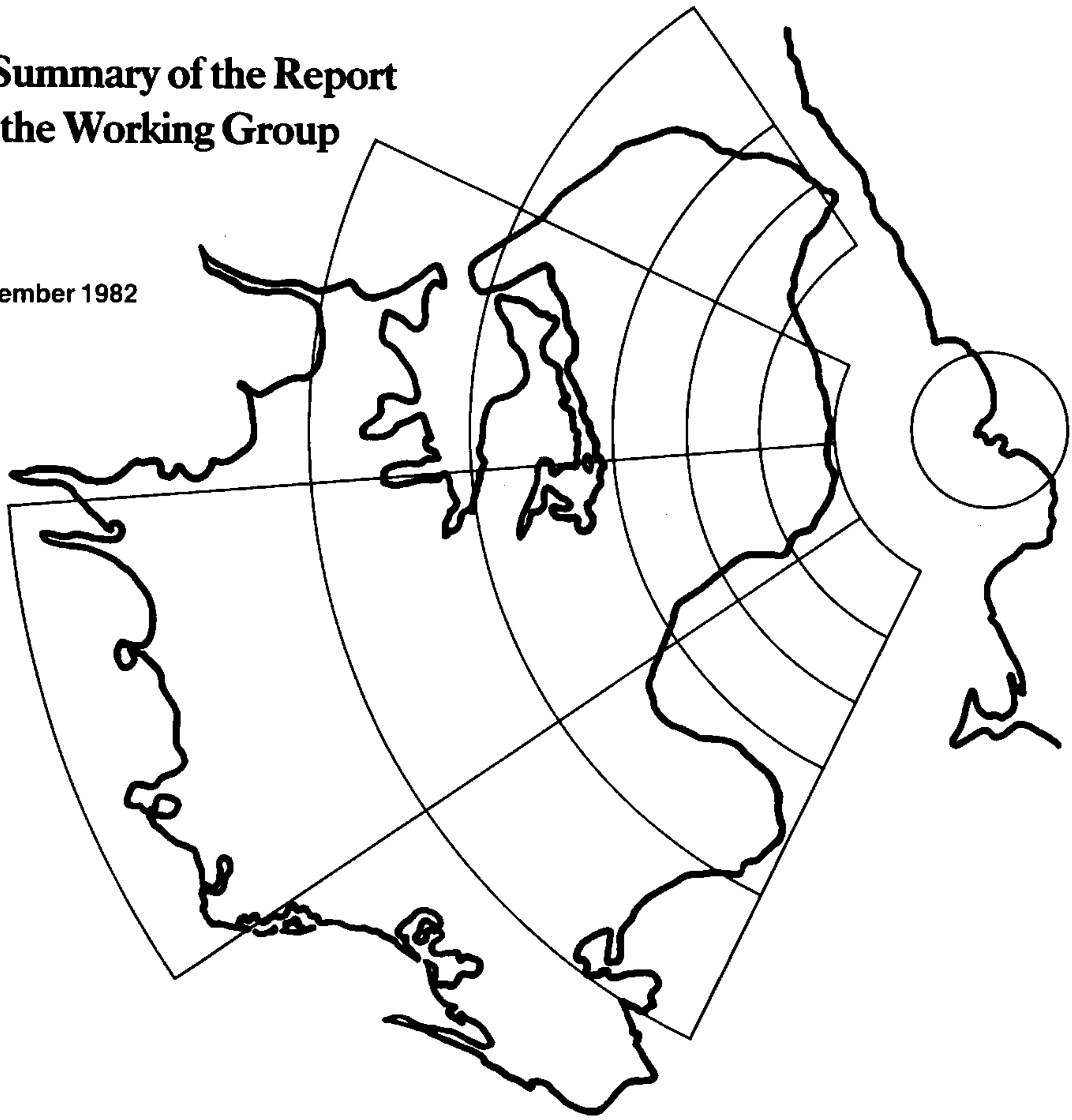
Radioactive Contamination of Danish Land Areas in the Event of a Large Scale Accident at the Swedish Barsebäck Nuclear Power Plant

A Summary of the Report by the Working Group

November 1982



The National Agency for Environmental Protection, Denmark

614.876 : 504.055 : 621.039.58
B 4 4.2

Radioactive Contamination of Danish Land Areas in the Event of a Large Scale Accident at the Swedish Barsebäck Nuclear Power Plant

A Summary of the Report by the Working Group

November 1982

The National Agency for Environmental Protection, Denmark

ISBN 87-550-0892-5 Forsøgsanlæg Risø

FOREWORD

This is a translation of the summary of a report from November 1981 on the possible consequences of serious radioactive contamination of areas of land in Denmark after a large scale, but at the same time highly unlikely accident at the Barsebäck nuclear power plant in Sweden.

The report was issued by the National Agency of Environmental Protection and was the work of a Working Group set up by the Agency in 1978. The National Board of Health, Risø National Laboratory, the Inspectorate of Nuclear Installations and the Agency itself were represented in the Group, of which Professor Ove Nathan was also a member.

Two special reports were prepared, one by Risø National Laboratory and one by Professor S. Kjeldsen-Kragh and lecturer P. E. Stryg of the Institute of Economics of the Royal Agricultural and Veterinary University, in connection with the present report. These describe, for example, the technical and economic calculations carried out at the request of the working Group; the members of the Group used the material presented in these two reports according to their own judgement when preparing the present report. (Both special reports are appended to the original, Danish-language version of the report).

Professor Nathan made a minority statement in which he took exception to the working of the report as a whole: this, too, is included in the Danish report.

It shoud be emphasized that the Agency's report is to certain extent based on studies and calculations carried out to a degree of detail not previously experienced in Denmark or abroad. The Agency thus finds it natural that the report should be the subject of discussion on a number of points.

Finally, when considering the risks associated with the Barsebäck nuclear power plant, it should be taken into account that the plant is designed to prevent the occurrence of accidents and subsequent releases of radioactive material to the environment.

Contents Page

1. INTRODUCTION.

1.1. Background and objectives of the report.

In November 1978 the National Agency of Environmental Protection issued a report on the possible consequences in Denmark of a "worst conceivable" accident at the Barsebäck nuclear power plant in Sweden. This included to a certain extent problems associated with the contamination of areas of land by radioactive material on the basis of studies carried out at Risø National Laboratory and in Sweden. The Agency admitted, however, that a number of questions relating to radioactive contamination of areas of land in Denmark were not exhaustively treated. Finding these questions of much importance, the Agency decided in collaboration with the National Health Authority to issue a special report on them.

In December 1978 the Agency set up a Working Group to deal with this matter. The members were nominated by Risø National Laboratory, the National Health Authority, the Inspectorate of Nuclear Installations and the Agency itself. At the time that the work of this Group was completed its members were:

- Niels Busch, deputy director (now director), Risø National Laboratory
- Poul K. G. Emmersen, consultant, National Agency of Environmental Protection (chairman)
- Professor Mogens Faber (nominated by the National Board of Health)
- H. L. Gjørup, head of division, Risø National Laboratory
- Per Grande, director, National Institut for Radiation Hygiene
- Henning Jensen, M. Sc., Inspectorate of Nuclear Installations
- Professor Ove Nathan, personal member (now headmaster of the University of Copenhagen)
- H. P. Ryder, consultant, National Agency of Envrinmental Protection
- Kirsten Leth, principal, National Agency of Environmental Protection (secretary)
- Preben C. Hansen, M. Sc., National Agency of Environmental Protection (technical secretary).

The task of the Group was to:

- provide a description of the possible fallout of radioactive material on Danish territory if an accident should occur at the Barsebäck nuclear reactor plant. The description was to cover selected accident sequences on meteorological circumstances, in order to:

- evaluate the possibility of and the costs involved in different countermeasures to limit radiation levels in the areas affected by fallout, and further to

- assess to what degree utilization of the affected areas should be curtailed. In continuation of this the Group was to evaluate the effects on society of the situations described.

Apart from the material that was either in the possession of or obtainable by the Agency, the working Group was empowered to call on the assistance of Risø National Laboratory, the Civil Defence authorities, and the Directorate of Labour Inspection, as well as any other bodies necessary.

1.2. The work and discussions of the Group.

During the Group's discussion of the above objectives, the Agency stated that work should not be carried out with a view to planning for emergencies but should be focussed only upon the more long-term social consequences if large areas of land should be contaminated. In the same connection, the National Board of Health voiced the opinion that it would not be meaningful in advance to set up dose criteria for the initiation of dose-reducing measures; the need for these would have to be evaluated in the actual situation taking into account the real circumstances.

On this background, and in accordance with international practice, the Working Group did not set up dose limits for the initiation of dose-reducing countermeasures, neither did they find it appropriate to establish dose limits, or other rules for radiation protection applicable in controllable (normal) situations, on which to evaluate so abnormal a situation as radioactive contamination of large areas of land.

The question of criteria for the initiation of countermeasures to limit radiation levels in areas affected by contamination (dose-reducing measures) was dealt by a subsidiary group. The findings of this group led to a decision that the report should elucidate the social consequences on the basis of alternative criteria for determining the areas from which the population might have to be relocated. Likewise, alternative criteria were selected for determining when businesses, etc., should be suspended.

With respect to foodstuffs grown on areas of contaminated land, the Group chose to assess the costs of different countermeasures having different dose-reducing effects, e.g., the destruction of crops and animal products for one or more years and the reorganisation of production in the agricultural areas affected.

1.3. The provision of assistance in the preparation of the report.

In order to provide a basis for the evaluations of the Working Group, Risø National Laboratory carried out a number of investigations and calculations relating to the consequences of radioactive contamination of land on Zealand following a core-melt accident at Barsebäck. These studies were carried out on lines laid down by the Working Group and on technical assumptions set up by the National Laboratory itself. The report produces by Risø constitutes annex 1 of the Danish version of the report.

The calculations of econimic consequences were made by professor Søren Kjeldsen-Kragh and P. E. Stryg, lecture, of the Institute of Economics of the Royal Agricultural and Veterinary University. This work was based on the contamination situations established by Risø, the assumed dose-reducing measures, as well as on assumptions determined by the authors themselves. Annex II of the Danish version of the report is a full description of this work. (Only available in Danish).

The activities of the Group were based on provisional versions of the two annexes. Incidentally, it should be noted that the Group exercised discretion when using this information - the material as a whole does not express the opinions of the Working Group.

Different information and data were provided by the Civil Defence authorities, the National Bureau of Statistics, and the National Institute for Building Research, just as the Ministry of Justice provided assistance on the preparation of a section dealing with compensation questions.

1.4. The report.

The report provides a summary of the calculations of the effects on health and economy on Danish territory of a "worst conceivable" accident at the Barsebäck plant, and of a rather less serious, but presumable more probable accident. Furthermore, it contains some considerations about the other effects - also the psychological ones - which might seriously effects the total picture of the consequences but which do not allow any calculations in advance.

A main assumption for the report was that it should be based on a "worst conceivable" accident at the Barsebäck plant. Both in the case of this accident, and in that of the rather less serious one, the Group agreed that calculations should be based on the release categories (BWR-2, BWR-3) defined in WASH-1400, the reactor safety study carried out in the USA.

The dose calculations carried out by Risø are highly dependent on the magnitudes of the release, as well as on a number of psysical or calculational quantities of which there is insufficient knowledge and which are associated with large uncertainties. An example is the velocity of deposition of radioactive particles on fields, streets and houses. Moreover, the calculations are extremely complicated and extensive, which implied the necessity of making a number of simplifications in the calculation procedures. These circumstances mean that there is considerable uncertainty associated with the results.

The Working Group points out that it was necessary to omit the treatment of a number of factors that it could not be ignored in an actual situation - e.g., problems concerning the special life styles of a few individuals, problems associated with the removal of contaminated matter, as well as problems of the capacity of the road system. However, the Group feel that these are circumstances that would not alter the essential details of the overall picture such as it appears from the report.

Finally, the Group wishes to emphasize the contamination pictures described in this report are the result of theoretical calculations of extremely improbable situations; the Group chose to make no actual evaluation of the probabilities that can be ascribed to the accident situations under consideration.

The calculations of the social consequences of such accidents must be viewed in this light; therefore they cannot be applied as a matter of course to considerations of the risk posed by Barsebäck, or of the extent of any measures to reduce this risk.

1.5. Appendix.

The task of the Group was to treat only the consequences of possible radioactive contamination of areas of land in Denmark in the event of a serious accident at the Barsebäck nuclear power plant.

As a result the effects of external radiation from the cloud of radioactivity and of the inhalation of radioactivity from this cloud are not included in the report.

The question of whether the largest average individual doses-totalled from the passage of the cloud itself and from the following land contamination - could be large enough to imply acute radiation injuries is treated in an appendix to the Danish version of the report, and it is concluded that this would not be the case.

This means that the effects on health resulting from the contamination of areas of land can be dealt with independently of the effect of the passage of the cloud itself.

2. SUMMARY AND CONCLUSION.

This describes the most important results and conclusions of the Group´s work.

The calculations on which this report is based were carried out at Risø (the report in English translation as Risø-R-462) and by professor S. Kjeldsen-Kragh and lecturer Poul Erik Stryg (De økonomiske virkninger af et stort Barsebäckuheld. (The economic Consequences of a serious accident at the Barsebäck plant)). The two reports are appended to the original Danish version of the present report.

It should be noted that the Group´s work was based on provisional versions of the two annexes, and that the Group exercised descretion when using this information - the material does not as a whole express the opinions of the Working Group.

2.1. Assumptions underlying the report.

Contamination following upon a release of radioactive material depends in general on a number of different factors, apart from on the magnitude and composition of the release. As shown on fig. 2.1-1 the most important of these are the dispersion of radioactive matter in the atmosphere (weather conditions), the deposition on the ground (nature of the surface and weather conditions), the level of contamination (time variation of the radiation and effect of the climate, etc.), shielding (this applies to external radiation), i.e., the shielding against radiation that is afforded by structures and roughness of the terrain, etc., and the food chains (this applies to internal radiation). Given knowledge of these factors, the doses to the population and thus the effects on health can be calculated in principle for the situation (reference situation) in which no special dose-reducing countermeasures are put into practice.

The Working Group considered, however, a number of possible dose-reducing countermeasures and from these they selected a

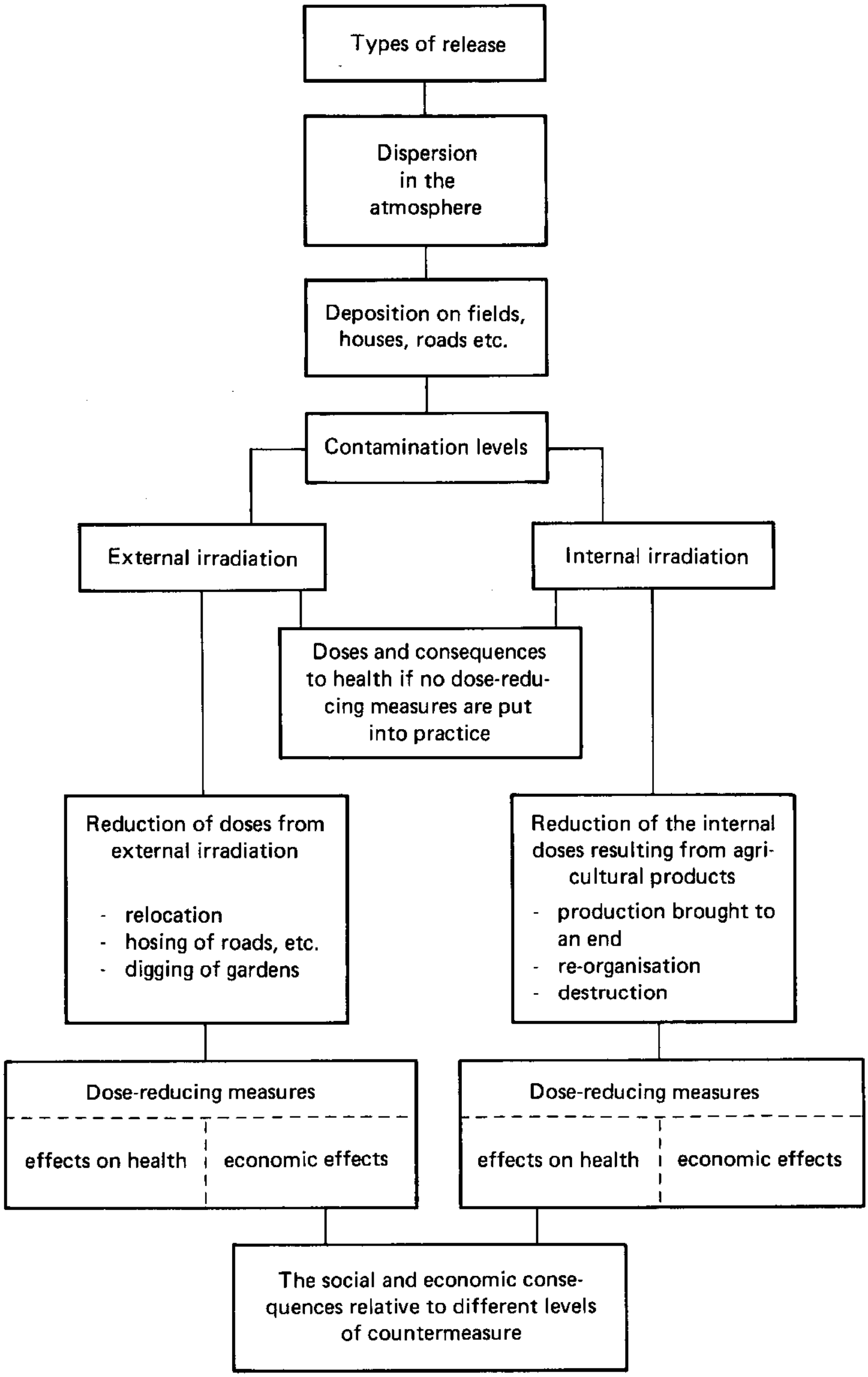


Fig.. 2.1-1. The principle underlying the sequence of calculations.

number of different, practically feasible ones on which to base the consequence calculations.

The countermeasures were finally combined at different levels representing different balances of achievable martinal reduction of the effects on health and the associated costs to the economy. For each level, the calculated residual effects on health and the total economic consequences of implementing the measures are presented.

The factors mentioned above and the underlying assumption used in the calculations of the consequences are briefly described in the following together with the most important dose-reducing measures and social consequences.

In a number of fields the dose calculations are based on theoretical considerations and on mathematical models with complete experimental foundation, just as there are certain circumstances that are excluded from the assumptions. For these reasons the results of this report can only be considered as a rough outline of a situation worth contamination of the land by radioactivity as it might appear in reality.

2.1.1. The release.

As mentioned in the introduction, a chief assumption of the report was that it should be based on a kind of "worst conceivable" release of radioactive material resulting from an accident at one of the reactor units of the Barsebäck nuclear power plant. In addition, the Working Group gave consideration to a rather less serious, but presumably more probable release.

No such serious release has ever occured in the history of nuclear power - not at a reactor plant of the same type as Barsebäck nor at any commercial nuclear power plant at all. Therefore the Group decided to base their report on two of the five release categories defined in WASH-14oo for the most serious accident sequences.

The largest of the two releases investigated is the so-called BWR-2 release. This is deemed to have the most serious consequences associated with land contamination, in part because a BWR-2 release contains the largest amount of the long-lived radioactive material caesium-137 and in part because it is doubtful whether there is any psysical basis for imagining a larger total release at all.

The smallest of the two releases investigated is a so-called BWR-3 release, which is caracterised by the fact that it contains five times less caesium than the BWR-2 release and nine times less radioactive iodine.

It must, however, be emphasized that both these releases are in fact model releases with little probability in therory and which have not taken place in practice.

New information has very recently come to light in the USA, and this seems to indicate that a release larger than a BWR-3 is a physical impossibility. Part of this information was provided by three chemists from American research institutes; their findings are based on an analysis of the release of radioactive material from the core of the reactor at Three Mile Island. Other information appeared in a report from the EPRI on "Realistic Estimates of the Consequences of Nuclear Accidents" issued in November 198o. This primarily concerns the release of radioactive iodine, but it is also indicated that the release of caesium may be considerably smaller than supposed hitherto.

The American reactor safety authorities recently initiated a re-evaluation of the foundation for determining the magnitudes of releases in relation to formal licensing requirements. The new information mentioned above will be included in this study.

<u>2.1.2. Dispersion of the radioactive release in the atmosphere.</u>
Should there be a release at the Barsebäck plant, the most serious consequences for Danish territory would, of course, occur if the wind was blowing from the east. The calculations assume that the mean wind direction after the release remains constantly

249^{o}. This implies, inter alia, that the most densely populated parts of Copenhagen would be affected.

For the "worst conceivable" release (BWR-2), calculations were made to investigate which weather situation would result in the most serious consequences. This situation, which is characterised for example by a wind speed of about 5 m/s and no precipitation, was used in the following calculations.

It should be emphasized that other weather situations could imply dispersion patterns giving considerably larger doses to small groups of the population but, at the same time, contamination would be confined to smaller areas.

For the rather less serious release (BWR-3), use is made of the most probable weather situation, which is characterised for example by a wind speed of lo m/s and no precipitation.

2.1.3. Deposition of radioactive materials.

Deposition of radioactive material on fields, roads, houses, etc., depends on the properties of the material in question, on the weather conditions and on the nature of the surface concerned.

Calculation technicalities necessitated the use of very simplified assumptions relating to the deposition velocity in different areas. The larger the deposition velocity for a given concentration of radioactivity in air, the larger the dose at the place concerned, however.

When the Working Group started on their work, Risø´s dose calculations were based on the same value for dry deposition velocity in both urban and rural areas, namely 2 cm/s. This value was chosen because, within the area at the distance considered and without making allowances for the nature of the surfaces, it implies the greatest contamination and hence the most serious effects on health. Later on Risø produced information that the deposition velocity applying to rough surfaces, such as fields of grass and grain, and so on, is less than 2 m/s, namely o.2-1 cm/s. Likewise Risø carried out measurements that led to the conclusion that the deposition velocity applying to smooth surfaces - such as the surfaces of structures and roads - is of a magnitude of one-fifth that applying to rough ones.

In their final calculations Risø thus found it correct to alter the deposition velocity applying to smooth surfaces to o.2 cm/s, even though in urban areas this implies smaller doses than those calculated initially. A deposition velocity of 2 cm/s was retained for rural areas.

In comparison it should be mentioned that WASH-14oo uses a common value of 1 cm/s deposition velocity, which applies both to rough and to smooth surfaces, inside a stated possible interval of o.1 - 1o cm/s. The Swedish report "Effektivare Beredskab" (Effective Preparedness) correspondingly uses a value of o.3 cm/s for all surfaces.

The Group took note of Risø's documentation for the deposition velocities, but it is felt that this question should be made the subject of continued study because of its importance for the pattern of land contamination.

2.1.4. The natural variation with time of radiation in contaminated areas.

Because of the natural decay of radioactive materials, radioactivity in contaminated areas decreases with time, most rapidly at first, and then gradually slower. One week after a release takes place, the radioactivity falls to approx. 5o%, after a month to approx. 1o%, and after a year to approx. 3% only because of natural decay. After ten years, the radioactivity has fallen to approx. o.7%. However, because of the effect of the climate, radioactivity actually decreases even further. In part, rain would imply some wash-out, and in part there would be a slow, continual wearing away of the deposited radioactive matter. Calculations relating to the surfaces of roads and structures take these factors into account.

2.1.5. Radiation shielding.

The external irradiation of the population, which results from radioactive material deposited on the ground (fields, roads, houses, vehicles, etc.) depends on the source of radiation (amount), on its distribution, and on the shielding effect of the materials through which the radiation passes.

The dose calculations make use of different average shielding factors applicable to people located out of doors, inside dwellings, at their places of work, and inside vehicles. For a location inside a dwelling, the distribution of types of dwelling (free-standing houses, blocks of flats) is taken into account. Moreover use is made of average times for time spent out of doors, inside the home, at work and inside a vehicle.

2.1.6. Internal irradiation resulting from the consumption of contaminated foodstuffs.

Radioactive contamination of agricultural areas implies an immediate contamination of all crops standing on the fields that are used to produce foodstuffs or as fodder for livestock. Furthermore, the soil itself will be contaminated and thus radioactive matter will be gradually taken up by crops via the roots. In this way both vegetable and animal foodstuffs can be contaminated. Different radioactive materials are not all taken up equally easily by the various organs of an animal or a human being. Similarly, a certain material is not taken up equally easily by different plants. Given knowledge of the radiactive materials, of the food chains and of the radiobiological factors involved, a calculation can be made of the internal irradiation of organs when there is knowledge of the level of contamination of the agricultural areas and the use of the crops for foodstuff production.

2.1.7. Dose-reducing countermeasures.

The countermeasures that society and individuals decide to put into practice to protect themselves against the effects of radiation of health in the case of land contamination should be in proportion to the reduction of health effects and to the economic resources of society. The Group considered different actions that could be taken to limit the doses received by the population and arrival at the following proposals for countermeasures that might be put into practice.

External irradiation.

A1: Relocation of the population living in the most highly contaminated areas. The effects of four different relocation criteria were studied. These are 3o, 1o, 3 and o.5 rem as wholebody dose over a month to the individual persuing normal activities; they are coded A1.4, A1.3, A1.2, A1.1 in the tables. As the calculated individual doses do not exceed 14 rem, the 3o rem criterion does not give rise to any relocation at all, for which reason it is not discussed any further in the report.

Calculations show that relocation as the only dose-reducing countermeasure to reduce the total collective dose (4o million manrem) resulting directly from radiation in the contaminated areas following upon a BWR-2 release by approximately o, 3, 10 and 12% - where the per cent values refer to the relocation criteria 3o, 1o, 3 and 0.5 rem as wholebody dose to the individual per month.

The dose reduction resulting from relocation alone would thus be relatively modest, irrespective of which of the four relocation criteria is applied. The per cent values show, moreover, that any further dose reduction that might be achieved by using the o.5 rem instead of the 3 rem criterion would be marginal.

Depending on which of the above or other criteria is applied when considering relocation of the population a lower criterion might be needed for special population groups e.g., pregnant women, children.

Moreover, the Group considered it reasonable that industry and the like could continue operation in areas from which the population was otherwise relocated so long as the wholebody dose from work and transport over a week did not exceed the "permissible" monthdose concerned.

For both the contamination situations investigated (BWR-2 and BWR-3), calculations showed that only the o.5 rem/week criterion would imply the closure of industry in urban areas, and then for one week only inside a smaller area. As calculations prove that effects on health of this criterion can hardly justify its application, it is the Group´s opinion that the closure of industries, etc., in urban districts of the Greater Copenhagen area would be unwarranted.

A2: Decontamination through fire-hosing of streets and roads in urban districts.

Approximately 4o% of the radioactivity can be removed so long as hosing is carried out during the first weeks after the accident. However, the dose-reducing effect is not correspondingly large, e.g., because radiation from structure surfaces, etc., is not reduced correspondingly.

A3: Decontamination through burial of the deposited radioactive material in gardens of free-standing houses.

In this case the total dose rates out of doors and indoors can be reduced by factors of approximately 6 and 4, respectively.

Common to both decontamination procedure is the circumstance that they are assumed to be implemented successively in districts where the wholy-body dose over the second month exceeds o.25 rem. Without decontamination, the total dose over 3o years resulting from a BWR-2 release would be greater than 1o rem everywhere in these areas.

In addition, several other decontamination procedures might be considered in the concrete situation should it prove necessary. For instance, taking the longer view it would be possible to replace paving stones of pavement and asphalt surfaces of road and open spaces.

In agricultural areas the above measures might also be put into practice to a certain extent, but this is not taken into account in the dose calculations, just as no allowance is made for the effect of routine annual ploughing here.

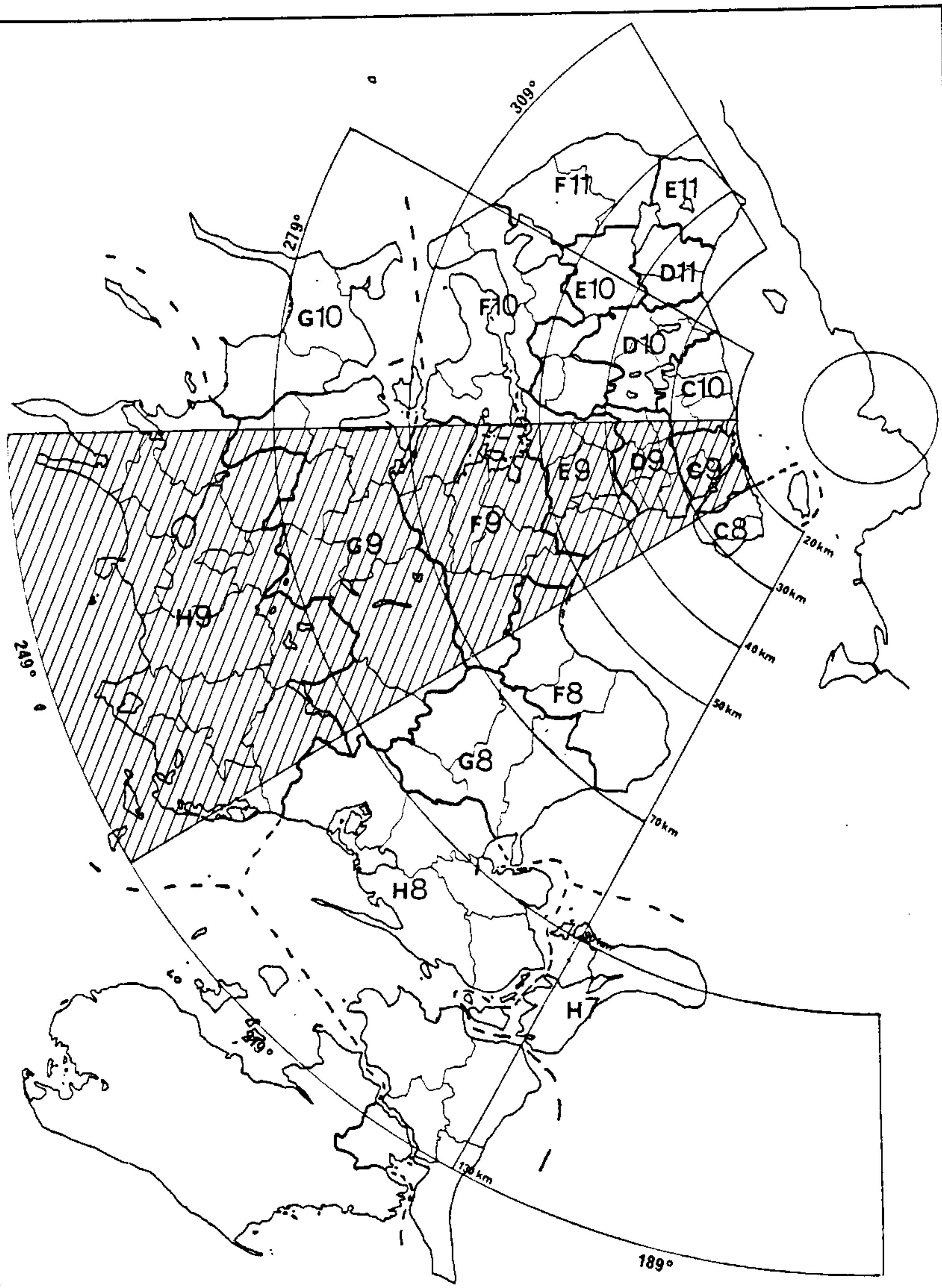


Fig. 2.1-2. Sector map of Zealand: The hatched area is that involved in counter-measures relating to agricultural production.

An effective reduction of the radiation levels on fields, etc., to afford protection from external (direct) irradiation could be achieved by ploughing in the deposited radiactivity. Ploughing experiments carried out at Risø combined with calculations showed that radiation levels can be reduced by about 90% by means of normal ploughing and by 98% by means of deep ploughing.

Internal irradiation.

The different proposals for countermeasures to reduce the internal irradiation resulting from the contamination of foodstuffs are the following:

B1: All foodstuff production in the contaminated areas of Zealand is discontinued for the first twelve month after the accident, see fig. 2.1-2.

B2: Foodstuff production in the contaminated area of Zealand is discontinued for the first 24 month after the accident.

B3: Agricultural production is brought to an end in the contaminated area of Zealand.

B4: The crops standing on the fields in the contaminated area of Zealand in the year of accident are destroyed. Livestock are housed and fed uncontaminated fodder. During the following two years (if possible already during the second year after the accident) field production is altered to a production of barley, and livestock production is confined to pigs fed on this barley. Alternatively, field production is confined to seed grain, seeds, sugar beet (for sugar production) and potatoes (for alcohol). Straw and other residual products are destroyed.

B5: Foodstuff production on the island of Funen is discontinued for the first twelve months after the accident.

Calculations show that proposals B3 and B4 are equally effective (approximately 100%) seen from the viewpoint of dose saving; as proposal B3 is associated with far the greatest costs, it was disregarded when selecting the different levels of countermeasure.

2.1.8. Effects on health of radioactive contamination of areas of land.

The possible effects on health of a release of radioactive material will depend on the radiation doses resulting in part directly from the passage of the radioactive cloud and in part from radioactive contamination of the land. According to the appendix (in the Danish version of the report), it appears that the calculated greatest average short-term doses to individuals combining those from the passage of the cloud and from contamination of the land, would not exceed the treshold value for acute radiation injuries.

Thus it can be concluded that the possible damage to the health of the population, corresponding to the calculated average individual doses resulting from a "worst conceivable" release from the Barsebäck plant over Danish territory, would as a general rule take the form of later-occurring effects such as leukaemia and other types of cancer and of genetic defects and foetal injuries. The cases of cancer would appear during a lifetime.

Nevertheless it cannot be excluded that a few individuals might receive doses that could give rise to acute radiation injury. This would apply in particular to individuals located out of doors during the passage of the cloud.

The assessment of the number of injuries was based on UNSCEAR´s risk figures. Use of these figures assumes that the risk to the individual increases in proportion to the radiation dose received, and that the total number of injuries in a population increases in proportion to the sum of all individual doses (the collective dose).

2.1.9. Economic consequences of radioactive contamination of land.

The decision to make use of certain dose-reducing countermeasures, and to what extent these should be implemented in the case of land contamination, can be taken in principle on the basis of a cost-benefit analysis.

However, the Group did not consider it their task to make such an analyses; they chose consider different practically feasible measures to varying extents, and to elucidate the associated effects on health and the costs to society.

2.2. Main results of the study of land contamination following upon a BWR-2 release.

2.2.1. The picture immediately after contamination of the land.

Figure 2.2-1 shows the areas inside which the average 3o-year individual dose might be greater that 5, 3o and 1oo rem. These values apply to the external (direct) irradiation from contaminated surfaces without implementation of any dose-reducing countermeasures.

The areas in question are of the following approximate sizes:

3o-year individual dose (rem) greater that	Area (km^2)	Greatest approximate distance from Barcebäck (km)
5	2ooo	11o
3o	475	7o
1oo	55	45

The collective dose over 3o years inside a distance of 11o km from Barsebäck is calculated to approximately 4o million manrem from external irradiation with no implementation of dose-reducing countermeasures.

The collective dose resulting from the consumption of contaminated foodstuffs made of agricultural products from Zealand and Funen would amount to approximately 204 million manrem, of which about 196 million are derived from foodstuffs originating on Zealand.

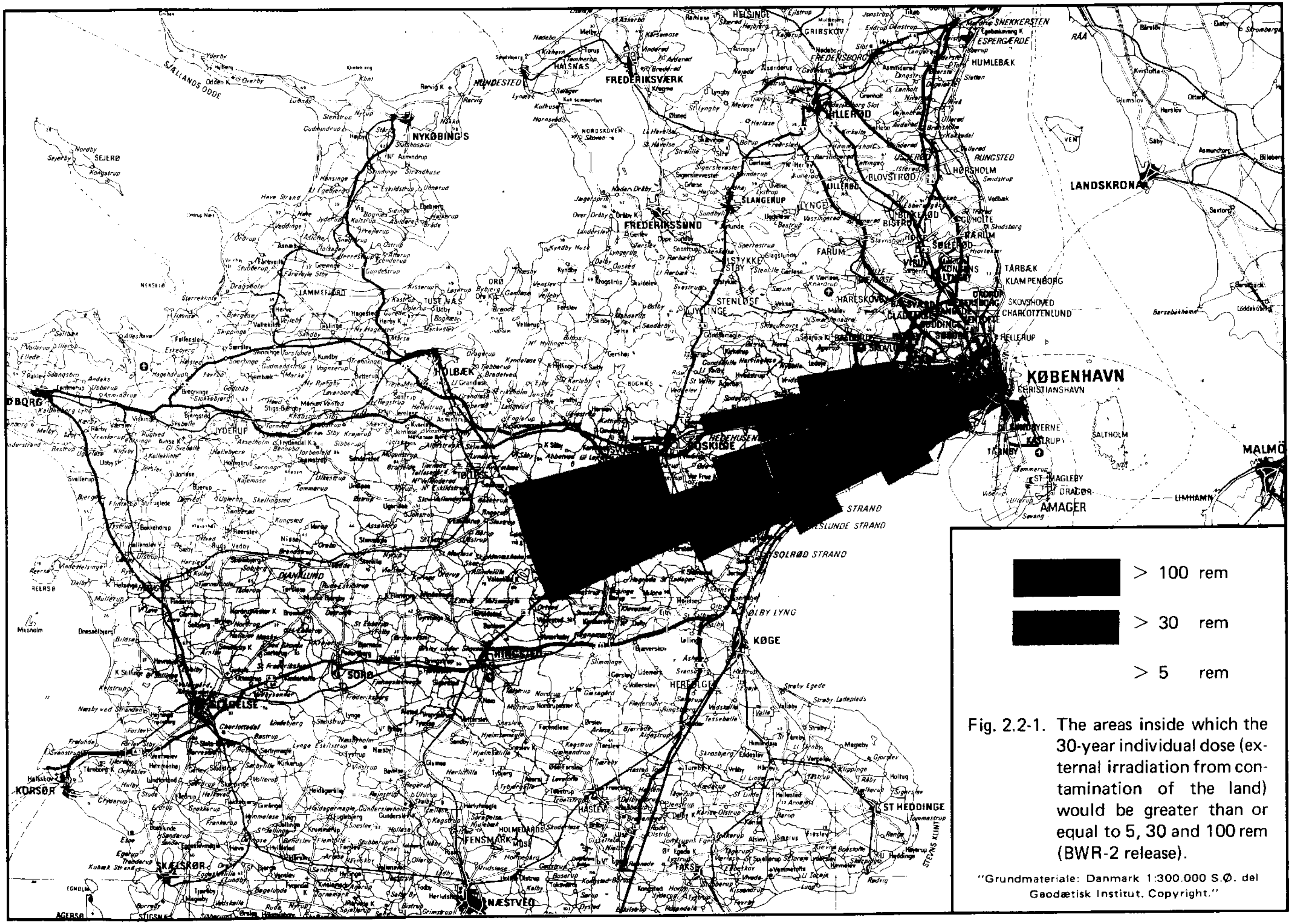


Fig. 2.2-1. The areas inside which the 30-year individual dose (external irradiation from contamination of the land) would be greater than or equal to 5, 30 and 100 rem (BWR-2 release).

"Grundmateriale: Danmark 1:300.000 S.Ø. del Geodætisk Institut. Copyright."

2.2.2. The proposed dose-reducing countermeasures.

The areas from which the population would be relocated when applying the evaluation criteria 10 rem/month and 3 rem/month are shown on fig. 2.2-2. The approximate size of the areas and the density of the population are as follows:

Criterion	Areas (km^2)	Number of population
10 rem/month	80	105 000
3 rem/month	565	630 000

Calculations show that no (average) individual dose would exceed 14 rem in the first month, for which reason a criterion of greater value would not imply relocation of the population.

If the 10 rem/month relocation criterion is applied, then the relocated population could return after one month without the implementation of decontamination procedures. With the exception of a few districts, the same would apply if the 3 rem/month criterion was used. If these districts are decontaminated, the relocated population could return to all areas after one month, also when the above criterion is applied.

According to the criterion proposed in this case, decontamination should be carried out in the areas shown on fig. 2.2-3. In the dose calculations it is assumed that decontamination procedures can be completed within two months.

With respect to agricultural production in the contaminated areas, it was decided, following upon an evaluation of the advantages and disadvantages of the individual measures proposed, to calculate the effects on public health and the economy that correspond to the following combinations of countermeasure: B1, B4 and B4 + B5, cf. the explanation given in section 2.1.7.

If the combinations of countermeasure relating to agricultural production thus selected are combined with the above-described countermeasures providing protection against external irradiation from contaminated surfaces, the result is three different total levels of countermeasure - I, II and III.

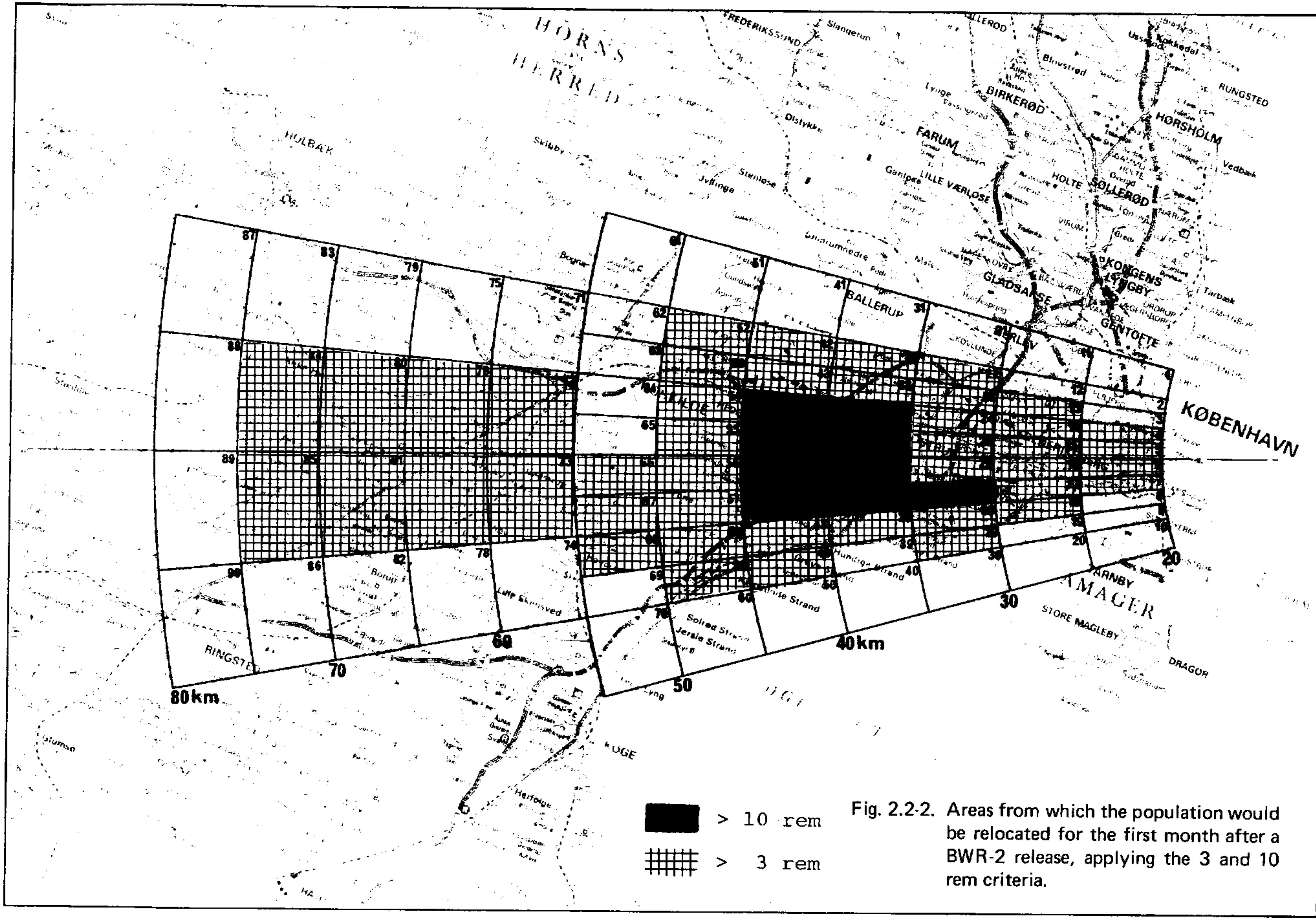


Fig. 2.2-2. Areas from which the population would be relocated for the first month after a BWR-2 release, applying the 3 and 10 rem criteria.

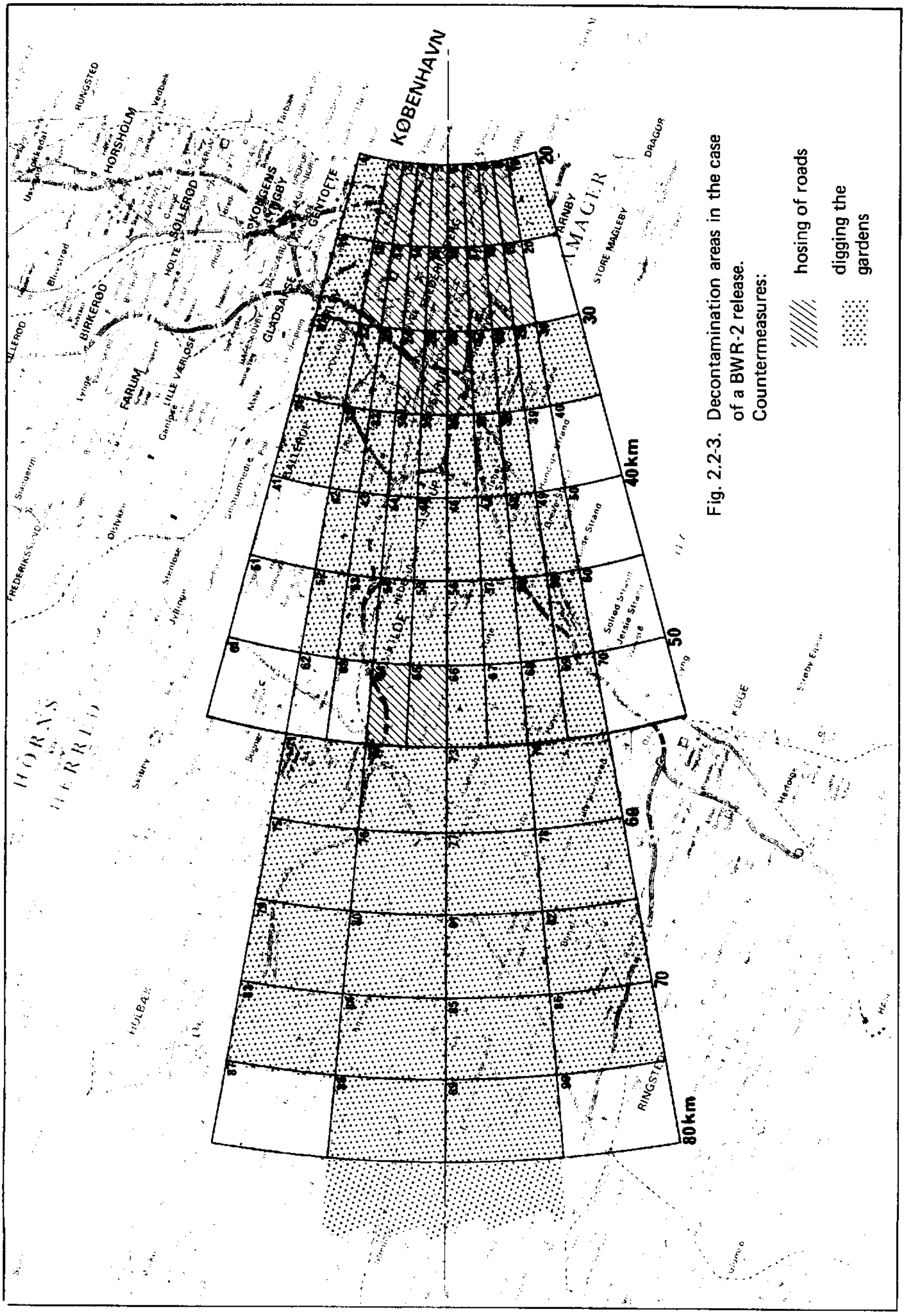


Fig. 2.2-3. Decontamination areas in the case of a BWR-2 release. Countermeasures:

Table 2.2.-1 gives a survey of the calculated effects on the health of the population, and on the economy, of a BWR-2 release from Barsebäck over Danish territory that apply to the three levels of countermeasure selected.

The countermeasures proposed by the Working Group for the reduction of the doses that might result from the consumption of contaminated foodstuffs would imply considerable costs to the economy. These measures relate primarily to the contaminated area of Zealand but parts of Funen might be affected too.

Furthermore, it cannot be excluded that marketing prospects for products from uncontaminated or only slightly contaminated areas would be reduced, although there would be no actual risk to health associated with the consumption of these foodstuffs.

When considering agricultural production an attemp was made to select the countermeasure most favorable to prices if a choice had to be made between countermeasures of equal dose-reducing effect.

In an economic assessment of the significance of land contamination on Greater Copenhagen area, an entirely decisive issue is whether or not work can be maintained in the areas from which the population is otherwise relocated.

2.3. Main results of study of land containimation following upon a BWR-3 release.

2.3.1. The picture immediately after contamination of the land.

Figure 2.3-1 shows the areas inside the average 30-year individuel dose might be greater that 5 or 10 rem. These figures apply to external (direct) irradiation from contaminated surfaces when no dose-reducing countermeasures are put into practice.

The areas in question are of the following approximate sizes:

Table 2.2-1. Survey of the calculated effects on health and on the economy of a BWR-2 release.

	"N"[3]	Relevant level of countermeasure[1]		
		I	II	III
Residual dose in million manrem		53	25	15
No. of deaths from leukaemia and other types of cancer	400.000	5300	2500	1500
Foetal injuries	60.000	340	160	96
First-generation genetic defects		1400	680	410
Genetic defects in all	200.000	4200	2000	1200
Cost in thousand of millions kroner		3.2	3.7/2.9[2]	7.7/6.9[2]
Negative effect on the balance of payments in milliard kroner		3.1	3.6/2.8[2]	7.2/6.4[2]

1.) Level of countermeasure:

I A 1.3 + A 2 + A 3 + B 1
II A 1.3 + A 2 + A 3 + B 4
III A 1.2 + A 2 + A 3 + B 4 +B 5

2.) The figures are the sum totalled over the first 10 years as a result of two variants of agricultural reorganisation.

3.) The number of naturally occurring cases in Denmark during 30 years is given in column "N", and the increases in these figures pertaining to countermeasure levels I, II and III and for 30 years residence are given in columns I, II and III.

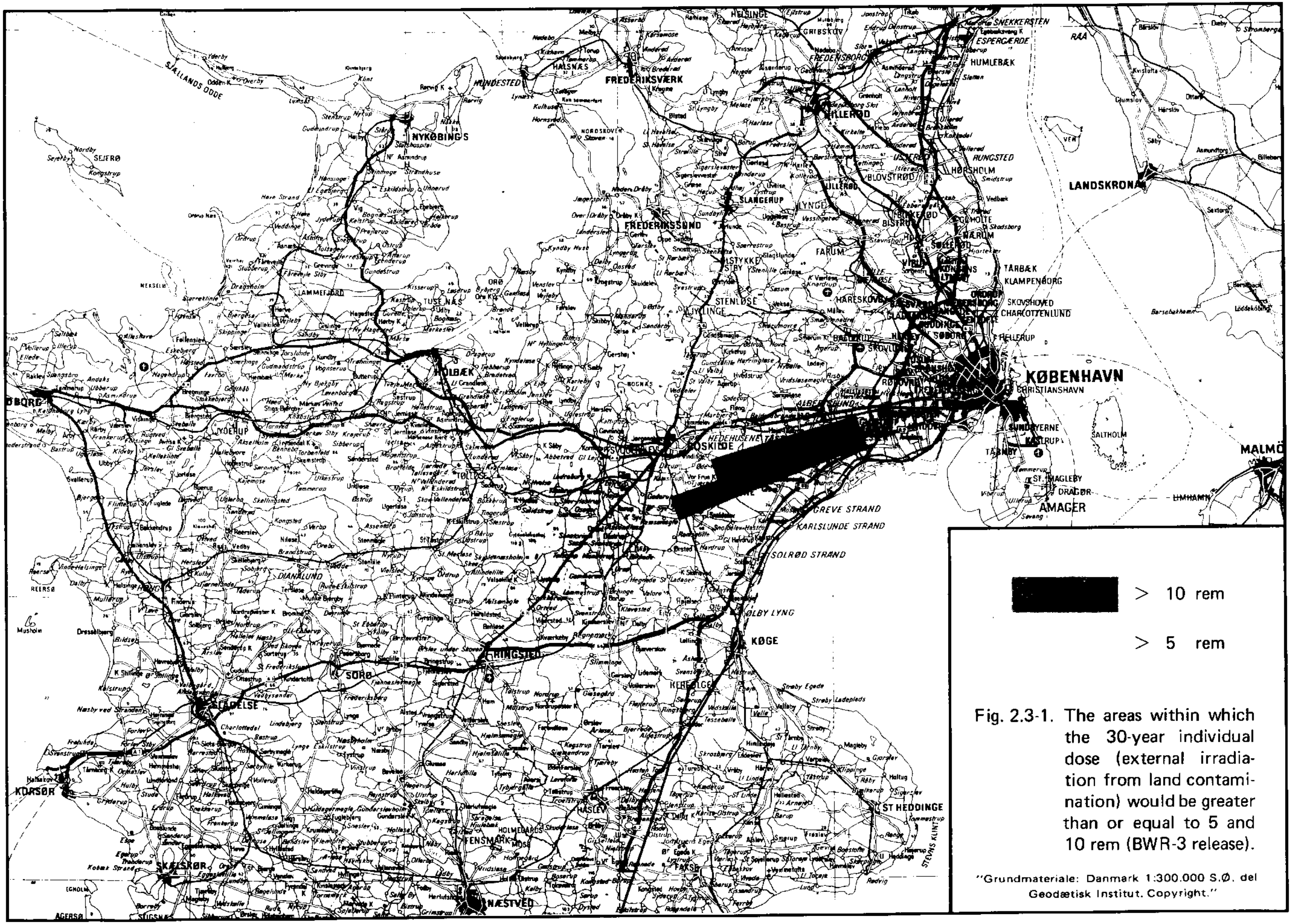


Fig. 2.3-1. The areas within which the 30-year individual dose (external irradiation from land contamination) would be greater than or equal to 5 and 10 rem (BWR-3 release).

30-year individuel dose (rem) greater that	Area (km^2)	Greatest approximate distance from Barcebäck (km)
5	325	70
10	70	55

The collective dose over 30 years within a distance of 110 km from Barsebäck is calculated to approx. 4 million manrem from external irradiation when no dose-reducing countermeasures are put into practice.

The collective dose resulting from the consumption of contaminated foodstuffs made of agricultural products from Zealand and Funen would, correspondingly, amounts to approx. 27 million manrem.

2.3.2. The proposed dose-reducing countermeasures.
Calculations showed that the average individuel doses over the first month would be less than 3 rem. For this reason relocation is not treated any further here.

Figure 2.3-2 shows the area in which the decontamination procedures A1, fire-hosing of roads, and A2, digging the gardens of free-standing houses, would be carried out according to the contamination criterion.

With respect to agricultural production in the contaminated areas, it was decided, as in the case of contamination following upon a BWR-2 release, to elucidate the effects on society that correspond both to countermeasure level B4 + B5 and to the level where no action is taken at all. It should be noted that, compared with the contamination situation after a BWR-2 release, it might be justifiable to take no action at all relation to agricultural production. On the other hand, if the decision was taken to put into practice large-scala countermeasures on Zealand (B4) after a BWR-3 release, it would be difficult to disregard the implementation of countermeasures on the island of Funen too (B5).

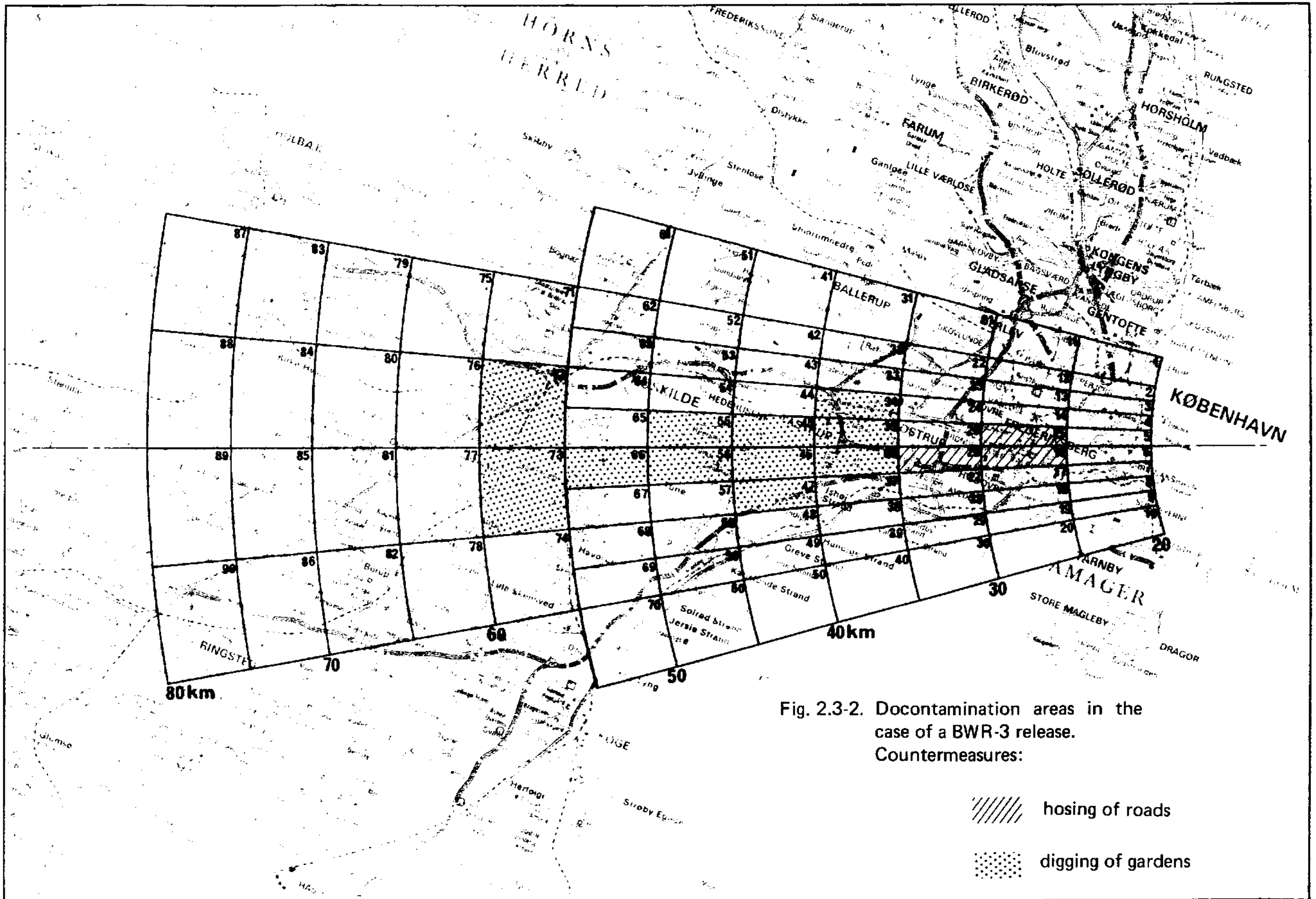


Fig. 2.3-2. Docontamination areas in the case of a BWR-3 release. Countermeasures:

Table 2.3-1. Survey of the calculated effects on health and on the economy of a BWR-3 release.

	"N"3)	Relevant level of countermeasure 1)	
		I	II
Residual dose in million manrem.		31	4
No. of deaths from leukaemia and other types of cancer	400.000	3100	400
Foetal injuries	60.000	200	26
First-generation genetic defects		840	110
Genetic defects in all	200.000	2500	320
Cost in thousand of millions kroner		small	7.2/6.4 2)
Negative effects on the balance of payments		none	7.2/6.4 2)

1.) Level of countermeasure:

I A 2 + A 3
II A 2 + A 3 + B 4 + B 5

2.) The figures are the sum totalled over the first 10 years as a result of two variants of agricultural reorganisation

3.) The number of naturally occurring cases in Denmark during 30 years is given in column "N", and the increases in these figures pertaining to countermeasure levels I and II and for 30 years residence are given in columns I and II.

Table 2.3-1 gives a survey of the calculated effects on health and the economy of the contamination of areas of Danish land following upon a BWR-3 release from the Barsebäck plant that apply to the two total countermeasure levels I and II selected.

2.4. Other effects on society.

The foregoing sections picture the effects on health and on the economy of two land contamination situations based on the different proposals for dose-reducing countermeasures set up by the Working Group.

However, it can hardly be avoided that the psychological reactions of the population, or other effects on society, might alter the assumptions underlying the calculations of the economic consequences, with the results that these could be considerably greater.

2.5. Conclusions.

In the case of a "worst conceivable" release of radioactive material following upon a core-melt accident at the Barsebäck nuclear plant, possible contamination of Danish territory could imply effects both on the health of the population and on the economy.

In certain areas this report is based on theoretical considerations and on a few mathematical models without underlying experimental material, for which reason its results should be considered only a rough picture of the radioactive contamination for that might occur in reality. Using the assumptions for the consequences applied in the report, the calculated largest average individual doses combined for the passage of the cloud and for land contamination do not exceed the treshold value for acute radiation injuries.

It would be realistic in the opinion of the Working Group to implement countermeasures to protect the population from the effects of radiation, whereby the effects on health in the form of deaths from cancer, foetal injuries and genetic defects could be reduced by about 90%. Alone the proposed countermeasures pertaining to agricultural production would be able to reduce the consequences by about 75%.

With the assumptions applied in the report, the consequences to health of the largest of the two releases investigated (BWR-2) are calculated to approx. 1500 deaths from cancer within a lifetime as a result of radiation during the first 30 years, approx. 100 foetal injuries, and approx. 410 cases of genetic defects in the first generation of offspring, when the proposed dose-reducing countermeasures in the form of temporary relocation, firehosing of roads and streets, digging of gardens, and the destruction of contaminated foodstuffs are put into practice.

If, for example, it is decided only to avoid the use of contaminated foodstuffs for one year, the consequences to health are calculated to approx. 5300 deaths from cancer during the cource of a generation, approx. 340 foetal injuries and approx. 1400 cases of genetic defects in the first generation of offspring.

In a situation deemed quite inconceivable by the Working Group - serious contamination of areas of land, no dose-reducing measures put into practice, consumption of foodstuffs from contaminated continuing without change - the resulting doses would correspond to approximately 24.000 deaths from leukaemia and cancer during one generation owing to radiation during the first 30 years, 1500 foetal injuries, and approximately 6500 cases of genetic defects in the first generation of offspring.

Two examples can be used to compare the effects on health thus calculated with the risks inherent in everyday life to which certain population groups are subjected:

With the present consumption of cigarettes in Denmark, some 200.000 millions cigarettes will be smoked in Denmark during the next 30 years. Based on British and American data relating to cigarette smoking, this is calculated to imply some 200.000 premature deaths as a result, e.g., from lung cancer. This corresponds to more that 100 times as many premature deaths as the approximately 1500 deaths from cancer owing to radiation following upon land contamination after decontamination countermeasures have been put into practice.

A further illustrative example is the risk to which people are exposed if they live in Copenhagen instead of in rural areas. For the approximately 600.000 inhabitants of Copenhagen itself and the district of Frederiksberg, the average life expectancy is some 2.5 years less that the average for 600.000 arbitrarily selected people living in rural Denmark. Thus difference corresponds to a loss of years of life that is 75 times greater than the loss of years of life corresponding to the calculated deaths from cancer as a result of land contamination.

The economic consequences to society associated with the proposed countermeasures affording protection against external radiation from contaminated surfaces (relocation and decontamination) might amount to about 1000 millions kroner. Costs could, however, increase by a further approximately 500 millions kroner if paid labour had to be used to dig up the gardens of private houses. Similarly, both the costs to the economy and the negative effects on the balance to agricultural production in order to avoid the use of contaminated foodstuffs could amount to a total of approx. 6000 millions kroner in the first three years, and a total of about 1000 millions kroner in the next seven years.

Thus, in all there could be costs to the economy of 8000 to 9000 millions kroner in the first ten years following upon land contamination. After the first ten years, the annual costs originating from the re-organisation of agricultural production would presumably decrease, for example as a result of the progress in adapting production.

There might be unpredictable effects on society that could alter the assumptions used in calculating the effects on the economy and on health.

In this respect experience from accidents involving chemical poisons or the like has proved that the psychological effects on society cannot be disregarded. It is hardly possible to evaluate the volume of mental symptoms and injuries that might occur in the population, and neither is it possible to estimate the possible magnitude of the costs to the economy of psychological effects.

These factors show, however, how important it is that the population knows of the risks to health associated with radioactivity, and that people are kept informed of these at all times. Furthermore, it is essential that people are kept correctly informed in an actuel accident situation. A chief task of the authorities must thus be a diligent dissemination of information.

In the case of an accident at Barsebäck, the same criteria for possible countermeasures should be applied both in Sweden and in Denmark. If any difference is made, then the reasons for this must be explained convincingly. Should a decision be taken to recommend special criteria in contaminated areas, then it is essential that there are lucid, simple arguments for this step.

Finally, it should be pointed out that professor Ove Nathan made a minority statement in which, for example, he claims that on several points this report considerably underevaluates the possible extent of the problem. Professor Nathan thus dissociates himself from the wording of the report as a whole; his statement is appended in full to the Danish version of the report.

ISBN 87-550-0892-5 Forsøgsanlæg Risø