THE EVALUATION OF THE SELECTED ON-SITE LOCATION FOR A NEW NUCLEAR FACILITY ON A MULTI-FACILITY SITE

H.E. SEALS
South African Nuclear Energy Corporation (NECSA),
Licensing Department,
Pretoria,
South Africa

Abstract

Pelindaba is a multi-facility nuclear and chemical site in the North West Province of South Africa where Necsa currently operates SAFARI-1. A proposed new dedicated isotope production reactor facility is to be constructed on this site. The siting process followed is tailored from the IAEA guidelines. This paper describes the site selection and site characterization for a new facility at Pelindaba.

1. INTRODUCTION

At the dawn of the nuclear renaissance, many new nuclear facilities are required for various activities in the nuclear fuel cycle, nuclear power plant development and in the nuclear isotopes industry. The question of where these new facilities should be located has many dimensions. Often it is most practical to develop new nuclear facilities on existing nuclear sites. Pelindaba is one such site.

Pelindaba is south of the Hartebeespoort Dam in the North West Province of South Africa. It is approximately 27 km west of Pretoria and stretches over 2362 hectares in area. The South Africa Nuclear Energy Corporation (Necsa) is based there. It houses multiple chemical and nuclear facilities including the material test reactor, SAFARI-1, and NTP PTY Ltd: the major international commercial isotope producer which includes Molybdenum-99 utilised for medical imaging. Pelindaba is the hub of South Africa's nuclear technology development.

Necsa intends to maintain excellence in nuclear research and development. SAFARI-1 is a valuable asset for training the next generation for the nuclear industry. Currently SAFARI-1 is almost entirely utilized for isotope production. A new research reactor dedicated to isotope production is proposed so SAFARI-1 can be returned to its original purpose of research and training, and NTP can continue its core business beyond SAFARI-1's lifetime. This new reactor would also be based at Pelindaba. This paper will discuss the siting aspects of this facility.

2. SITE SELECTION

2.1. Site selection strategy

There are two processes relating to the siting of a new facility: Site Selection and Site Evaluation. Within these two processes the IAEA recommends the five stages below 0. The first three stages are discussed in detail here.

— Site Survey Stage;
— Site Selection Stage;
— Site Assessment Stage;
— Pre-operational Stage;

— Operational Stage.

The site survey stage is predominately used for identifying potential sites across the country or region that are suitable for a nuclear facility and narrowing the number of possible sites down. For the Dedicated Isotope Production Reactor, there is existing infrastructure (facilities, programmes and supporting infrastructure) at Pelindaba that is vital to the project's financial viability. Therefore, the site survey stage is not really applicable. However, elements of the site survey have been combined with the site selection stage in order to identify and rank candidate locations on the existing multi-facility site at Pelindaba. Site selection is then divided into two steps in order to facilitate a screening to eliminate unsuitable sites and an assessment to rank and compare candidate sites. The strategy applied is illustrated in FIG. 1.

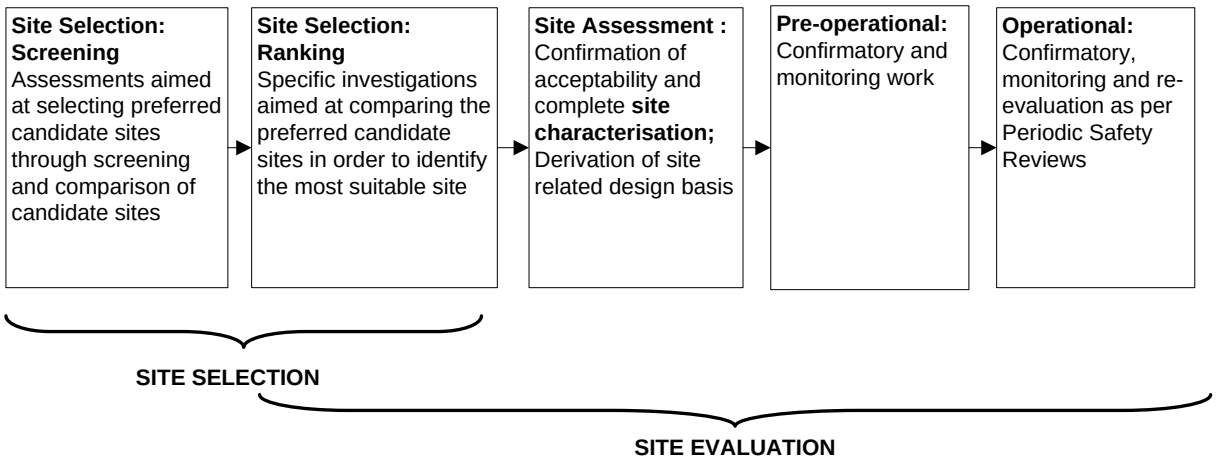

FIG. 1 Tailored Siting Process for a Brownfield Site

By using the existing site, the parameters related to the demographics, emergency planning, the ultimate heat sink, and some aspects of storage and transport of radioactive waste, fresh and spent fuel are common to all the site locations considered at Pelindaba. Thus, they have no influence on the site selection, but are rather dealt with during site assessment.

Criteria against which site locations are judged are either safety related, security related or not related to safety. Safety related criteria are classified into four types 0. The first type addresses the site's natural hazards that could potentially impact the facility. The second type comprise of the human induced hazards associated with the site that could potentially impact the facility. The third type addresses the site characteristics that relate to the dispersion and transport of radioactive material through the environment and the potential exposure of the public. The fourth type includes the site characteristics that may influence the implementation of an emergency plan.

2.2. Site selection: Screening

An expert panel (based on Necsa's Suitably Qualified and Experienced Person framework) was convened to identify, rank and compare potential site locations for the Dedicated Isotope Production Reactor. They used the criteria listed below for accepting or rejecting a site location.

— Size of the site location;
— Terrain of the proposed site location and construction area;
— Ease of integration into the existing facilities and infrastructure;
— Proximity to hazardous facilities;
— Any other known disqualifier.

Based on these criteria, the east campus of Pelindaba was rejected due to the proximity to the Hydrogen Fluoride production facility, the challenge of integration to the existing facilities and infrastructure, and risks associated with transporting irradiated materials to the isotope processing facilities at Pelindaba West.

Eight site locations were identified on Pelindaba West as shown in FIG. 2. A disqualifier was identified for site location 7, as it is a natural wetland and not suitable for development from an environmental perspective. The site locations were ranked qualitatively according to the parameters listed in TABLE I in a series of meetings. A multi-attribute analysis was done so that the relative safety of the site locations could be compared and the less attractive sites eliminated from further consideration. After screening the resulting candidate site locations were site locations 3, 5 and 6.

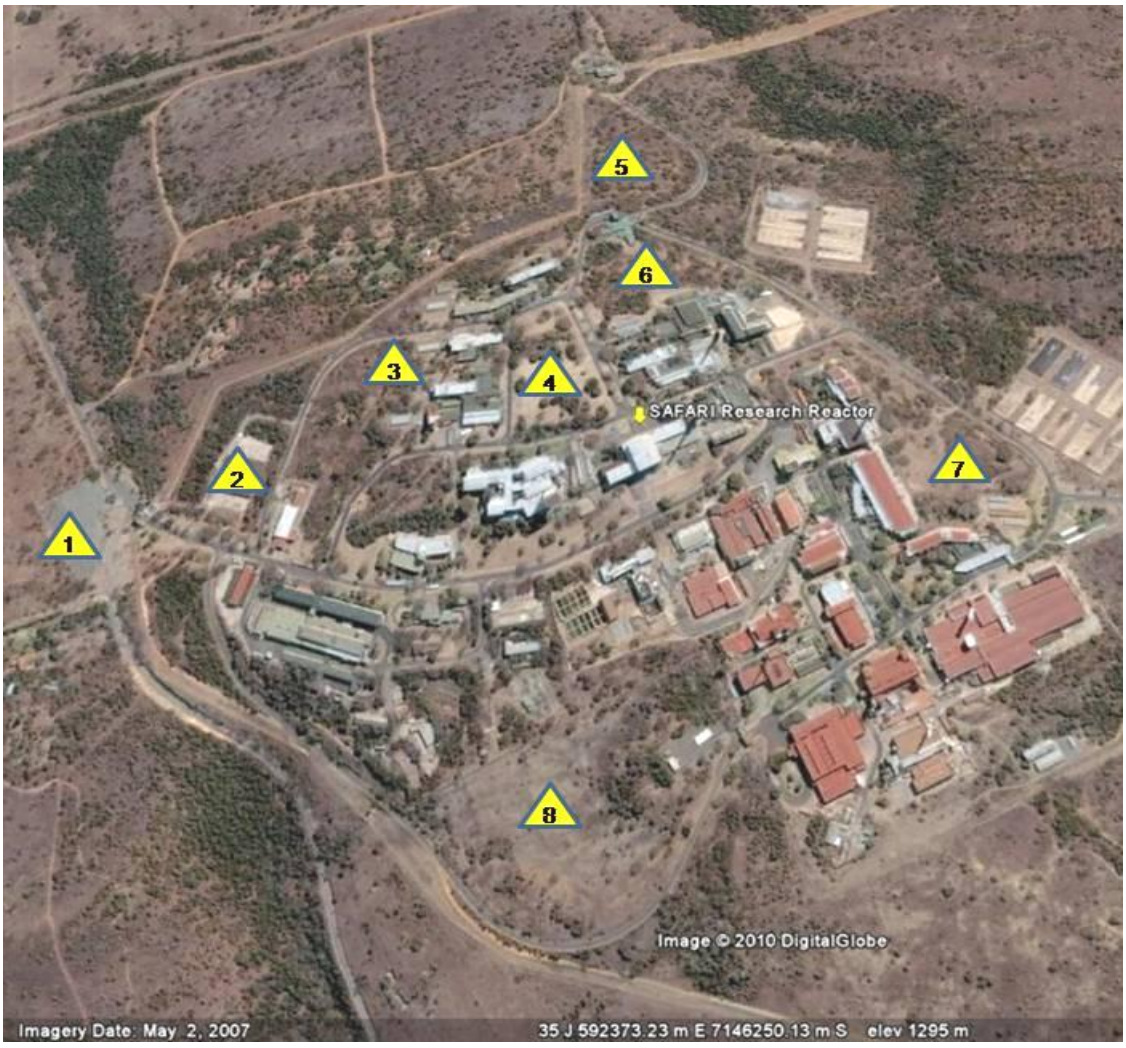

FIG. 2: Potential Site locations for the Dedicated Isotope Production Reactor on Pelindaba West.

TABLE I: SITE SAFETY PARAMETERS CONSIDERED FOR THE SCREENING OF SITE LOCATIONS

Environmental	Level of Clearance and Excavation
Security	Proximity to Necsa Perimeter
	Ability to isolate the site location during construction
	Access to perimeter fence from outside
	Visibility from perimeter fence
Site Safety and Necsa's	Impact on existing facilities

Emergency Plan	Impact of existing facilities
	Proximity to the Public
Construction	Size of site location
	Health Safety Environment impact associated with construction
	Health Safety Environment impact during construction
	Site location accessibility during construction

2.3. Site selection: Identifying the preferred site

The multi-attribute analysis performed for the site screening (discussed above) demonstrated that there was no significant difference between the three candidate sites when ranked against the safety related parameters. A number of specialist areas were identified, to refine the comparisons between these sites and identify the preferred site location. The following studies were initiated: geology, geotechnical and geophysical; seismology; environmental sensitivity; atmospheric dispersion (as an indicator for radiological impact); security; and utility requirements.

The findings of the preliminary studies are as follows:

— The geology investigation showed no structural disturbances on any of the sites. Previously known faults run across site locations 3 and 5. Site location 5 has the steepest topography. Site 6 was identified as the preferred site regarding geological considerations;
— The geotechnical assessment indicated no significant differences between the sites regarding slope instability. Due to steeper topography on site 5, excavation depth would have to be deeper; thus site 3 and 6 are preferred;
— Seismic site response studies showed site location 5 and then 6 are preferred;
— Environmental sensitivity assessment showed no Red Data, threatened or sensitive species were recorded on any of the sites. Site 6 is the most disturbed site of the three. Dedicated Isotope Production Reactor is considered to have low environmental impact due to its size;
— The atmospheric dispersion investigation assessed a hypothetical on and off-site dose given a unit source term for a typical year's weather. The results were not significantly different for the three sites as anticipated. Nevertheless, site 6 was considered to be the preferred site from an atmospheric dispersion perspective;
— In terms of the security and site impact, site location 5 would have less impact on other site activities, but in terms of security site 6 is preferred;
— Utility requirements for water and effluent estimates were assessed and site 6 was the preferred option.

Additionally, considering the hazard associated with aircraft crashes, the flight path for small aircraft (the calculated risk from other aircraft types is negligible for the site) is near the Pelindaba western boundary. Those site locations that are further from the western boundary are more favourable with respect to the aircraft crash hazard. Therefore, site location 5 and 6 are better than site location 3.

Although the differences in the three sites for all the parameters studied were not significant, the most favourable location is site location 6. Thus site location 6 is earmarked and proposed as the preferred site for which the detailed site characterization is performed.

3. SITE CHARACTERIZATION

A detailed review of the IAEA guidance 0 and 0 was performed to derive a specification for the Dedicated Isotope Production Reactor Site Safety Report. The IAEA identifies a number of site characteristics to be addressed. Since the reactor is to be developed on the existing Pelindaba site, all the characteristics apply to Pelindaba as a whole but some require in addition more specific characterisation of the site location where the reactor is to be constructed, as indicated in TABLE II. The site wide assessment was reviewed (or developed if not available) and the information collated into the Pelindaba Site Description. Additional assessments were initiated for the Dedicated Isotope Production Reactor site location specifically (refer to the items marked "Site Location" in TABLE II). A few examples of the assessments are discussed in the sections below.

TABLE II: SITE CHARACTERISTICS 0 & THE DEDICATED ISOTOPE PRODUCTION REACTOR ASSESSMENT STRATEGY.

Site Characteristic	Assessment strategy
Geography and site location	Pelindaba
Monitoring	Pelindaba & Site Location
Ecology	Pelindaba & Site Location
Demography	Pelindaba
Land use	Pelindaba
Nearby Transportation, Industrial and military facilities	Pelindaba & Site Location
Meteorology	Pelindaba
Hydrology and Hydraulics	Pelindaba
Geohydrology	Pelindaba & Site Location
Water Supply	Pelindaba
Geology and Geotechnical Characterization	Pelindaba & Site Location
Seismic Characterization	Pelindaba & Site Location
Ambient Radioactivity	Pelindaba & Site Location

3.1. Ambient radioactivity characterization

Environmental monitoring for Pelindaba is ongoing and started prior to operations at the site. (SAFARI-1 was commissioned in 1965.) The current environmental monitoring programme regularly monitors the atmosphere, hydrosphere and lithosphere for radioactive material. A review of the last ten years of data was performed and trends recorded, in order to define a reference level of environmental activity concentrations from which the impact of a new facility can be measured. In addition to the historical data, soil samples were taken from the selected site location. Nine samples were taken in a randomised triangular grid 0 and analysed at the radioanalysis laboratory at Pelindaba. For the majority of the isotopes identified for analysis, the activity concentrations were below the minimum detectable activity values. Trace values for K-40 and Sr-90 were measured and some samples had measurable uranium concentrations, all consistent with the historical data.

3.2. Geology and seismology

The geology and seismology of the region and the Pelindaba site have been subject to numerous studies over the years. Pelindaba sits in the foothills of the Magaliesberg, one of the oldest ranges in Southern Africa (rocks are of Achaean age, more than 2600 Ma). The rock under Pelindaba is predominantly of the Timeball Hall and Rooihoogte formations from the

Pretoria group and Transvaal Supergroup. This is mostly slate; interbedded quartzite and slate. The rock layers can be seen clearly around site. A Probabilistic Seismic Hazard Analysis at Senior Seismic Hazard Analysis Committee (SSHAC) Level 2 was performed for a previous project on the Pelindaba site, based on the US NRC methodology provided in RG 1.208. The assessment is valid for the area within a radius of a few kilometres and thus encapsulates the site locations for the Dedicated Isotope Production Reactor. Of note seismically are the Brits Graben fault (post-Bushveld age, 2050 Ma) and the mining activities in the region.

Given the regional and site geology and seismology, some site specific geotechnical characterisations and development of site response spectra were performed for the selected site location. Specialist (including geologists, seismologists, engineering geologists, geotechnical engineers and structural engineers) were contracted in to study the site location in detail primarily to define the civil constraints (geotechnical and seismic site related design basis) for the site location and to develop the design base earthquake parameters for the site location. The field study included ten boreholes (up to 35 m) for core analyses and nine test pits for soil profiling.

Preliminary results show that the site location is geologically and geophysically suitable for the proposed facility. No geological hazards were identified for the site location. No water rest level was found within 35 m of the surface. Another deep borehole intersecting hard rock (rock with Vs greater or equal to 2800 m/s) will be cored soon in order to finalise the seismic characterization.

3.3. Nearby transportation, industrial and military facilities

The IAEA lists a number of potentially hazardous facilities that can result in human induced external events. The region around the Pelindaba site is mostly rural and agricultural land. There is no large scale piping infrastructure in the region and the closest industrial facilities are in Brits, approximately 20 km away from the site. The closest public road is approximately 1 km from the site location. Thus the hazards from these facilities and road transportation are negligible. Similarly, there are no military facilities in the vicinity.

Pelindaba itself houses a number of chemical and radiological facilities. A review of all the facilities on-site was performed. Four facilities have been identified as potentially presenting a radiological hazard to the new facility, including SAFARI-1 which is approximately 250 m away from the site location. In terms of chemical and toxic hazards, there are at least ten Major Hazardous Installations (MHI) on site in accordance with the MHI Act. Most notable are the fluorine production facility in the vicinity of the site location and, as already mentioned, the hydrogen fluoride facility on Pelindaba East. The potential hazards from all these facilities shall be incorporated into the design and safety assessment of the Dedicated Isotope Production Reactor.

With regards to potential air craft crash events, a model was developed for the site to calculate crash probabilities. All the airports and airstrips in the vicinity of Pelindaba were considered. There are four civil and two military airports, and five small airfields in the region. Within 20 km of Pelindaba, there are two small airfields and one civil airport: Lanseria. There is a prohibited flying area around the Pelindaba site which extends to 6500 ft altitude. There are two commercial air corridors from OR Tambo over the Pelindaba site, both above 8000 ft. The probability of a commercial aircraft crash for any facility (conservatively sized 50 m x 50 m x 50 m) on site is less than $1x10^{-7}$ accidents/year, thus it is not considered further. Similarly, military aircraft were screened out. For general aviation, the probability of an aircraft crash is more significant due to the proximity to Lanseria. Thus, a detailed calculation was performed given the exact site location position in relation to the flight paths and the proposed facilities effective area. The crash probability is approximately $9.5x10^{-7}$

accidents/year. Thus, the reactor facility needn't be designed for an aircraft crash. Nevertheless, an aircraft crash shall be considered as an external event in the safety assessment to address any concerns regarding cliff-edge effects.

3.4. Environmental impact

In South Africa, it is legislated that the Environmental Impact Assessment is performed by an independent Environmental Assessment Practitioner. Such a practitioner has been appointed and the formal assessment process is underway. The first of the public participation meetings are scheduled for November this year, for the public to provide comment on the proposed development. A second round of public participation meetings are to be held in mid 2012 and then the findings are consolidated in order for the Minister of the Department of Water and Environmental Affairs to provide a record of decision. Construction cannot commence without a positive record of decision.

4. SITE SAFETY ASSESSMENT

The site evaluation goes beyond just characterizing the site. An important part of the process is presenting the potential radiological impact that the proposed facility may have, particularly to the members of the public. Since the selected site location is on a bigger site where there are other facilities, a combined impact should be considered for the normal operational conditions. Currently Necsa assigns dose constraints to various facilities and a tenth of those constraints become investigation levels. For accidental doses this does not apply, but the emergency planning incorporates the potential accidents from each facility.

Currently there is limited information on the design of the facility to be built on the proposed site location. Thus the radiological impact assessment is very simplistic and based on experience of similar facilities. A study to determine the reference individual from the information regarding the land use and the local demographics has been performed and the final dose assessment will incorporate those findings. Preliminary results with a generic exposure scenario indicate that the dose associated with normal operation is well below the design goal of 10 µSv annual effective dose to the public. A hypothetical accident scenario with core damage has been modeled with conservative release assumptions and average dispersion conditions. Preliminary results are in the order of 40 mSv at 1 km maximum individual dose (excluding ingestion). A process is underway to define the reference case accident for the new facility and ensure that it is addressed in the existing Pelindaba emergency plan.

A current challenge is the assessment of the risk. The draft siting regulations issued by the Department of Energy in July 2009 0 call for a probabilistic risk assessment of the proposed facility. The results are to be compared against the probabilistic risk limits which are average annual population risks and maximum annual individual risks. These regulations were designed for nuclear power plants. A methodology applying the hazard graded approach for the assessment of risk for the site evaluation is still to be developed.

5. LICENSING STRATEGY AND REGULATORY INTERACTIONS

Engagement with the National Nuclear Regulator (NNR) on this project is still in the beginning stages. A notice of application has been presented by Necsa regarding the intention to license the new facility. The licensing strategy follows a staged approach: siting, construction and operation. The initial licensing stage is the siting where much of the information presented in this paper is submitted to the regulator. The bulk of the siting information is presented in the Site Safety Report which is scheduled to be submitted to the

NNR in the first quarter of 2012. A few early technical workshops have been held with the NNR in order to clarify aspects of the regulations and table proposed methodologies.

6. CONCLUSIONS

The IAEA recommendations have provided a valuable basis for the site selection and site evaluation of the propose Dedicated Isotope Production Reactor. Siting on a multi-facility site such as Pelindaba has many benefits such as a depth of historical data, but does not diminish the need for studies of the specific site location. Additionally, the radiological impact addresses the whole site, not just the proposed facility. The siting of the Dedicated Isotope Production Reactor is progressing well and we have confidence that the Site Safety Report will be well received by the South African National Nuclear Regulator.

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