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NUCLEAR POWER GENERATION

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G. NUCLEAR POWER PLANT SITING

This report forms one of sixteen related reports presented to the Royal Commission on Nuclear Power on 1.12.76.

Titles of the series are -

A. The Nuclear Power Industry in U.S.A.

B. The Nuclear Power Industry in Canada

C. The Nuclear Power Industry in Europe

D. The Nuclear Power Industry in Japan and Russia

E. Biological Effects of Radiation on Man

F. Biological Hazards of Plutonium

*G. Nuclear Power Plant Siting

H. Radioactive Releases from Nuclear Power Plants

I. Reactor Safety (including comments on criticisms of WASH 1400)

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L. Transportation of Fuel and Wastes

M. Nuclear Insurance

N. Decommissioning of Nuclear Power Facilities

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* This report also exists as one of the Nuclear Input series, and is available from the Institute of Nuclear Sciences (DSIR) as NIP 12.

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Introduction

The selection of a site for a nuclear power plant is a complex process involving considerations of public health and safety, engineering design, economics and environmental impacts. Although policies adopted in various countries differ in some details, a common philosophy underlies the criteria adopted by different countries.

The basic requirements fall into three broad categories, namely (a) those mainly relating to engineering and economics, (b) factors associated with health and safety, and (c) environmental factors.

Although in the discussion that follows site criteria are discussed under the above three categories, there is a considerable overlap amongst the categories - for example, many of the safety features are incorporated for economic considerations rather than for health considerations.

Section 1 Factors primarily determined by engineering, design and economic considerations

1.1 Availability of cooling water -

The major part of nuclear power generated today and within the near future is by thermal reactors which generate electricity from steam turbines similar to those in fossil-fuelled stations but with a lower thermal efficiency, approximately 32%. A typical condenser cooling water requirement for a 1000 MW(e) station is 50-60 m^3/sec of water which will be raised in temperature by 8°C. The lower thermal efficiency of nuclear power stations compared with modern fossil fuelled stations (up to 50% more cooling water may be required) is a disadvantage in areas where cooling water is at a premium, especially where river water is used and in some cases cooling towers or ponds are used at a considerable economic penalty.[1)]

However, New Zealand with a long shoreline is in a position to use sea water for cooling, and so the provision of adequate cooling water should not pose a problem. The environmental factors which should be taken into consideration when choosing a source of cooling water are discussed in Section 3. The subject of thermal discharges from nuclear reactors is the subject of a separate paper.[2)]

1.2 Location relative to load centre and transmission network

It is obvious that location near a load centre will result in economies, as line costs are currently $90,000/km for 1000 MW(e). Line losses are 360 kW/km at 220 kV.[1)] The optimum location, however, will also depend on a number of other possibly conflicting considerations such as future load distribution patterns, and environmental considerations associated with transmission lines.

1.3 Accessibility and transport

During plant construction some very large items require to be transported. For example, a 1000 MW(e) PWR may require single items weighing up to 550 tonnes.[3)]

When the plant is in operation, heavily shielded spent fuel containers require transport. The weight of these shipping casks depends on the transport available - road flasks weigh 30 tonnes, rail flasks 100 tonnes. During operation, generator rotors may require maintenance. If this work is carried out off-site, loads of up to 180 tonnes must be moved.

In view of roading costs and the nature of the terrain, it is possible that some form of barge transport would be used during the construction phase of a power reactor in New Zealand and possibly also for fuel transport. A suitable port located near the site will also be a siting factor in this case.

Section 2 Factors primarily associated with operational safety requirements

Under this category factors such as geologic, seismic, hydrologic and atmospheric characteristics are considered together with potential effects on the plant from accidents associated with nearby industrial, transportation and military facilities. Also considered are population densities and distributions in the environs of the site as they relate to protecting the general public from the potential radiation hazards of postulated serious accidents. It should be noted that safety to the population can be achieved either by remote siting or by improved engineering safeguards. In practice, a compromise is made; but in densely populated countries such as in Europe only small (possibly factors of 3-5) safety improvements can be achieved by utilising the remotest sites, whereas improvements by factors of 10-100 are possible by improvements in reactor system design.[4] In the U.S.A. at least where standards for 'as low as practical' emissions from routine operation of power stations have been defined[5] and plants must be designed to meet these standards, population densities and distributions are really not a constraint in relation to routine releases. The low levels of routine releases that have been achieved have stilled most of the early criticisms of possible health effects[6] and most public concern with siting is associated with accident conditions leading to the release of radioactivity.

In the event of a serious accident there is a possibility that gaseous fission products will be released. It is generally considered that there will be a delay between the time an accident occurs and before gaseous fission products escape to the atmosphere, hence an effective evacuation programme is likely to be implemented. However, due to the large inventory of radioactive fission products in a reactor, even a small fraction released would give rise to a severe radiological hazard. This topic is discussed in more detail in 'Nuclear Power Plant Safety'.[7]

2.1 Geologic/seismic considerations -

In a seismically active country such as New Zealand, the potential hazards from earthquakes pose extremely severe demands on the safety features of power reactors.

In assessing the probability of failure of the various systems comprising an installation, the usual assumption made is that failure of one system occurs independently of the failure of any other. Thus the overall probability of failure of a given item is obtained from the product of the probability of occurrence of the initiating event, and the probability of failure of the system when subject to that event.

In the case of earthquakes, however, the entire installation becomes subject to exciting forces simultaneously and a 'common mode of failure' is introduced. That is, the probability of failure of the various systems can no longer be considered separately as a result of the common source of excitation. In this instance, it becomes necessary to know the failure probabilities under the particular earthquake conditions, of all the components comprising the complete system before the probability of failure of a single item can be assessed.[8)]

The delay between the occurrence of an accident and the release of gaseous fission products, referred to above, may be very small in a multiple-damage accident caused by an earthquake. Thus the time available for evacuation from the neighbourhood may be small and the process hindered by disrupted communications and public bewilderment following a major earthquake. Such considerations bear on the relationship of nuclear sites to population densities.

Details of seismic design criteria are being studied by a working group of the Safety Criteria Sub-committee of the N.Z. Atomic Energy Committee.

Reactors have been designed to operate in such seismically active areas as Japan and California. The U.S.A. has detailed regulations (Appendix A of ref. 9) governing siting in seismically active areas, but these regulations are not all necessarily valid for New Zealand conditions since earthquakes in California are associated generally with surface faulting and probably differ in some important respects from most New Zealand quakes.

Records of earthquakes in New Zealand are less complete and cover a shorter period than those of Japan and California and it is doubtful if a single "safe-shutdown earthquake"[9] for a site could be specified. Rather it will be necessary to examine the risks associated with a range of earthquake severities. For the largest (and least frequent) earthquakes neither the characteristics of the shaking nor the effects on large modern industrial structures are at all well known. So, unless reactors can be isolated from major effects, e.g., by base isolators[10], it may be necessary to compensate for engineering uncertainties by a "defence in depth" philosophy which includes the adoption only of sites remote from population centres. Criteria for ranking possible sites in seismic area have been discussed by Nair et al.[11]

In general, bedrock sites are to be preferred to sites with layered soils, although this preference may be difficult to satisfy in New Zealand. At rock sites the foundations will be adequately strong and free from risk of settlement or deformation. Also, the maximum acceleration and velocity response spectra of earthquakes will be smaller than at soil sites (unless they are limited at the latter by plastic deformation of the soil - a difficult phenomenon to predict quantitatively). Rock is by far the most satisfactory site material if a base isolated system such as that described by Skinner et al.[10] is to be employed.

If bedrock sites are not available, it is prudent to select sites having a low liquefaction potential. Earthquake-related hazards such as landslides, subsidence and tsunamis should also be taken into consideration. Sites close to active faults are considered unsuitable for nuclear power stations. The U.S. Nuclear Regulatory Commission has set out detailed guidelines (Appendix A of ref. 9) regarding suggested distances from faults known or expected to be active, but as stated above, in view of the differing nature of earthquakes in New Zealand and the USA, this is one situation where it would be inappropriate to apply US criteria in New Zealand without modification.

In any seismically active area (all of New Zealand would come into this category) extensive and detailed geologic (including soil mechanics) and seismic field studies would be required for a proposed site.

The concept of underground siting of nuclear power plants seems attractive and indeed some reactors have been built underground[12]. Although placing the plant underground may provide some additional levels of safety in specific circumstances it is not clear what cost penalties would be incurred. Until a serious evaluation program is completed it is not clear that the additional complications of underground siting are warranted. This topic is discussed in detail by Crowley et al.[12] and Karpenko and Walter[13].

In New Zealand the problems associated with siting power reactors in seismic areas are being considered by a working group of the Safety Criteria Sub-committee of the N.Z. Atomic Energy Committee. Its terms of reference are:

> "To examine and report on problems relating to design requirements and the construction of nuclear reactor installations in New Zealand, resistant to seismic effects.
>
> To recommend such design requirements and safety regulations for inclusion in New Zealand nuclear reactor installation specifications."

Although the terms of reference of the working group are oriented towards seismic design requirements and safety standards, it would appear appropriate for the group to present some guidelines to assist in site selection. No such guidelines have yet been established.

2.2 Natural and man-made hazards -

Sites must be chosen keeping in mind such natural hazards as flooding,[14] (e.g., on a coastal site phenomena such as tsunamis should be considered; the consequences of the failure of reservoirs or of temporary dams caused by landslides should also be borne in mind) tornadoes, salt-drift. In New Zealand the hazards associated with volcanism should also be taken into consideration. For example, sites in the central North Island might be deemed unacceptable on these grounds. To date no estimates of the potential hazards associated with volcanism appear to have been made. The N.Z. Atomic Energy Committee might consider it appropriate to extend the terms of reference of the seismic working group to include this hazard.

Man-made hazards include the proximity of dangerous industries, missiles, closeness to the flight paths of military and/or civilian aircraft, military training areas and transportation services. The reason that the last factor should be considered is that dangerous cargoes may be transported and in the event of an explosion or dangerous gas leak a nearby nuclear power plant could be affected. The fact that such releases could occur in the vicinity of a proposed site need not preclude that site from consideration provided engineering safeguards are installed to cope with such an eventuality.[15)]

Similarly, if hazards from aircraft are higher than would normally be deemed acceptable (a probability of an aircraft strike less than about 10^{-7} per year is considered acceptable in the U.S.A.[16)]), additional protection in the form of concrete and the protection of air intakes against ingestion of combustible fuels could be provided. An example of this is the Three Mile Island nuclear plant where up to two metres of reinforced concrete was provided on flat-walled structures to protect against the impact of a 90-tonne aircraft striking at a velocity of 360 km/hr.[16)]

2.3 Hydrologic considerations -

Apart from the factors previously discussed (cooling-water supply, flooding, etc.) consideration should be taken of the consequences of both routine and accidental releases of radioactivity.[17)] In modern plants designed to meet the 'as low as practicable' guideline, routine releases of radioactivity [5)] impose little restraints on siting. However, if following an accident, it is possible that significant quantities of radioactive effluent could flow in streams or rivers or find ready access to undergound water tables, a site might prove unacceptable unless adequate engineering safeguards were included.

2.4 Meteorological conditions -

As the dispersion of radioactivity from a site is largely determined by the prevailing meteorological conditions, it is important to have a detailed knowledge of wind directions and velocities. Sites with frequent temperature inversions, or where stable conditions and consequent poor dispersion characteristics are likely to apply, should be avoided.

2.5 Population density and land use -

In view of the potential hazards associated with all aspects of nuclear power generation, it is necessary to take into consideration the population likely to be affected during both routine operation and in the event of an accident involving release of radionuclides. Consideration should also be taken of land use in the vicinity of the reactor site. For example in the event of an accident, vital transport links might be denied if a site were chosen close to main routes. High safety standards are required both for economic reasons and for the health of reactor operations personnel, and so reactor siting relative to population centres is determined principally by potential health hazards associated with postulated accident conditions. The approach generally adopted is to estimate the amount of radioactivity likely to be released in a hypothetical accident, and to limit the radiation dose to the population to within internationally agreed standards.

Although details of the hypothetical accidents and the techniques adopted to meet the International Commission for Radiation Protection (ICRP) standards differ in some details from one country to another, the general philosophy is similar; and so to keep this presentation simple the U.S. policy will be described. The regulations employed in some other countries are given in Appendix A.

The Americans define three areas associated with reactor operation, namely - (1) the exclusion area, (2) the low population zone and (3) the population centre distance.[9] Briefly the 'exclusion area' means that area surrounding the reactor in which the reactor licensee has the authority to determine all activities including exclusion or removal of personnel and property from the area. The 'low population zone' means the area immediately surrounding the exclusion area which contains residents, the total number and density of which are such that there is a reasonable probability that appropriate protective measures could be taken on their behalf in the event of a serious accident. The 'population centre distance' means the distance from the reactor to the nearest boundary of a densely populated centre containing more than about 25,000 residents.

In evaluating a proposed site it is necessary to assume a fission product release from the core, the expected demonstrable leak rate from the containment, and the meteorological conditions pertinent to the site, to derive an exclusion area, a low population zone and population centre distance. An exclusion distance of 600 metres is usually sufficient to ensure engineered safety features can be designed to bring the calculated dose within the guidelines of 10 CFR Part 100.[9] Similarly, a distance of 5 km to the outer boundary of the low population zone is usually adequate.[18] Models and assumptions used for evaluating the potential radiological consequences of certain accidents are provided in Regulatory Guides 1.3, 1.4, 1.5, 1.24 and 1.25.[19] It should be noted that in a country with complex topographic features such as New Zealand, the simple theories used to predict the dispersion of airborne radioactive material may need refinement.

The factors which determine the sizes of the various zones are as follows:

(a) The exclusion area must be of such size that an individual located at any point on its boundary for two hours immediately following onset of the postulated fission product release would not receive a total radiation dose to the whole body in excess of 25 rem or a total radiation dose in excess of 300 rem to the thyroid from iodine exposure.

(b) The low population zone should be of such size that an individual located at any point on its outer boundary who is exposed to the radioactive cloud resulting from the postulated fission product release (during the entire period of its passage) would not receive a total radiation dose to the whole body in excess of 25 rem or a total radiation dose in excess of 300 rem to the thyroid from iodine exposure.

(c) The population centre distance should be at least 1 1/3 times the distance from the reactor to the outer boundary of the low population zone.

It appears that in developing siting criteria, the health and safety of the population in the vicinity of the reactor has been the over-riding consideration, and little or no thought has been given to the economic consequences of a large release of radioactivity in an agricultural area. It is clear that consideration should be given to such factors in evaluating sites in New Zealand.

Section 3. Factors primarily related to environmental considerations

The potential impacts of the construction and operation of nuclear power plants on the physical and biological environments and on social, cultural, and economic features are similar to the site of any major industrial facility, but nuclear power stations are unique in the degree to which potential impacts to the environment by their safety must be considered. While safety considerations could be said to have dominated early siting criteria in overseas countries, environmental considerations and public acceptance have become increasingly important.

3.1 Biota and ecological systems -

Examples of potential environmental effects by plant construction and operation that must be assessed are physical and chemical environmental alterations in habitats of important species,* including plant-induced rapid changes in environmental conditions that result in injurious shock to the biota, change in normal current direction or velocity of the cooling water source and receiving water, scouring and silting resulting from dredging and spoil disposal, and interference with shoreline processes. In general, the uniqueness of a habitat or ecological system within the region under consideration, the amount of the habitat or ecological system destroyed or disrupted relative to the total amount in the region, and the vulnerability of the reproductive capacity of important species populations to the effects of construction and operation of the plant and ancillary facilities are important considerations in the balancing of costs and benefits.

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*A species, whether animal or plant, is considered important -

1) if it is commercially or recreationally valuable;
2) if it is endangered or threatened;
3) if the species or the specific population has important or unique esthetic or scientific value; or
4) if it affects the well-being of some important species within criteria (1), (2), (3), or if it is critical to the structure and function of a valuable ecological system.

3.2 Land use -

Land conversion involving areas where specialty crops are grown and where change in land use might result in severe market dislocation, may be considered unacceptable (marine crops such as oysters would also need to be considered). In particular, areas devoted primarily to forestry production would be preferred to those devoted to crop or dairy production.

The future use of an area should be considered - i.e., the rapid build-up of population in the plant environs may be undesirable.

Siting in recreational areas would be favourably considered as this would be a way of maintaining and usefully using a low population zone.

Sites containing historic or archaeological relics and those having unique natural features would require special consideration.

3.3 Socioeconomics -

Changes due to the presence of a large population during construction and a substantial permanent addition to the local population should also be considered as an environmental effect. The MOWD has indicated its willingness to cover this aspect of siting in detail.[20)]

3.4 Site selection and public acceptance -

Due to the current public concern about various aspects of nuclear power it is most important that early contact be made with all groups in the region surrounding a proposed reactor site likely to be affected in any way by the facility. Public acceptance of nuclear power in Britain owes much to the early realisation of the need for a dialogue between the generating authorities, the public and local bodies. In view of the importance of this facet of site selection the procedures adopted in England by the Central Electricity Generating Board

(CEGB) are given below in some detail.[21]

"At the earliest stages in the site selection process, the CEGB notifies Government Departments, the Countryside Commission, Nature Conservancy and local planning authorities of the general area being considered for sites.

When possible sites have been identified, more detailed studies are made, and the same parties are informed, together with interested MP's, affected landowners, and other parties concerned. A public announcement is made identifying the sites considered suitable for detailed investigation.

When a site is adopted for development the CEGB refers its proposals confidentially to a Government Inter-Departmental Committee to make sure that the relevant Departments are properly informed, have no objections, and foresee no special problem. It is at this stage that the Board will decide whether to make a formal application to the Secretary of State for Energy for a consent under the Electric Lighting Act. Because of publicity and interest aroused locally, the CEGB are often under considerable pressure to reveal their intentions, and usually make their final decision public soon after obtaining the views of the Committee.

The public are kept informed at all stages by press statements, meetings and often exhibitions. By organising opposition they can persuade the Secretary of State to hold a public inquiry in which they can fully participate.

The CEGB pursues a deliberate policy of trying to maximise public acceptance of the siting of nuclear plants. Efforts are made to secure the co-operation both of local authorities and of the general public by keeping them fully informed at all stages.

During the final stages of site selection public exhibitions and conferences may be held. Physicists, engineers and planners describe the CEGB's proposals and answer questions. Leading landscape consultants and architects who are engaged by the CEGB often present, in model form, their proposals for the site to the local planning authority and general public.

Local representatives are invited to visit other nuclear installations to meet the local authorities and see the surrounding areas. The fact that the CEGB can point to an outstanding safety record since their first reactors went into commission in 1962 enables them to reassure those with genuine fears about the construction of nuclear power stations in their area.

At an early stage the CEGB will begin to hold a dialogue with the local authorities and establish a Local Liaison Committee which continues into the operational phase. Such Committees include representatives of the local statutory bodies, farming interests, and the police, and are used to provide information and assurance to local inhabitants on the operation of the power station and its possible effects on the local environment. When the stations are operational, guides are recruited from the wives of operational staff to conduct the general public around the station.

This is reported to have become increasingly popular and many thousands of visitors are received annually at nuclear stations.

The CEGB does not provide houses for its staff, who may number 500 for each station, but encourages them to live in the local community. A large number of non-technical staff are recruited locally."

The reasons put forward for objecting to specific sites are many and varied. A list of site-specific objections lodged against nuclear power stations in Germany is given by Kohler.[22)]

KEY TO REFERENCES

Many reports have been listed as letter codes. The following list gives the publication source for these reports.

AAEC - Australian Atomic Energy Commission (Sutherland, NSW)

ACRL=ARCRL - Agricultural Research Council Radiological Laboratory (Risley, UK)

AEC - U.S. Energy Research and Developement Agency (Washington, DC)

AECL - Atomic Energy of Canada Ltd (Ottawa, Ontario)

AERE - Atomic Energy Research Establishment (Harwell, UK)

ANL -
BNWL -
BRH/DER -
CONF -
DBE=BRH/DBE -
EPA -
ERDA - } U.S. Energy Research and Development Agency (Washington, DC)

DSIR Report NIP- See NIP

EUR - European Atomic Energy Community (Brussels)

IAEA/STI -
IAEA/INFCIRC -
IAEA/WHO - } International Atomic Energy Agency (Vienna)

ICRP - International Commission for Radiological Protection (UK)

IEEE - Institute of Electrical and Electronics Engineers (New York)

INFCIRC - See IAEA

INSL - held by the library, Institute of Nuclear Sciences (Lower Hutt)

LA -
LA-UR - } U.S. Energy Research and Development Agency (Washington, DC)

NCRP - National Council on Radiation Protection and Measurement (USA)

NIP - "Nuclear InPut" - file held at the Institute of Nuclear Sciences, DSIR (Lower Hutt). The six-digit number following some references is the abstract number in the NIP file (e.g., 000398)

NRC - U.S. Energy Research and Development Agency (Washington, DC)

NRL - National Radiation Laboratory (Christchurch, NZ)

NRPB - National Radiation Protection Board (UK)

OECD/NEA - Organisation for Economic Co-operation and Development, Nuclear Energy Agency (Paris)

ORNL -
ORO -
RD -
USAEC -
WASH - } U.S. Energy Research and Development Agency (Washington, DC)

REFERENCES

1) Recent NZED studies for Auckland Thermal No.1 Station indicate additional costs for a 1000 MW(e) station with the following types of cooling towers -

Natural draft	$48,000,000
Mechanical draft	$25,000,000
Spray cooling	$25,000,000

NZED estimates for two double circuit 220 kV lines wired in single conductor/phase to deliver power from a 1000 MW(e) station are as follows:

Total capital cost/km	$90,000
Losses/km	360 kW
Value of losses/y/km	$18,000
Capitalised costs of losses	$160,000/km

over lifetime (40 years) of transmission line.

2) Thermal Discharges NIP-5

3) Details of the major single pieces of equipment in a 1000 MW(e) PWR are as follows:

Pressure vessel: 5.2 m diameter, 12.8 m long, 450 tonnes

Steam generators (4 required) 4.3 m diam.,19 m long, 300 tonnes

500 MW turbine generators (2 required 5.5 m diameter, 30 m long, major segment up to 550 tonnes.

4) F.R. Farmer, in 'Containment and Siting of Nuclear Power Plants', IAEA, Vienna, 1967, p.326.

5) U.S. Nuclear Regulatory Commission Code of Federal Regulations, 10 CFR, Part 20.

6) A.P. Hull: Radioactive effluent releases and the public acceptance of nuclear facility sites in 'Siting of Nuclear Facilities'. IAEA,Vienna 1975, p.247.

7) Nuclear Power Plant Safety. Report NIP-9 of this series.

8) Seismic analysis of nuclear power plants - survey of current 'state of the art'. G.K. Alderton, p.104, Nuclear Investigation Branch, Development Division NZED, May 1973.

9) U.S. Code of Federal Regulations 10 CFR Part 100.

10) R.I. Skinner, G.N. Bycroft and G.H. McVerry: A Practical System for Isolating Nuclear Power Plants from Earthquake Attack. Nucl.Eng. and Design 36 (1976) 287.

11) K.Nair, G.E. Brogan, L.S. Kuff, I.M. Idriss and K.T. Mao: An Approach to Siting Nuclear Power Plants; The Relevance of Earthquakes, Faults and Decision Analysis in 'Siting of Nuclear Facilities'. IAEA, Vienna 1975, p.435.

12) J.H. Crowley, P.L. Doan and D.R. McCreath: Underground Nuclear Plant Siting; A Technical and Safety Assessment. Nuclear Safety 15 (1974) 519.

13) V.N. Karpenko and C.E. Walter: Underground Siting of Nuclear Power Reactors in 'Siting of Nuclear Facilities'. IAEA, Vienna 1975, p.581.

14) See for example USEAC Regulatory Guide 1.59 : Design Basis Floods for Nuclear Power Plants. August 1973.

15) USAEC Regulatory Guide 1.78 : Assumptions for Evaluating the Habitability of a Nuclear Power Plant Control Room during a Postulated Hazardous Release. June 1974.

16) B.K. Grimes: External Hazards as they Affect Nuclear Power Plant Siting, in 'Siting of Nuclear Facilities'. IAEA, Vienna 1975, p.140.

17) For example, section 50.34a of 10 CFR Part 50 sets forth the requirements for design objectives for equipment to control releases of radioactive material in effluents from nuclear power stations.

18) USAEC Regulatory Guide 4.7, September 1974.

19) Regulatory Guide 1.3, 1.4, 1.5, 1.24, 1.25 } see footnote to Regulatory Guide 4.7, p.6.

20) Letter from MOWD to DSIR dated 17 December 1975. Ref.92/25/1/12/1.

21) European Parliament Working Document 392/75/Annex, p.27-29.

22) H.A.G. Kohler: Sites of Light-water Reactor Power Plants in the Federal Republic of Germany in 'Siting of Nuclear Facilities', IAEA, Vienna 1975, p.183.

23) 'Siting of Nuclear Facilities'. IAEA, Vienna 1975.

24) Peaceful Uses of Atomic Energy. Vol.3. Proceedings of the Fourth International Conference, Geneva, September 1971.

Other Useful References

1. Report on the conditions for a community policy on the siting of nuclear power stations taking account of their acceptability for the population.
European Parliament Working Documents 1975-1976
Document 392/75 and 392/75/Annex

In these documents the siting policies of the Federal Republic of Germany, U.K., France, Italy, Netherlands and Switzerland are given.

2. Safety-related site parameters for nuclear power plants.
WASH-1361 January 1975.

This report presents values of the principal safety-related site parameters that have been used in the design of nuclear plants licensed in the USA.

3. Earthquake Guidelines for Reactor Siting. IAEA Technical Report No.139, 1972.

4. Japanese Regulatory Guide of Design Earthquake Ground Motions for Nuclear Power Facilities - Interim report of the Seismic Design Committee. March 24, 1975.

5. Rationale of Reactor Site Selection for Public Safety.
J.R. Beattie, in Nucl. Technology 27 (1975), 233.

Appendix A Details of Exclusion Zones and Maximum Permissible Doses

Country	Exclusion Zone	Maximum Permissible Dose: Routine Operation	Maximum Permissible Dose: Accident Condition	Reference
U.S.S.R.	3 km	170 mrem/a for external whole body exposure for individual members of population. 5 rem/a for dose to thyroid from inhalation and intake of ^{131}I through water and food.	25 rem at boundary	23) p.84
Germany		Must not exceed 30 mrem/a due to liquid waste and 30 mrem/a due to gaseous waste. Radiation load on thyroid gland of small children due to radio-iodine ingested via the food chain must not exceed 90 mrem/a.	The consequences of any accidents which may possibly occur in the reactor plant, up to and including the design-basis accident must be kept within the lowest possible limits in respect of the radiation exposure of the population.	23) p.191
Denmark	2 to 3 km Population build-up controlled up to 10 km.		Emergency reference level for evacuation - 300 rem to the thyroid.	23) p.295
Canada		0.5 rem/a whole body to individual member of the public, 5 rad/a thyroid to individual member of the public. Integrated exposure to population: 10^4 man-rem/a, 10^4 man thyroid-rad/a (Integration to be carried out for individual doses exceeding 5 mrem/a)	Individual member of public at exclusion area boundary 25 rem whole body, 250 rad thyroid. Integrated exposure to public: 10^6 man-rem, 10^6 man thyroid-rad (Integration to be carried out for individual doses exceeding 0.5 rem)	24) p.184
Pakistan	Defined such that a child located at any point on its boundary during the entire time of passage of activity from the maximum design accident would not receive more than 250 rem to the thyroid or 25 rem to the whole body.			23) p.161