.30

NORTH/SOUTH

ADDITION OF X:6690000 AND Y:1610000 GIVES RAK COORD.

UNIT: METERS

TUNNEL NO	ENDPOINT 1		ENDPOINT 2	
	X-COORD	Y-COORD	X-COORD	Y-COORD
211	6154.89	6295.15	6364.43	6239.01
212	6125.56	6277.13	6357.96	6214.86
213	6100.35	6258.01	6351.49	6190.71
214	6093.88	6233.86	6345.02	6166.56
215	6087.41	6209.71	6466.12	6108.23
216	6080.94	6185.56	6495.45	6074.49
217	6074.47	6161.41	6522.33	6041.41
218	6068.00	6137.26	6545.14	6009.41
219	6061.53	6113.12	6563.81	5978.53
220	6055.06	6088.97	6557.34	5954.38
221	6048.59	6064.82	6550.87	5930.23
222	6042.12	6040.67	6544.40	5906.09
223	6035.65	6016.52	6537.93	5881.94
224	6029.18	5992.38	6531.46	5857.79
225	6022.71	5968.23	6524.99	5833.64
226	6016.24	5944.08	6518.52	5809.49
227	6009.76	5919.93	6512.05	5785.35
228	6003.29	5895.78	6505.58	5761.20
229	5996.82	5871.64	6499.11	5737.05
230	5990.35	5847.49	6492.63	5712.90
231	5983.88	5823.34	6486.16	5688.75
232	5977.41	5799.19	6479.69	5664.60
233	5970.94	5775.04	6473.22	5640.46
234	5964.47	5750.89	6466.75	5616.31
235	5958.00	5726.75	6460.28	5592.16
236	5951.53	5702.60	6453.81	5568.01
237	5945.06	5678.45	6447.34	5543.86
238	5938.59	5654.30	6440.87	5519.72
239	5932.12	5630.15	6434.40	5495.57
240	5925.65	5606.01	6427.93	5471.42
241	5919.18	5581.86	6421.46	5447.27
242	5912.71	5557.71	6414.99	5423.12
243	5906.24	5533.56	6408.52	5398.98
244	5899.77	5509.41	6402.05	5374.83
245	5893.30	5485.26	6395.58	5350.68
246	5886.83	5461.12	6389.11	5326.53
247	5880.36	5436.97	6382.64	5302.38
248	5873.88	5412.82	6376.17	5278.23
249	5867.41	5388.67	6369.70	5254.09
250	5982.95	5331.83	6363.23	5229.94
251	6105.61	5273.08	6356.75	5205.79

NORTH/SOUTH

ADDITION OF X:6690000 AND Y:1610000 GIVES RAK COORD.

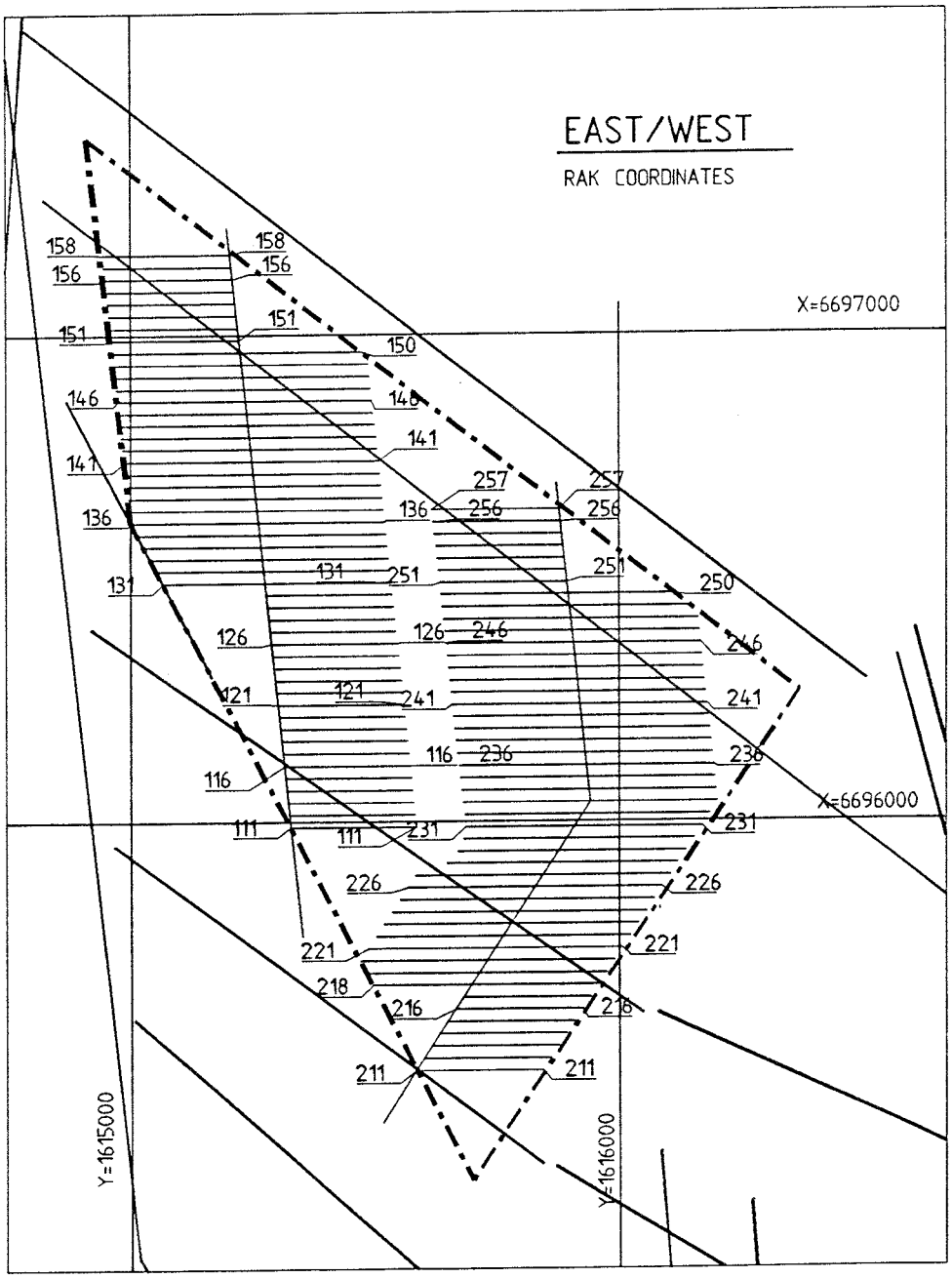
UNIT: METERS

TUNNEL NO	ENDPOINT 1		ENDPOINT 2	
	X-COORD	Y-COORD	X-COORD	Y-COORD
311	6592.47	5699.13	6843.61	5631.83
312	6586.00	5674.98	6837.14	5607.69
313	6579.53	5650.83	6830.67	5583.54
314	6573.06	5626.68	6824.20	5559.39
315	6566.59	5602.53	6817.73	5535.24
316	6560.12	5578.39	6967.09	5469.34
317	6553.65	5554.24	6992.78	5436.57
318	6547.18	5530.09	7016.77	5404.26
319	6540.71	5505.94	7042.99	5371.36
320	6534.24	5481.79	7036.52	5347.21
321	6527.77	5457.65	7030.05	5323.06
322	6521.30	5433.50	7023.58	5298.91
323	6514.83	5409.35	7017.11	5274.76
324	6508.36	5385.20	7010.64	5250.62
325	6501.89	5361.05	7004.17	5226.47
326	6495.41	5336.90	6997.70	5202.32
327	6488.94	5312.76	6991.23	5178.17
328	6482.47	5288.61	6984.76	5154.02
329	6476.00	5264.46	6978.28	5129.87
330	6469.53	5240.31	6971.81	5105.73
331	6463.06	5216.16	6965.34	5081.58
332	6456.59	5192.02	6958.87	5057.43
333	6450.12	5167.87	6952.40	5033.28
334	6443.65	5143.72	6945.93	5009.13
335	6437.18	5119.57	6939.46	4984.99
336	6430.71	5095.42	6932.99	4960.84
337	6540.11	5040.23	6675.38	5003.98

Appendix 3

Coordinates for deposition drifts for the alternative with east/west orientation

Coordinates, x and y in the RAK system, are given for the endpoints of centre lines at bottom of drifts. Drifts are labelled according to key plan below.



EAST/WEST

ADDITION OF X:6690000 AND Y:1610000 GIVES RAK COORD.

UNIT: METERS

TUNNEL NO	ENDPOINT 1		ENDPOINT 2	
	X-COORD	Y-COORD	X-COORD	Y-COORD
111	5989.01	5325.69	5989.01	5585.69
112	6014.01	5323.06	6014.01	5583.06
113	6039.01	5320.43	6039.01	5580.43
114	6064.01	5317.81	6064.01	5577.81
115	6089.01	5315.18	6089.01	5575.18
116	6114.01	5312.55	6114.01	5572.55
117	6139.01	5309.92	6139.01	5569.92
118	6164.01	5307.30	6164.01	5567.30
119	6189.01	5304.67	6189.01	5564.67
120	6214.01	5302.04	6214.01	5562.04
121	6239.01	5299.41	6239.01	5559.41
122	6264.01	5296.79	6264.01	5556.79
123	6289.01	5294.16	6289.01	5554.16
124	6314.01	5291.53	6314.01	5551.53
125	6339.01	5288.90	6339.01	5548.90
126	6364.01	5286.28	6364.01	5546.28
127	6389.01	5283.65	6389.01	5543.65
128	6414.01	5281.02	6414.01	5541.02
129	6439.01	5278.39	6439.01	5538.39
130	6464.01	5275.77	6464.01	5535.77
131	6489.01	5065.27	6489.01	5533.14
132	6514.01	5052.15	6514.01	5530.51
133	6539.01	5040.43	6539.01	5527.88
134	6564.01	5026.84	6564.01	5525.26
135	6589.01	5014.19	6589.01	5522.63
136	6614.01	5000.00	6614.01	5520.00
137	6639.01	4997.37	6639.01	5517.37
138	6664.01	4994.74	6664.01	5514.74
139	6689.01	4992.12	6689.01	5512.12
140	6714.01	4989.49	6714.01	5509.49
141	6739.01	4986.86	6739.01	5506.86
142	6764.01	4984.23	6764.01	5504.23
143	6789.01	4981.61	6789.01	5501.61
144	6814.01	4978.98	6814.01	5498.98
145	6839.01	4976.35	6839.01	5496.35
146	6864.01	4973.72	6864.01	5493.72
147	6889.01	4971.10	6889.01	5491.10
148	6914.01	4968.47	6914.01	5488.47
149	6939.01	4965.84	6939.01	5485.84
150	6964.01	4963.21	6964.01	5470.86
151	6989.01	4960.59	6989.01	5220.59
152	7014.01	4957.96	7014.01	5217.96
153	7039.01	4955.33	7039.01	5215.33
154	7064.01	4952.70	7064.01	5212.70
155	7089.01	4950.08	7089.01	5210.08
156	7114.01	4947.45	7114.01	5207.45
157	7139.01	4944.82	7139.01	5204.82
158	7164.01	4942.19	7164.01	5202.19

EAST/WEST

ADDITION OF X:6690000 AND Y:1610000 GIVES RAK COORD.

UNIT: METERS

TUNNEL NO	ENDPOINT 1		ENDPOINT 2	
	X-COORD	Y-COORD	X-COORD	Y-COORD
211	5489.01	5583.26	5489.01	5843.26
212	5514.01	5599.50	5514.01	5859.50
213	5539.01	5615.73	5539.01	5875.73
214	5564.01	5631.97	5564.01	5891.97
215	5589.01	5648.20	5589.01	5908.20
216	5614.01	5664.44	5614.01	5924.44
217	5639.01	5680.67	5639.01	5940.67
218	5664.01	5494.76	5664.01	5956.91
219	5689.01	5482.42	5689.01	5973.14
220	5714.01	5469.38	5714.01	5989.38
221	5739.01	5485.61	5739.01	6005.61
222	5764.01	5501.85	5764.01	6021.85
223	5789.01	5518.08	5789.01	6038.08
224	5814.01	5534.32	5814.01	6054.32
225	5839.01	5550.55	5839.01	6070.55
226	5864.01	5566.79	5864.01	6086.79
227	5889.01	5583.02	5889.01	6103.02
228	5914.01	5648.43	5914.01	6119.26
229	5939.01	5670.63	5939.01	6135.49
230	5964.01	5682.90	5964.01	6151.73
231	5989.01	5685.82	5989.01	6167.96
232	6014.01	5684.06	6014.01	6184.20
233	6039.01	5680.43	6039.01	6200.43
234	6064.01	5677.81	6064.01	6197.81
235	6089.01	5675.18	6089.01	6195.18
236	6114.01	5672.55	6114.01	6192.55
237	6139.01	5669.92	6139.01	6189.92
238	6164.01	5667.30	6164.01	6187.30
239	6189.01	5664.67	6189.01	6184.67
240	6214.01	5662.04	6214.01	6182.04
241	6239.01	5659.41	6239.01	6179.41
242	6264.01	5656.79	6264.01	6176.79
243	6289.01	5654.16	6289.01	6174.16
244	6314.01	5651.53	6314.01	6171.53
245	6339.01	5648.90	6339.01	6168.90
246	6364.01	5646.28	6364.01	6166.28
247	6389.01	5643.65	6389.01	6163.65
248	6414.01	5641.02	6414.01	6161.02
249	6439.01	5638.39	6439.01	6144.90
250	6464.01	5635.77	6464.01	6112.83
251	6489.01	5633.14	6489.01	5893.14
252	6514.01	5630.51	6514.01	5890.51
253	6539.01	5627.88	6539.01	5887.88
254	6564.01	5625.26	6564.01	5885.26
255	6589.01	5622.63	6589.01	5882.63
256	6614.01	5620.00	6614.01	5880.00
257	6639.01	5617.37	6639.01	5877.37

List of SKB reports

Annual Reports

1977-78
TR 121
KBS Technical Reports 1 – 120
Summaries
Stockholm, May 1979

1979
TR 79-28
The KBS Annual Report 1979
KBS Technical Reports 79-01 – 79-27
Summaries
Stockholm, March 1980

1980
TR 80-26
The KBS Annual Report 1980
KBS Technical Reports 80-01 – 80-25
Summaries
Stockholm, March 1981

1981
TR 81-17
The KBS Annual Report 1981
KBS Technical Reports 81-01 – 81-16
Summaries
Stockholm, April 1982

1982
TR 82-28
The KBS Annual Report 1982
KBS Technical Reports 82-01 – 82-27
Summaries
Stockholm, July 1983

1983
TR 83-77
The KBS Annual Report 1983
KBS Technical Reports 83-01 – 83-76
Summaries
Stockholm, June 1984

1984
TR 85-01
Annual Research and Development Report 1984
Including Summaries of Technical Reports Issued during 1984. (Technical Reports 84-01 – 84-19)
Stockholm, June 1985

1985
TR 85-20
Annual Research and Development Report 1985
Including Summaries of Technical Reports Issued during 1985. (Technical Reports 85-01 – 85-19)
Stockholm, May 1986

1986
TR 86-31
SKB Annual Report 1986
Including Summaries of Technical Reports Issued during 1986
Stockholm, May 1987

1987
TR 87-33
SKB Annual Report 1987
Including Summaries of Technical Reports Issued during 1987
Stockholm, May 1988

1988
TR 88-32
SKB Annual Report 1988
Including Summaries of Technical Reports Issued during 1988
Stockholm, May 1989

1989
TR 89-40
SKB Annual Report 1989
Including Summaries of Technical Reports Issued during 1989
Stockholm, May 1990

Technical Reports
List of SKB Technical Reports 1991

TR 91-01
Description of geological data in SKB's database GEOTAB
Version 2
Stefan Sehlstedt, Tomas Stark
SGAB, Luleå
January 1991

TR 91-02
Description of geophysical data in SKB database GEOTAB
Version 2
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SGAB, Luleå
January 1991

TR 91-03
1. The application of PIE techniques to the study of the corrosion of spent oxide fuel in deep-rock ground waters
2. Spent fuel degradation
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TR 91-04
Plutonium solubilities
I Puigdomènech[1], J Bruno[2]
[1]Enviromental Services, Studsvik Nuclear, Nyköping, Sweden
[2]MBT Tecnologia Ambiental, CENT, Cerdanyola, Spain
February 1991

TR 91-05
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SGAB, Luleå
April, 1991

TR 91-06
Description of background data in the SKB database GEOTAB
Version 2
Ebbe Eriksson, Stefan Sehlstedt
SGAB, Luleå
March 1991

TR 91-07
Description of hydrogeological data in the SKB's database GEOTAB
Version 2
Margareta Gerlach[1], Bengt Gentzschein[2]
[1]SGAB, Luleå
[2]SGAB, Uppsala
April 1991

TR 91-08
Overview of geologic and geohydrologic conditions at the Finnsjön site and its surroundings
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[1]Conterra AB
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January 1991

TR 91-09
Long term sampling and measuring program. Joint report for 1987, 1988 and 1989. Within the project: Fallout studies in the Gideå and Finnsjö areas after the Chernobyl accident in 1986
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Sealing of rock joints by induced calcite precipitation. A case study from Bergeforsen hydro power plant
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[2]Golder Geosystem AB
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Impact from the disturbed zone on nuclide migration – a radioactive waste repository study
Akke Bengtsson[1], Bertil Grundfelt[1],
Anders Markström[1], Anders Rasmuson[2]
[1]KEMAKTA Konsult AB
[2]Chalmers Institute of Technology
January 1991

TR 91-12
Numerical groundwater flow calculations at the Finnsjön site
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Hans Lindberg, Jan Bjelkås
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February 1991

TR 91-13
Discrete fracture modelling of the Finnsjön rock mass
Phase 1 feasibility study
J E Geier, C-L Axelsson
Golder Geosystem AB, Uppsala
March 1991

TR 91-14
Channel widths
Kai Palmqvist, Marianne Lindström
BERGAB-Berggeologiska Undersökningar AB
February 1991

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December 1990

TR 91-16
Porosity, sorption and diffusivity data compiled for the SKB 91 study
Fredrik Brandberg, Kristina Skagius
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April 1991

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Robert Lagerbäck
May 1991

TR 91-18
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May 1991

TR 91-19
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[1]Starprog AB
[2]SKB AB
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TR 91-20
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R Stanfors, M Erlström, I Markström
June 1991

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K-E Almén, O Zellman
June 1991

TR 91-22
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P Wikberg, G Gustafson, I Rhén, R Stanfors
June 1991

TR 91-23
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Gunnar Gustafson, Magnus Liedholm, Ingvar Rhén, Roy Stanfors, Peter Wikberg
June 1991

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Jan-Erik Andersson, Rune Nordqvist, Göran Nyberg, John Smellie, Sven Tirén
February 1991

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The role of the disturbed rock zone in radioactive waste repository safety and performance assessment. A topical discussion and international overview.
Anders Winberg
June 1991

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Testing of parameter averaging techniques for far-field migration calculations using FARF31 with varying velocity.
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[1]KEMAKTA Consultants Co
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Verification of HYDRASTAR. A code for stochastic continuum simulation of groundwater flow
Sven Norman
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July 1991

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SGAB, Uppsala
June 1991

TR 91-29
Soil map, area and volume calculations in Orrmyrberget catchment basin at Gideå, Northern Sweden
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June 1991

TR 91-30
A resistance network model for radionuclide transport into the near field surrounding a repository for nuclear waste (SKB, Near Field Model 91)
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Department of Chemical Engineering,
Royal Institute of Technology, Stockholm
June 1991

TR 91-31
Near field studies within the SKB 91 project
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[1]Conterra AB
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June 1991

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Transient nuclide release through the bentonite barrier - SKB 91
Akke Bengtsson, Hans Widén
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May 1991

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SIMFUEL dissolution studies in granitic groundwater
I Casas[1], A Sandino[2], M S Caceci[1], J Bruno[1],
K Ollila[3]
[1]MBT Tecnologia Ambiental, CENT, Cerdanyola, Spain
[2]KTH, Dpt. of Inorganic Chemistry, Stockholm, Sweden
[3]VTT, Tech. Res. Center of Finland, Espoo, Finland
September 1991

TR 91-35
Storage of nuclear waste in long boreholes
Håkan Sandstedt[1], Curt Wichmann[1],
Roland Pusch[2], Lennart Börgesson[2],
Bengt Lönnerberg[3]
[1]Tyréns
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