PEER REVIEW REPORT

ASSESSMENT OF THE POTENTIAL RADIOLOGICAL IMPACT ON THE PUBLIC AND THE ENVIRONMENT

FOR NUCLEAR 1 ENVIRONMENTAL IMPACT ASSESSMENT

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VERSION 1 **DATE: NOVEMBER 2015**

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1 INTRODUCTION

Dr C A R Bain Pri. Sci. Nat. Consultant was appointed by Gibb (Pty) Ltd. To undertake a peer review of specialist report "Assessment of the Potential Radiological Impact on the Public and the Environment" (referred to subsequently as the Report) compiled by PSI Risk Consultants CC for the proposed Nuclear 1 Power Station project which covers the three sites situated at Thyspunt in Eastern Cape Province and Bantamsklip and Duynefontein in the Western Cape Province of South Africa.

2 SCOPE OF WORK

The scope of work as supplied by Gibb for this review study is the following:

1. Assess the document/ Report in terms of its fulfilment of its Terms of Reference set;
2. Consider whether the Report is entirely objective;
3. Consider whether the Report is technically, scientifically and professionally credible;
4. Consider whether the method and the study approach is defensible;
5. Identify whether there are any information gaps, omissions or errors;
6. Consider whether the recommendations presented are sensible and present the best options;
7. Consider whether there are alternative viewpoints around issues presented in the Report and if these are clearly stated;
8. Consider whether the style of the Report is written so as to make it accessible to non-specialists, technical jargon is explained and impacts are described using comparative analogies where necessary; and
9. Report on whether normal standards of professional practice and competence have been met.

3 REVIEW FINDINGS

3.1 Fulfilment of Terms of Reference

The terms of reference are explicitly mentioned on page 20 of the Report and it is pointed out that the standard EIA approach of rating environmental impacts of low, medium or high significance is not followed. Rather the internationally accepted regulatory norms for radiological protection, as adopted by the South African National Nuclear Regulator are used. Furthermore the early stage of nuclear authorisation process is followed. This in practice means assessment is required to determine if specific dose and risk criteria equivalent to low impact (for normal operation) are not exceeded. This approach is fully justified for nuclear impacts and for this stage of an EIA process that considers feasibility of a number of possible sites. In addition the four questions posed in the Executive Summary can be seen as further terms of reference and are answered in the four separate sections of the Report reviewed, namely a) nuclear power plant normal operational public dose b) accident risk to public, c) radiation risk to non-human biota and d) background radiation. In this context it can be said that the Report fully meets the terms of reference set.

3.2 Report Objectivity

Objectivity can be rated both on the issue of radiological impacts and the merits or otherwise of the three sites assessed.

Radiological impacts: such impacts certainly invoke the most concern in any nuclear related project and need to be conscientiously assessed. The issue of complex scientific ideas contrasted with general level of understanding of concepts by the public is handled by steering a course without embellishment through sets of facts, regulatory limits, site data and accident information. Much information and explanation (including appendices) is given to reveal the complex methodology of arriving at dose estimates both for routine and accident scenarios based on internationally accepted radiological norms. These estimates are based on the conservative dose assessment approach which overestimates dose.

Each of the three proposed sites is equally assessed with site specific data collected for the purpose. It must be stated however that for certain parameters such as wind, marine and terrestrial monitoring there is much more data available for the Duynefontein site which is part of the existing Koeberg nuclear power plant area. Nevertheless additional monitoring and sampling was done at the Duynefontein site and revealed some high naturally occurring radiological impacts both in the marine food chain and in terrestrial geological outcrops. Although results show there are differences between the three sites for measured background radiation and for modelled dose impacts to the various critical groups identified for both normal and accidental discharges, the sites have not been explicitly ranked. This is acceptable because such doses fall within the range of background radiation and the modelled doses meet the specified radiological criteria. So technically at this stage all sites are acceptable on all criteria assessed. Further evaluation will take place at subsequent stages of nuclear licensing.

The dose assessments have closely followed the international best practice for radiological impact and have followed a conservative approach for this stage of site investigation. The evaluation is considered to be wholly objective.

3.3 Technical, Scientific and Professional Credibility

The subject matter which is of a high technical and scientific nature is covered in a comprehensive well-structured manner. The various computer models used for air dispersion and dose assessment are widely employed internationally particularly in Europe. These computer codes are also used by Eskom and National Nuclear Regulator in South Africa. Verification and validation of software use is not reviewed here but is part of the nuclear licence process. The Report admits to limitations, assumptions and uncertainties that affect radiological assessment using models. These are summarized in section 3.4 below. The marine dispersion box model is very basic but appropriate for early phase studies. The yearlong sets of site specific data for wind, background radiation etc. are adequate for this stage of site evaluation. The selection of sample types of terrestrial plants, food stuffs and of marine biota is appropriate for a screening study. The professional quality control aspects of sample collection and radio-analytical data is noted. Species choice for non-human radiation impact is credible. The Report is well supported with photos, diagrams, graphs and tabulations. Historical accident reports at nuclear power plants are well summarized. Appendices provide further detailed information. Extensive up to date references are cited, adding to the credibility.

3.4 Defensibility of Methodology and Study Approach

The methodology and structure of the Report is given in broad terms in the introductory section (with a mention of not following the EIA approach - see this review comment in section 3.1) and in the four main sections presented. However a summary of the methodology details is not given. (The detailed Table of Contents for Chapter 1 could serve as a framework for this purpose for normal discharge impacts). The basic stance for assessing radiological impact from **normal operations** is to see if doses potentially incurred by the public are within internationally accepted limits as implemented by the local nuclear authority. The doses are assessed by application of various models. The Report discusses four areas of uncertainties, limitations and assumptions. Firstly source term related, meaning quantities and qualities of discharges; related to installed reactor power 4000 MW_{th} to 10 000 MW_{th} and nuclide species and their associated chemical species where C-14 is a prime example being the dominant source of dose for normal operations. Secondly, atmospheric dispersion uncertainties in general and for this stage not having specified number and height of discharge stacks. Thirdly, marine dispersion which assumes a single point discharge into limited size box model, with further complexity of variable sediment uptake and large variation in bioaccumulation. Fourthly, the public dose dependent on choice of critical group which at this stage is hypothetical and maximized. At later stage of nuclear licensing most of these uncertainties will be resolved and more realistic data used. In part, uncertainties are accounted for at this early phase assessment by adopting a conservative approach at each step of the process. This means where different options are available, the one giving the higher dose is chosen. This review points out that the different conservative choices in the modelling process may be nested in a hierarchy of various levels which may have a multiplier effect. Various steps used in the Report that maximize ultimate dose estimated include choice of: power source term, nuclide source set, chemical species, ground level release for max concentration, closeness to site , critical groups character (and combined groups), occupancy factors (eg time on beach, time outdoors), food consumption masses & types, all age groups, high factors for sediment uptake and bioaccumulation.

A specific justification of not including groundwater exposure pathways for public dose related to normal operation of a nuclear power plant is given in Appendix 2 of the Report. This is supported.

The conservative philosophy outlined here of constantly erring on the side of higher resulting dose will mean that if such an estimate currently is within limits a more realistic approach based on future more thorough studies will yield lower doses. All in all the many considerations used in the different stages of the methodology in deriving the dose results for both the routine atmospheric and marine discharges are eminently defensible and show all three sites to be well within the regulatory dose constraint.

Radiological risk to the public from nuclear power plant **accidents** is assessed against meeting nuclear safety principles, relevant dose criteria and requirements of emergency response. This is done in the context of criteria for the new Generation III (GEN III) type nuclear power plants proposed for this project. The evolutionary development of nuclear reactor safety form Generation I to III type power plants is outlined. An extensive case is laid out using various diagrams and tabulations of all the steps in ensuring reactor safety to limit public dose from design basis accidents to less than 50mSv. New features of Gen III reactors seek to eliminate accidents through passive safety where no human intervention is required for safe shut down, while "core catchers" limit consequences of core melt down. The design philosophy of Defence-in-Depth is explained together with the concepts of deterministic and probabilistic safety analysis. The Report admits there is some scepticism in numerical risk values. The calculation of such low numerical values on their own are not sufficient for approval by regulators who still seek additional design features for even more assurance of safety. The Report refers to Nuclear-1 EIA Emergency Response Report (Appendix E26 of Revise Draft EIR Ver 2), where the GEN III reactor limited off-site radiological impacts for severe accident are discussed and show that all three sites meet the objectives for an emergency response plan. Only two major reactor accidents have involved light water reactors namely at Three Mile Island in USA and at Fukushima in Japan. A presentation of these two past major nuclear accidents illustrate both the level of containment and discharge from the old Gen II design. The lessons learnt from the Fukushima accident have been incorporated into new guidelines for reactor safety that will make the GEN III type even safer.

Note, further justification relating to accidents is covered in a separate specialist EIA report viz. Beyond-Design-Basis Accidents (Sep 2015).

The extension of focus to **non-human biota** is to broaden the assessment of potential radiological impacts to include wider environmental concerns. Although there is not yet a formal document from the National Nuclear Regulator detailing requirements for assessing non-human radiological dose, the presentation of the ERICA software tool for such evaluation is appropriate for the site studies under discussion. For routine discharges a Tier 2 screening assessment on terrestrial and marine species was done on selected relevant species using environmental radionuclide concentrations based on site modelled atmospheric and marine data. For the screening study reported the terrestrial atmospheric concentration was very conservative being for a position just 100m distance from a ground level release. Dose results showed all species (marine and terrestrial) had dose rates below the screening level of 10µGy/h and mostly just a fraction thereof. The ERICA tool is widely used in Europe and the finding presented here are defensible for this project. The Report does point out that more detailed radio-ecological studies will be required at later licensing stages for further confirmation. The Report as part of its methodology also covers aspects of radiological risk to non-human biota following significant nuclear accidents and quotes from relevant reports. Much uncertainty exists but a good summary of the Chernobyl and Fukushima impact on non-human biota is given.

The section on **background radiation** is an important element in putting into perspective the potential radiological impacts from nuclear power plants. As such it is key to public understanding that ionizing radiation is part of everyday life and can vary quite considerably in nature from place to place. The main objectives of the background survey is well summarized in six bulleted points (p100). The choice of sampling and monitoring points was judiciously done with the help of identification of potential impact areas at each site as based on the air dispersion modelling results. The range of environmental media chosen for background measurements is comprehensive enough for such a preliminary investigation. The emphasis for terrestrial biota on the dairy industry is appropriate. The field and laboratory work is supported by a high level of quality control covering sampling, use of calibrated equipment and accredited analytical facilities. The duration of some sample sets is not optimum but for this stage is suitable. The limited sampling at Dynefontein which falls within the existing Koeberg nuclear site is supported with the philosophy of adding further value by rather selecting different sampling locations and including additional naturally occurring radionuclides Po-210 and radon (Rn-222).

The six objectives mentioned have all been met and briefly referred to below. External radiation from natural anomalies have been identified on the sites as well as radiation from imported gravels. Such information is useful for further surveys. Of particular note are findings of high natural levels of Po-210 particularly in marine foodstuffs. It is disappointing that it was not possible to sample abalone at Bantamsklip for Po-210 analysis, but the importance of follow-up is noted. At each site there are already traces of artificial nuclides namely Cs-137 and Sr-90 which are part of worldwide contamination of historical atmospheric nuclear weapon testing. The concentrations and resulting doses from naturally occurring radioactive material are shown to be dominant compared with artificial radionuclides. At Koeberg for instance the radiotoxicity of the artificial nuclide silver Ag-110m is shown to give a much lower dose from white muscle consumption than that of the natural nuclide Po-210. Information for future monitoring programs is provided for example that sour figs could be used as indicator species for accumulation of artificial Cs-137 and Sr-90 radionuclides. Lastly there is ample evidence in numerous diagrams, figures and tabulations showing information suitable for communicating the complex natural radioactive world we all inhabit. The Report concludes that people living near the three sites receive a background radiation dose of less than 2 mSv/y which is lower than the average global dose. This can be compared with the site dose constraint of 0.250 mSv/y and the even lower site dose based on allowable discharge of radionuclides achieved by Koeberg nuclear power station of less than 0.010 mSv/y over past few years. Routine radiological impacts are seen to be a very small fraction of natural background. The information on background radiation presented in the Report supports the methodology outlined.

General comment for defence of methodology and study approach is that references are current, models used are up to date and newly collected/measured site specific data are employed.

3.5 Information Gaps, Omissions or Errors

Typographical and Clarity: Generally small grammatical errors are not noted. The following few typographical, layout errors are noted.

P 15: Dose to read: Absorbed dose: is the

P 25: First line to read: The Major Hazard Installation

P 36: For greater clarity a radial scale is needed in figures of Table 1.2

P 38: Should explain units in Table 1-3

P 41: For clarity the dose axis in Fig 1-8 should be explain for which critical group

P 58: After three bullets 2nd line to read: ERICA, a radioecology

P 64: Formatting layout error, the top of Table 1.15 margin missing and then whole Table 1.15 is repeated.

P 97: In the 4th paragraph the superscript of 5 for a footnote reference on the 100 µGy/h is confusing to public – should rather be placed on previous word.

P 146: Formatting layout error, Table 4-28 is repeated 3 times on each of page 145, 146 & 147 with title missing on first two pages.

P 186: Formatting error, item 2. Should have a part a. and b. as per item 3

Additions to Glossary and Abbreviations: The following could be considered for inclusion.

CR Concentration Ratio

KD Sediment Distribution Coefficient

Possible Gaps

The assessment of radiological impacts makes no mention of that due to nuclear waste and transport. This is justifiable since another specialist report covers such impacts. Similarly decommissioning impacts are not addressed. This can be neglected at a siting phase study and such impacts are much lower than the operational phase. A decommissioning study is however required for nuclear licensing. Doses under accident conditions are covered while dose limitation through effective emergency plan is covered in a separate specialist report in the EIA process on Emergency Response Planning. Similarly more information on accidents is provided in a Beyond Design Basis Accident report.

Inadequate discussion is given on possible impacts due to climate change over the 60 year time span considered. Changes in rain and wind conditions may affect air dispersion. Agricultural production may also change. Such changes will together affect dose predictions. Similarly there should be some comment on sea level rise together with Tsunami linked to accident probability. The very conservative approach in dose estimates may cover such uncertainties but some reasoned comment is required or cross referenced to other specialist report such as the Geological Hazard Environment Impact Report and Review in the EIA re Tsunamis.

3.6 Sensibility of Recommendations and Presentation of Best Options

The main finding of the radiological assessment for a Generation III type Nuclear Power Plant normal impact, is that all three sites meet the regulatory dose constraint of 0.250mSv per year to a member of the public. Similarly for non-human biota, screening assessments at all three sites meet the radiological reference level of less than 10 microgray per hour (µGy/h) for a set of reference animals and plants. Although the sites had varying results the sites were not ranked for suitability as such data are not intended for optimisation and not required for nuclear site licensing. A best site option was therefore not considered. Similarly all three sites meet requirements for GEN III reactor accident conditions and for emergency response. Any reactor design chosen will be subject to approval of a final nuclear safety case from the National Nuclear Regulator.

A specific recommendation is that the owner of the quarry at Grassy Ridge, Thyspunt should be made aware of the high level of natural radioactivity in the quarry and not allow further spreading of aggregate. A consistent recommendation, in fact a requirement, throughout the Report is that in moving on from the EIA phase, a follow up assessment with more detailed work should be undertaken for all site aspects to meet nuclear regulatory needs.

All recommendations provided by the Report are sensible as they are based on presenting well documented findings of site characteristics that meet regulatory criteria and methodology for international good practise. Options for more detailed investigations are indicated.

3.7 Alternative Viewpoints Presentation and Clarity of Statement

There are no significant alternative viewpoints presented in the Report. The methodology used and study approach have followed the internationally approved scientific basis for radiological impacts and the nuclear industry standards for risk studies. The International Commission on Radiological Protection (ICRP), the International Atomic Energy Agency (IAEA), the National Commission on Radiation Protection (NCRP) in USA and various other national bodies all support the Linear no Threshold (LNT) dose model which is the basis on which the dose limits and constraints used in the nuclear industry are founded. There are some dissenting opinions from groups such as French Academies who say there should be a threshold below which no effects occur. Some groups support hormesis or beneficial model that says below a certain small dose benefits occur. The organizations first mentioned currently still endorse the LNT model although they have debated and investigated the alternatives. Recently in 2014 the United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR) who support LNT have warned against its misuse with the practice of calculating the hypothetical number of cancers that might occur from very small doses received by very large numbers of people as it is inappropriate and misleading. Small doses can be considered at levels of order 10mSv. The Report does not touch on these alternative views but stays with the accepted international scientific consensus and is clear in its conclusions.

3.8 Accessibility of Style of Report to Non-specialists

The executive summary of the Report has an effective approach of posing four questions that the public may ask of a nuclear development. This connects with the non-specialists and is followed through with well-illustrated and comprehensive answers. There are copious photographs, diagrams and tabulations that cover the details of a complex topic. This is supported with a helpful glossary, list of abbreviations and units, detailed referencing and appendices. There are seven appendices that allow the critical reader to better understand the comprehensiveness of the assessment process, the methodology and the level of detail required for input to the models used. Some analogies are used to simplify complexities such as in risk and safety analysis where a driver in a road accident scenario illustrates steps to prevent, control, limit and mitigate risk through a process providing defence in depth barriers.

Although the broad gamut of the methodology is outlined for the Report as a whole a reader can get lost in the detail so there is a need for a summary of the methodology per section to allow the non- specialist to appreciate the steps being taken. Some extra terms and abbreviations could be included in the glossary and lists as suggested in Section 3.5. In such a long and detailed Report it would be useful to have more explicit conclusions or findings for different sections or subsections. The use of abbreviations m and μ (micro) in dose units can be confusing if used interchangeably in the same discussion or paragraph and the factor 1000 difference in magnitude may be lost. For example see page 63 in text and in Fig 1-16.

In general the Report style allows non-specialist to access the complexity of radiation protection and appreciate the findings made.

3.9 Meeting of normal Standards of Professional Practice and Competence

The Report meets the normal standards of professional practice as reflected in the competent execution of field work, the diligence in covering the many factors in setting the scene and accomplishing the assessment of radiological impact on the public and environment. The report is structured to meet international and local regulatory requirements and this has been achieved competently.

4 CONCLUSIONS

The review process has addressed all 9 points of the Scope of Work and is satisfied they have been met to the extent indicated in each section.