Office for Nuclear Regulation

New Reactor Division – Generic Design Assessment

Step 2 Assessment of the Civil Engineering of UK HPR1000 Reactor

Assessment Report: ONR-GDA-UKHPR1000-AR-18-005
Revision 0
October 2018

Published 10/18

EXECUTIVE SUMMARY

This report presents the results of my Civil Engineering assessment of the UK HPR1000 undertaken as part of Step 2 of the Office for Nuclear Regulation's (ONR) Generic Design Assessment (GDA).

The GDA process calls for a step-wise assessment of the Requesting Party's (RP) safety submission with the assessments increasing in detail as the project progresses. Step 2 of GDA is an overview of the acceptability, in accordance with the regulatory regime of Great Britain, of the design fundamentals, including ONR's review of key nuclear safety and nuclear security claims (or assertions). The aim is to identify any fundamental safety or security shortfalls that could prevent ONR from permitting the construction of a power station based on the design.

During GDA Step 2 my work has focused on the assessment of the Civil Engineering aspects within the UK HPR1000 Preliminary Safety Report (PSR), and a number of supporting references and supplementary documents submitted by the RP, focusing on design concepts and claims.

The standards I have used to judge the adequacy of the RP's submissions in the area of Civil Engineering have been primarily ONR's Safety Assessment Principles (SAPs), in particular the Engineering Principles SAPs, and ONR's Technical Assessment Guide NS-TAST-GD-017 – Civil Engineering. I have also used guidance from the International Atomic Energy Agency (IAEA), such as NS-G-1.6; 2003 - Seismic Design and Qualification for Nuclear Power Plants, Safety Guide.

My GDA Step 2 assessment work has involved regular engagement with the RP in the form of technical exchange workshops and progress meetings, including meetings with the plant designers.

The UK HPR1000 PSR is primarily based on the Reference Design, Fangchenggang Unit 3 (FCG3), which is currently under construction in China. Key aspects of the UK HPR1000 preliminary safety case related to Civil Engineering, as presented in the PSR, its supporting references and the supplementary documents submitted by the RP, can be summarised as follows:

- Demonstration that nuclear safety-related structures can deliver safety functional requirements.
- Demonstration that the categorisation process and classification of UK HPR1000 nuclear safety-related structures will adopt relevant good practice codes and standards.
- Demonstration that the methods of analysis and the determination of design parameters are applicable for the design of nuclear safety-related structures. A demonstration that the design methodology, load combinations and seismic design for UK HPR1000 will comply with relevant good practice codes and standards.
- Demonstration that UK HPR1000 civil structures will adopt relevant good practice codes and standards. In addition, a demonstration that the design will be compatible with UK construction practices and materials.
- Demonstration that nuclear safety risks related to the design, procurement, construction, operation, maintenance, decommissioning of Civil Engineering structures have been reduced so far as is reasonably practicable (SFAIRP).
- Demonstration that the design of UK HPR1000 will consider applicable UK regulations relevant to Civil Engineering.

In addition, Civil Engineering is responsible for the demonstration that the plant has sufficient resilience against non-accidental aircraft impact.

During my GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Civil Engineering I have identified the following areas of strength:

- The RP has developed a plan to deliver a clear and logical document hierarchy which includes analysis and design submissions, to articulate the Civil Engineering Safety Case. Once completed, this should demonstrate the “golden thread” through the Civil Engineering Safety Case.
- The seismic categorisation process, of relevance to nuclear-safety related structures, is commensurate with relevant IAEA guidance.
- The RP will adopt the latest internationally recognised and accepted nuclear-specific codes and standards for the analysis and design of safety-related nuclear structures. This should lead to a conservative analysis commensurate with the importance of the safety function(s) being performed and reflect relevant good practice.
- The RP has established an Aircraft Impact Multi-Disciplinary Working Group to oversee and coordinate the activities required for the Aircraft Impact topic.

During my GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Civil Engineering I have identified the following areas that require follow-up:

- Demonstration of the “golden thread” within the Civil Engineering Safety Case, including identification of Safety Functional Requirements, engineering requirements and acceptance criteria for nuclear safety-related structures.
- Additional work to demonstrate that the Spent Fuel Pool (SFP) is capable of delivering the Safety Functional Requirements, to meet ONR expectations for defence in depth.
- Other civil structures, systems and components will be sampled to ensure that they are capable of delivering the claimed Safety Functional Requirements (e.g. use of grouted tendons for pre-stressed inner containment).
- Application of nuclear safety categorisation and classification, and seismic categorisation to the design of civil structures.
- Ground parameters included in the Generic Site Envelope Report.
- Barrier Substantiation, as reported in the UK HPR1000 GDA Step 2 Internal Hazards Assessment Report.
- Combining of codes and standards needs to be adequately justified and their mutual compatibility demonstrated, particularly when using British or European material parameters in American design codes.
- Evidence to demonstrate compliance with ONR expectations for Aircraft Impact.
- The RP has identified that two types of aircraft impact shell exist for the HPR1000. I consider this a novel concept for the UK and the implications for the Civil Engineering assessment and generic aircraft impact safety case need to be further explored.

During my GDA Step 2 assessment, I have not identified any fundamental safety shortfalls in the area of Civil Engineering that might prevent the issue of a Design Acceptance Confirmation (DAC) for the UK HPR1000 design.

LIST OF ABBREVIATIONS

ACI	American Concrete Institute
ALARP	As Low As Reasonably Practicable
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
BAT	Best Available Technique
BMS	Business Management System
BRB	Bradwell ‘B’
BSL	Basic Safety Level (in SAPs)
BSO	Basic Safety Objective (in SAPs)
CDM	Construction (Design and Management) Regulations
CGN	China General Nuclear Power Corporation
DAC	Design Acceptance Confirmation
EA	Environment Agency
EDF	Électricité de France
FCG	Fangchenggang (Nuclear Power Plant)
FQ	Fuqing (Nuclear Power Plant)
GNI	General Nuclear International
GNS	Generic Nuclear System Ltd
GSR	Generic Security Report
IAEA	International Atomic Energy Agency
JPO	(Regulators’) Joint Programme Office
MDEP	Multinational Design Evaluation Process
NNSA	(Chinese) National Nuclear Safety Administration
NPP	Nuclear Power Plant
ONR	Office for Nuclear Regulation
PCSR	Pre-construction Safety Report
PCER	Pre-construction Environmental Report
PSA	Probabilistic Safety Analysis
PSR	Preliminary Safety Report (includes security and environment)
RGP	Relevant Good Practice
RHWG	Reactor Harmonization Working Group (of WENRA)
RI	Regulatory Issue
RIA	Regulatory Issue Action
RO	Regulatory Observation
ROA	Regulatory Observation Action
RP	Requesting Party
RQ	Regulatory Query

SAP(s)	Safety Assessment Principle(s)
SFAIRP	So far as is reasonably practicable
SFP	Spent Fuel Pool
SFR	Safety Functional Requirements
SSC	Structures, systems and components
SSI	Soil-Structure Interaction
SSSI	Soil-Structure-Soil Interaction
TAG	Technical Assessment Guide(s)
TSC	Technical Support Contractor
TSF	Technical Support Framework
UK	United Kingdom
WENRA	Western European Nuclear Regulators' Association

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1 INTRODUCTION

1. The Office for Nuclear Regulation's (ONR) Generic Design Assessment (GDA) process calls for a step-wise assessment of the Requesting Party's (RP) safety submission with the assessments increasing in detail as the project progresses. General Nuclear System Ltd (GNS) has been established to act on behalf of the three joint requesting parties (China General Nuclear Power Corporation (CGN), Électricité de France (EDF) and General Nuclear International (GNI)) to implement the GDA of the UK HPR1000 reactor. For practical purposes GNS is referred to as the 'UK HPR1000 GDA Requesting Party'.

2. During Step 1 of GDA, which is the preparatory part of the design assessment process, the RP established its project management and technical teams and made arrangements for the GDA of the UK HPR1000 reactor. Also, during Step 1 the RP prepared submissions to be assessed by ONR and the Environment Agency (EA) during Step 2.

3. Step 2 commenced in November 2017. Step 2 of GDA is an overview of the acceptability, in accordance with the regulatory regime of Great Britain, of the design fundamentals, including ONR's assessment of key nuclear safety and nuclear security claims (or assertions). The aim is to identify any fundamental safety or security shortfalls that could prevent ONR permitting the construction of a power station based on the design.

4. My assessment has followed my GDA Step 2 Assessment Plan for Civil Engineering (Ref. 8) prepared in October 2017 and shared with GNS to maximise openness and transparency.

5. This report presents the results of my Civil Engineering assessment of the UK HPR1000 as presented in the UK HPR1000 Preliminary Safety Report (PSR) (Ref. 12) and supporting documentation (Refs. 17 - 37).

2 ASSESSMENT STRATEGY

6. This section presents my strategy for the GDA Step 2 assessment of the Civil Engineering aspects of the UK HPR1000 (Ref. 9) in line with my Assessment Plan (Ref. 8). It also includes the scope of my assessment and the standards and criteria I have applied.

2.1 Scope of the Step 2 Civil Engineering Assessment

7. The objective of my GDA Step 2 assessment was to assess relevant design concepts and claims made by the RP related to Civil Engineering. In particular, my assessment has focussed on the following:

- Familiarising myself with the HPR1000 and UK HPR1000 designs.
- Reviewing the RP's safety submissions to confirm whether safety claims made on civil nuclear safety-related structures are complete and reasonable. Civil Engineering safety claims are explicitly defined in my Step 2 Assessment Plan (Ref. 8).
- Raising Regulatory Queries (RQ) and Regulatory Observations (RO), as defined in the Guidance to Requesting Parties (Ref.7).
- Enabling the RP to deliver a meaningful GDA through teleconferences and face-to-face technical meetings and workshops.

8. During GDA Step 2 I have also evaluated whether the safety claims related to Civil Engineering are supported by a body of technical documentation sufficient to allow me to proceed with GDA work beyond Step 2.

9. Finally, during Step 2 I have undertaken the following preparatory work for my Step 3 assessment:

- Engaged with the RP to develop a Civil Engineering submission schedule. This will allow me to develop a Step 3 Assessment Plan which identifies the need for Technical Support Contractors (TSCs) and specific areas of interest to be investigated during Step 3.
- Further developed my knowledge of the UK HPR1000 design by means of site visits to the design reference plant (Fangchenggang 3) and another HPR1000 (Fuqing 5), which are both under construction in China.
- Liaised with other ONR inspectors, as appropriate, to inform and focus my Step 2 assessment work. In addition, I have undertaken preparatory work regarding interfaces with other disciplines for Step 3.
- Undertaken a coarse review of an advance copy of the UK HPR1000 Pre-Construction Safety Report (PCSR). Having early visibility of the scope and content of this chapter/s has been useful in the planning of my GDA Step 3 assessment work.

2.2 Standards and Criteria

10. For ONR, the primary goal of the GDA Step 2 assessment is to reach an independent and informed judgment on the adequacy of a preliminary nuclear safety and security case for the reactor technology being assessed. Assessment was undertaken in accordance with the requirements of the Office for Nuclear Regulation (ONR) How2 Business Management System (BMS) guide NS-PER-GD-014 (Ref. 1).

11. In addition, the Safety Assessment Principles (SAPs) (Ref. 2) constitute the regulatory principles against which duty holders' and RP's safety cases are judged. Consequently the SAPs are the basis for ONR's nuclear safety assessment and have therefore been used for the GDA Step 2 assessment of the UK HPR1000. The SAPs 2014 Edition are aligned with the International Atomic Energy Agency (IAEA) standards and guidance.

12. Furthermore, ONR is a member of the Western European Nuclear Regulators' Association (WENRA). WENRA has developed Reference Levels (Ref. 5), which represent good practices for existing nuclear power plants, and Safety Objectives for new reactors.

13. The relevant SAPs, IAEA standards and WENRA reference levels are embodied and expanded on in the Technical Assessment Guides (TAGs) on Civil Engineering (Ref. 3). This guide provides the principal means for assessing the Civil Engineering aspects in practice.

2.2.1 Safety Assessment Principles

14. The key SAPs (Ref. 2) considered within my assessment are listed in Annex 1.

2.2.2 Technical Assessment Guides

15. The following Technical Assessment Guide (Ref. 3) has been used as part of this assessment:

- Civil Engineering, NS-TAST-GD-017 Rev. 3, May 2013

16. With additional guidance from:

- Guidance on Demonstration of As Low As Reasonably Practicable (ALARP), NS-TAST-GD-005 Rev. 9, March 2018
- Internal Hazards, NS-TAST-GD-014 Rev. 3, September 2016
- Decommissioning, NS-TAST-GD-026 Revision 4, September 2016
- Construction Assurance, NS-TAST-GD-076 Revision 2, September 2015

2.2.3 National and International Standards and Guidance

17. The following national and international standards and guidance have been considered as part of this assessment:

- Relevant IAEA standards (Ref. 4)
  - Safety Standards: Safety of Nuclear Power Plants: Design, Specific Safety Requirement; SSR-2/1 (Revision 1); 2016
  - Safety Standards: Fundamental Safety Principles; SF-1; 2006
  - Safety Standards: Safety Assessment for Facilities and Activities General Safety Requirements Part 4; GSR Part 4; 2016
  - Safety Standards: Seismic Design and Qualification for Nuclear Power Plants, Safety Guide; NS-G-1.6; 2003
  - Safety Standards: Safety Classification of Structures, Systems and Components in Nuclear Power Plants; SSG-30; 2014
- WENRA references (Ref. 5)
  - Reactor Safety Levels for Existing Reactors; September 2014
  - Statement on Safety Objectives for New Nuclear Power Plants (March 2013) and Safety of New NPP Designs (March 2013)

2.3 Use of Technical Support Contractors

18. During Step 2 I have not engaged TSCs to support my assessment of the Civil Engineering for the UK HPR1000.

2.4 Integration with Other Assessment Topics

19. In this assessment I recognised the importance of working closely with other ONR inspectors (including Environment Agency's assessors) as part of the Civil Engineering assessment process. Similarly, other inspectors sought input from my assessment of the Civil Engineering for the UK HPR1000. I consider these interactions are vital to the success of the project in order to prevent, or mitigate any gaps, duplications or inconsistencies in ONR's assessment. From the start of the project, I have endeavoured to identify potential interactions between the Civil Engineering and other technical areas, with the understanding that this position will evolve throughout the UK HPR1000 GDA.

20. The key interactions that I have identified are:

- External Hazards provides input to design aspects of the Civil Engineering assessment. This formal interaction has commenced during GDA Step 2. This work is being led by the External Hazards inspector. This work includes relevant aspects of the generic aircraft impact safety case, which is yet to be produced.
- Internal Hazards provides input to design aspects of the Civil Engineering assessment. This formal interaction has commenced during GDA Step 2. This work is being led by the Internal Hazards inspector.
- Structural Integrity provides input to the containment aspects (including material grade) of the Civil Engineering assessment. This formal interaction has commenced during GDA Step 2. This work is led by myself in coordination with the Structural Integrity team.
- The Civil Engineering assessment provides input to the structural analysis of Level 2 Probabilistic Safety Analysis (PSA) assessment. This formal interaction has not commenced during GDA Step 2. This work will be led by the PSA inspector.
- The Civil Engineering assessment will, where required, provide input to the building design and plant layout aspects of the Security assessment. This formal interaction has not commenced during GDA Step 2. This work will be led by the Security inspector.
- The Civil Engineering assessment will, where required, provide input to the building design and construction aspects of the Conventional Health & Safety assessment. This formal interaction has not commenced during GDA Step 2. This work will be led by the Conventional Health & Safety inspector.

21. I have also provided Civil Engineering input into the following cross-cutting topics:

- Safety case development;
- Categorisation of safety functions & classification of structures, systems and components (SSCs);
- ALARP and Best Available Technique (BAT) methodologies;
- Safety case commitments, assumptions etc. capture;
- GDA scope; and
- Design control – Design Reference, Master Document Submission List, design changes etc.

22. Project wide assessment of the cross-cutting topics is reported in the Summary of the Step 2 Assessment of the UK HPR1000 Reactor (Ref. 13). Assessment of the categorisation of safety functions & classification of SSCs is reported in the Fault Studies report (Ref. 14).

23. Other assessment reports which have significant overlap with Civil Engineering during Step 2 are:

- GDA Step 2 Assessment of External Hazards (Ref. 15)
- GDA Step 2 Assessment of Internal Hazards (Ref. 16)

24. The potentially conflicting requirements of nuclear safety, security, safeguards, fire and conventional safety will be taken into account to ensure that the measures adopted do not compromise one another.

3 REQUESTING PARTY'S SAFETY CASE

25. During Step 2 of GDA the RP submitted a PSR and other supporting references, which outline a preliminary nuclear safety case for the UK HPR1000. This section presents a summary of the RP's preliminary safety case in the area of Civil Engineering. It also identifies the documents submitted by the RP which have formed the basis of my Civil Engineering assessment of the UK HPR1000 during GDA Step 2.

3.1 Summary of the RP's Preliminary Safety Case in the Area of Civil Engineering

26. The aspects covered by the UK HPR1000 preliminary safety case in the area of Civil Engineering focus on demonstrating the following:

- Civil structures provide confinement of radioactive materials in the event of the failure of the reactor coolant system boundary.
- Civil structures provide the environmental conditions to suit the SSCs.
- Civil structures provide protection against internal and external hazards.

27. In order to demonstrate that these objectives have been met they can be rationalised into several topics:

- **Delivery of Safety Functions.** Demonstration that nuclear safety-related structures can deliver safety functional requirements.
- **Categorisation Process and Classification of Civil Structures.** Demonstration that the categorisation process and classification of UK HPR1000 nuclear safety-related structures will adopt RGP codes and standards.
- **Analysis and Design Methodologies.** Demonstration that the methods of analysis and the determination of design parameters are applicable for the design of nuclear safety-related structures. A demonstration that the design methodology, load combinations and seismic design for UK HPR1000 will comply with relevant good practice (RGP) codes and standards.
- **Application of Codes and Standards.** Demonstration that UK HPR1000 civil structures will adopt RGP codes and standards. In addition, a demonstration that the design will be compatible with UK construction practices and materials.
- **ALARP considerations.** Demonstration that nuclear safety risks related to the design, procurement, construction, operation, maintenance, decommissioning of civil engineering structures have been reduced so far as is reasonably practicable (SFAIRP).
- **Compliance with Regulation.** Demonstration that the design of UK HPR1000 will consider applicable UK regulations relevant to Civil Engineering.

28. In addition, Civil Engineering is responsible for the demonstration that the plant has sufficient resilience against non-accidental aircraft impact.

3.2 Basis of Assessment: RP's Documentation

29. The RP's documentation that has formed the basis for my GDA Step 2 assessment of the safety claims related to the Civil Engineering aspects of the UK HPR1000 is:

- PSR, Chapter 16 – Civil Works & Structures (Ref. 12);
- Additional Step 2 Submissions (Ref. 17 - 24);
- The RP's responses to relevant RQs and ROs listed in Annex 2 (Refs. 25 - 37)

30. The PSR (Ref. 12) presents the RP's initial safety case for Civil Engineering to be used for the design, construction, operation and decommissioning of a generic UK HPR 1000. The fundamental objectives of the PSR are described as follows:

- Design characteristics of the UK HPR1000 reflect a generic UK site that bounds suitable locations.
- Design will be developed in an evolutionary manner, using a robust design process, building on relevant good international practice, to achieve a strong safety and environmental performance.
- Design and intended construction and operation of the UK HPR1000 will protect the workers and the public by providing multiple levels of defence to fulfil the fundamental safety functions.
- Design and intended construction and operation of the UK HPR1000 will be developed to reduce, so far as is reasonably practicable, the impact on the workers, the public, and the environment.
- Designed and intended to be operated so that it can be decommissioned safely using current methods, with minimal impact on the environment and people.

31. Supplementary Civil Engineering specific Step 2 Submissions are listed below:

- Programme of Schedule Delivery (Ref. 17). The submission presents the Civil Engineering delivery programme; deliverable objectives; document hierarchy; and safety case development schedule.
- Codes and Standards submission (Ref. 18). The submission discusses options on Civil Engineering codes & standards available to the RP; their optioneering process; and selection of their final solution.

32. Supplementary multidisciplinary and cross-cutting Step 2 Submissions are listed below:

- UK HPR1000 Generic Site Report (Ref. 19). The submission aims to identify the necessary parameters to describe the UK HPR1000 Generic Site Envelope and the Site Characteristics, and propose values using publicly available information.
- Requirements on Optioneering & Decision Making (Ref. 20). The submission aims to demonstrate that all work, decisions and modifications are undertaken in accordance with ALARP and BAT principles, as well as reflecting the UK expectations of security and conventional safety principles.
- ALARP & BAT - Principles & Requirements for UK HPR1000 GDA (Ref. 21). The submissions presents the nuclear safety and environment principles; the holistic ALARP and BAT requirements; and an overview of the holistic ALARP and BAT processes including their objectives and deliverables to support an optimised UK HPR1000 design.
- ALARP Methodology (Ref. 22). The submission sets out the approach to assessing the generic design of the UK version of the UK HPR1000 to determine whether the nuclear safety risks of the construction, operation and decommissioning are ALARP.
- Scope for UK HPR1000 GDA Project (Ref. 23). The submission proposes the technical scope for the UK HPR1000 GDA Project.
- Methodology of Safety Categorisation and Classification (Ref. 24). The submission presents the UK HPR1000 safety function categorisation and SSC classification methodology, and aims to justify that it is suitable for the UK context, in support of GDA and future site licensing.

33. The RP’s response to RQs has provided clarification in certain topics. Responses of interest to the Civil Engineering Step 2 Assessment are listed in Annex 2.

34. During April 2018 GNS submitted to ONR, for information, an advance copy of the UK HPR1000 Pre-Construction Safety Report (PCSR). Chapter 16, Civil Works & Structures (Ref. 38) addresses Civil Engineering. My comments on the PCSR advance copy are recorded in Ref. 39.

4 ONR ASSESSMENT

35. This assessment has been carried out in accordance with HOW2 guide NS-PER-GD-014, “Purpose and Scope of Permissioning” (Ref. 1).

36. My Step 2 assessment work has involved regular engagement with the RP’s Civil Engineering specialists, i.e., various Technical Exchange Workshops (in China and the UK) and progress meetings have been held. During my trips to China, I have also visited:

- Fangchenggang (FCG) Unit 3 (FCG3) construction site (30/05/18) – Design Reference Plant.
- Fuqing (FQ) Unit 5 construction site (29/03/18) – Different option of HPR1000.

37. During my GDA Step 2 assessment, I have identified some gaps in the documentation formally submitted to ONR. Consistent with ONR’s Guidance to Requesting Parties (Ref. 7), these normally lead to RQs being issued. At the time of writing my Step 2 Civil Engineering assessment report, I had raised five RQs to facilitate my assessment.

38. Similarly, and again consistent with ONR’s Guidance to Requesting Parties (Ref. 7), more significant shortfalls against regulatory expectations in the generic safety case are captured by issuing ROs. At the time of writing my Step 2 Civil Engineering assessment report, I had raised no ROs.

39. Details of my GDA Step 2 assessment of the UK HPR1000 preliminary safety case in the area of Civil Engineering, including the conclusions I have reached, are presented in the following sub-sections of the report. This includes the areas of strength I have identified, as well as the items that require follow-up during subsequent Steps of the GDA of UK HPR1000.

40. For the purpose of my assessment I have used the building names taken from the PSR general layout as shown in Figure 1.

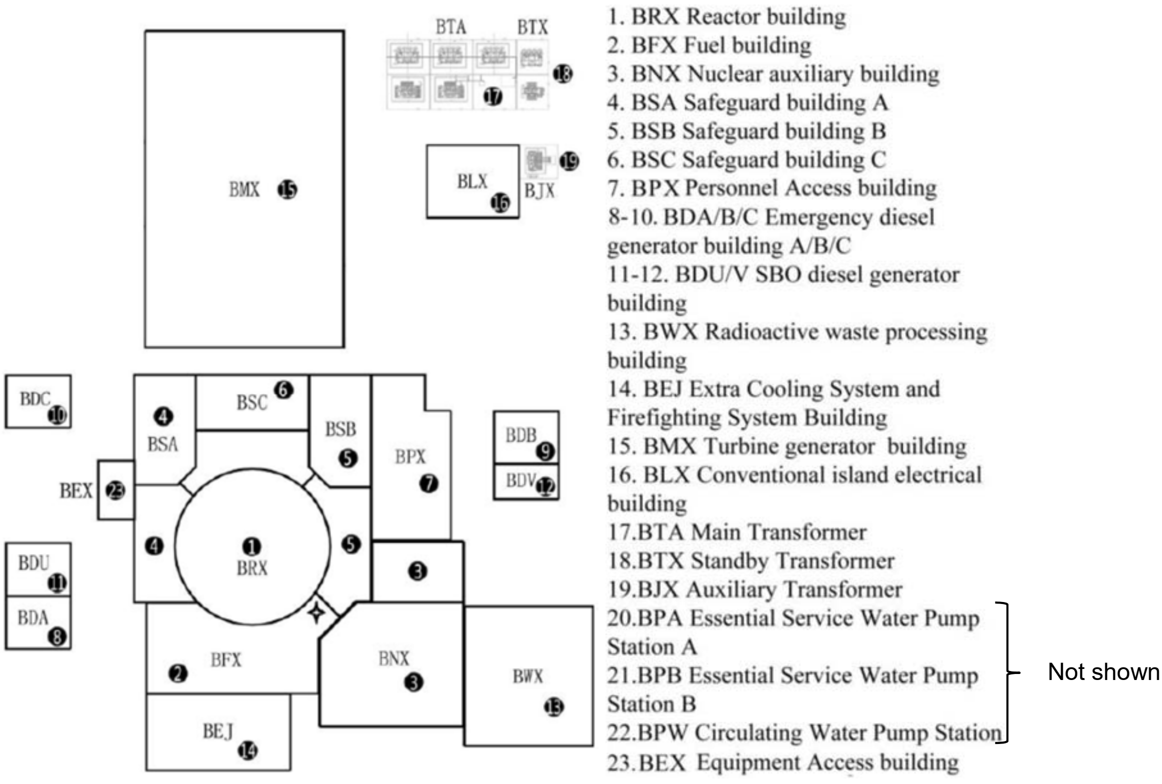

Figure 1 – General Layout of HPR1000 (FCG3) (Ref. 12)

41. I have not assessed the general layout during GDA Step 2 and this will be subject to further examination in GDA Steps 3 and 4; particularly on claims made within the aircraft impact safety case.

4.1 Delivery of Safety Functions

4.1.1 Assessment

42. As part of my assessment I examined the “golden thread” through the Civil Engineering Safety Case and sampled the ability of the Spent Fuel Pool (SFP) to deliver its containment safety function.

43. My assessment is based on the PSR–Chapter 16 (Ref. 12); the response to RQ-UKHPR1000-0097 (Ref. 33); the response to RQ-UKHPR1000-0013 (Ref. 29) & supporting information (Ref. 30); and the Programme of Schedule Delivery (Ref. 17).

44. The PSR states high-level safety function claims, whilst various other requirements are noted within the report; however it is unclear how they link together. At this stage in GDA, the “golden thread” is not visible within the safety case and needs greater clarity. I am not satisfied that the Civil Engineering Safety Case is demonstrably complete for its intended purpose and therefore the RP does not currently meet the requirements of SAP SC.4.

45. The response to RQ-UKHPR1000-0097 (Ref. 33) provides clarification on implementation of safety functional requirements (SFRs) and engineering requirements for structures. It is apparent that the RP understands the links between the engineering evidence and SFRs but has not yet been able to demonstrate this through the safety case. In addition, the Programme of Schedule Delivery (Ref. 17) states the intended document hierarchy for future Civil Engineering submissions which will establish the “golden thread”.

46. I am therefore satisfied that safety functions and structural performance of the civil engineering structures under normal operating, fault and accident conditions should be achievable, to satisfy the intent of SAP ECE.1. This, in turn, will allow for the development of a complete safety case which can likely satisfy the requirements of SAP SC.4, for Civil Engineering.

47. In response to RQ-UKHPR1000-0013 (Ref. 29) on steel lined concrete structures the RP provided a presentation (Ref. 30) on the structure of SFP. The RP claims that multiple barriers are present to ensure containment, comprising a primary stainless steel liner and secondary reinforced concrete barrier. I note that the performance of concrete would need to be justified to ensure its suitability as a barrier since its performance may be compromised through potential defects leading to adverse conditions (e.g. effects of borated water).

48. In addition, I note that there is only one monitoring system available to detect leaks in either of the claimed barriers. Currently, the arguments for the containment function of the SFP presented would not meet ONR expectations for defence in depth, nor the requirements of SAP ECE.3. In the response to RQ-UKHPR1000-0013 (Ref. 29) the RP recognises the need for additional work that will be undertaken during Steps 3 and 4 of GDA to substantiate their claims.

4.1.2 Strengths

49. During my GDA Step 2 assessment on the delivery of safety functions I have noted the following areas of strength:

- The RP has developed a plan to deliver a clear and logical document hierarchy to the support the PCSR which should demonstrate the "golden thread" through the Civil Engineering Safety Case once completed.

4.1.3 Items that Require Follow-up

50. During my GDA Step 2 assessment on the delivery of safety functions I have identified the following additional potential shortfalls that I will follow-up during Step 3 of GDA:

- Demonstration of the "golden thread" within the Civil Engineering Safety Case, including identification of SFRs, engineering requirements and acceptance criteria for nuclear safety-related structures.
- Additional work to demonstrate that the SFP is capable of delivering the SFRs to meet ONR expectations for defence in depth.
- Other civil-related SSCs will be sampled to ensure that they are capable of delivering the claimed Safety Functional Requirements (e.g. use of grouted tendons for pre-stressed inner containment).

4.1.4 Conclusions

51. Based on the outcome of my assessment on the delivery of safety functions, I have concluded that the RP's plans for the proposed future Civil Engineering submissions and document hierarchy should be sufficient to demonstrate the ability to deliver SFRs. To ensure this, I will undertake further sampling of other civil engineering-related SSCs during Steps 3 and 4 of GDA.

4.2 Categorisation Process and Classification of Civil Structures

4.2.1 Assessment

52. ONR's overall assessment of the RP's arrangements for the safety categorisation and classification of SSCs is being coordinated by the Project Technical Inspector, and is reported in (Ref. 13). My Civil Engineering specific assessment is based on the PSR–Chapter 16 (Ref. 12); and the Methodology of Safety Categorisation and Classification (Ref. 24).

53. Information presented in the PSR (Ref. 12) relates to the safety categorisation and classification process used for FCG3 which is based on IAEA Safety Standards SSG-30 (Ref. 4); and not the UK HPR1000. Section 16.2.2 of the PSR provides the classification of all buildings at FCG3. Table 1 below lists the safety classification applied at FCG3 for buildings which the RP has declared in the Scope for UK HPR1000 GDA Project (Ref. 23).

Building	Functional Classification	Functional Safety Classification	Seismic Classification
Emergency Diesel Generator Buildings (BDA, BDB & BDC)	FC1	F-SC1	SSE1
SBO Diesel Generator Buildings (BDU & BDV)	FC1	F-SC1	SSE1
Equipment Access Building (BEX)	NC	NC	SSE2
Fuel Building (BFX)	FC1	F-SC1	SSE1
Nuclear Auxiliary Building (BNX)	FC3	F-SC3	SSE1
Personnel Access Building (BPX)	NC	NC	SSE2

Reactor Building (BRX)	FC1	F-SC1	SSE1
Safeguard Buildings (BSX)	FC1	F-SC1	SSE1
Radioactive Waste Treatment Building (BWX)	FC3	F-SC3	SSE1
Extra Cooling System and Fire-fighting System Building (BEJ)	FC3	F-SC3	SSE1

Table 1 – FCG3 Classification of Buildings within GDA Scope

54. The majority of information supplied in Methodology of Safety Categorisation and Classification (Ref. 24) relates to the proposed application of the process to systems and not structures. The RP claims, that for safety-classified structures the appropriate classification will be achieved through the use of appropriate nuclear standards. The application of codes and standards is explored further in Section 4.4 of this report.

55. The seismic categorisation methodology developed by the RP is commensurate with relevant IAEA Safety Standards: Seismic Design and Qualification for Nuclear Power Plants, Safety Guide; NS-G-1.6; 2003 (Ref. 4). Whilst the application of this methodology has not yet been assessed the seismic classification of buildings at FCG3 is commensurate with other PWR reactors which have undergone GDA.

56. The classification and categorisation process of nuclear-safety-related structures as presented is sufficient for Step 2 requirements as it shows commitment to meet the intent of SAPs ECS1, ECS.2 and ECS.3. At present there is insufficient information present for me to form an opinion on whether the process is being applied correctly as no relevant submissions have been supplied. This will be subject to further examination in Step 3.

4.2.2 Strengths

57. During my GDA Step 2 assessment of the safety categorisation and classification process of civil structures I have noted the following areas of strength:

- The seismic categorisation process, of relevance to nuclear-safety related structures, is commensurate with relevant IAEA guidance

4.2.3 Items that Require Follow-up

58. During my GDA Step 2 assessment of the safety categorisation and classification process of civil structures I have identified the following additional potential shortfalls that I will follow-up during Step 3 of GDA:

- The application of nuclear safety categorisation and classification, and seismic categorisation to the design of civil structures needs to be explored further in Step 3. I will examine this principally through the supplied Basis of Safety Case documents and additional supporting evidence. I will also ensure consistency with work being undertaken by fault studies and PSA inspectors.

4.2.4 Conclusions

59. Based on the outcome of my assessment of the categorisation process and classification of civil structures sufficient information has been provided to satisfy Step 2 requirements.

4.3 Analysis and Design Methodologies

4.3.1 Assessment

60. My assessment is based on the PSR–Chapter 16 (Ref. 12); the response to RQ-UKHPR1000-0011 (Ref. 25); the response to RQ-UKHPR1000-0096 (Ref. 32); the response to RQ-UKHPR1000-0097 (Ref. 33) & supporting presentation (Ref. 34); the UK HPR1000 Generic Site Report (Ref. 19); and Programme of Schedule Delivery for Civil Engineering Schedule (Ref. 17).

61. Information presented in the PSR is based on the FCG3 HPR1000 and not the UK HPR1000. Safety claims in the PSR state that the UK HPR1000 methods of analysis and design will be applicable for the design of nuclear safety-related structures and comply with RGP codes and standards in the UK. This application of codes and standards is explored further in Section 4.4 of this report. I consider that the load combinations and approach to design stated within the PSR are commensurate with those provided by similar American and European standards.

62. As information presented in the PSR is related to the HPR1000 and not the UK HPR1000, I queried gaps in relation to UK context. The response to RQ-UKHPR1000-0011 (Ref. 25) clarifies areas that the RP has recognised as having potential difference between the Chinese and UK approaches that will require additional work. I probed this area further through RQ-UKHPR1000-0097 (Ref. 33) and technical workshops. The response to RQ-UKHPR1000-0097 (Ref. 33) states that for nuclear safety-related structures, safety functional requirements will be derived from the fault schedule and captured in Basis of Safety Case documents. These will subsequently be implemented in the Basis of Design documents and demonstrated through supporting evidence documents (e.g. design substantiation reports).

63. As part of my Step 2 assessment I sampled the progress made by the RP into developing a suitable seismic analysis methodology. The supporting presentation (Ref. 34) supplied with the response to RQ-UKHPR1000-0097 was delivered during a technical workshop in May 2018 and summarised the RP's position at that time. The RP has developed 4 different seismic analysis methodologies which they are considering for use on UK HPR1000, all of which they claim to have developed in accordance with ASCE4-16. The RP is still considering which of these methods they will employ for the UK HPR1000 and ONR will assess the chosen methodology upon submission. I note that ASCE4-16 is considered RGP as the latest internationally recognised and accepted code for the seismic analysis of nuclear safety-related structures.

64. The RP has an existing analysis and design for the HPR1000 civil structures which will need to be revised for the UK HPR1000. Whilst the bulk of the work to undertake the UK HPR1000 civil analysis and design has yet to be completed, the RP has a strong starting position; coupled with a planned structure of deliverables for the Civil Engineering Safety Case and list of supporting deliverables (Ref. 17). I am satisfied that these deliverables are likely to meet ONR expectations as set out in SAPs ECE.6 and ECE.12.

65. Information provided regarding ground conditions in the Generic Site Report (Ref. 19) and response to RQ-UKHPR1000-0096 (Ref. 32) is insufficiently mature. Ref. 19 presents a single ground parameter that has been chosen to allow for a demonstration that the UKHPR1000 is suitable for construction on a variety of sites within Great Britain. It is my opinion that the ground parameter presented is neither representative of the Bradwell 'B' (BRB) site nor a generic UK site. The response to RQ-UKHPR1000-0096 (Ref. 32) states that an updated Generic Site Report will be submitted at the end of GDA Step 2. I will assess the suitably of generic ground parameters upon receipt of the revised submission.

66. It is not required that the RP undertakes intrusive ground investigations to support their design during GDA. However, it is expected that sufficient investigation work (for example a desktop study) is undertaken to produce a generic design envelope which is representative of natural site materials to support the foundation loadings in accordance with SAP ECE.4. The design of foundations and sub-surface structures should utilise generic information to understand the attendant limitations such a choice may have on deployment of the UK HPR1000 within the UK. It is my opinion that, at present, the RP does not meet the intent of SAPs ECE.4 or ECE.5.

4.3.2 Strengths

67. During my GDA Step 2 assessment of the analysis and design methodologies I have noted the following areas of strength:

- The RP will adopt the latest internationally recognised and accepted nuclear-specific codes and standards for the analysis and design of safety-related nuclear structures. The correct application of these codes and standards should lead to a conservative analysis in accordance with SAP ECE.13.
- The RP has developed a plan to develop a clear and logical document hierarchy to the support the PCSR which includes analysis and design submissions to support the Civil Engineering Safety Case.

4.3.3 Items that Require Follow-up

68. During my GDA Step 2 assessment of the analysis and design methodologies I have identified the following specific shortfalls:

- Ground parameters included in the Generic Site Envelope Report (Ref. 19). The updated revision of the Generic Site Envelope Report is scheduled for delivery at the end of Step 2. If insufficient information is included within the updated report it will be subject to enhanced regulatory scrutiny.

69. During my GDA Step 2 assessment of the analysis and design methodologies I have identified the following additional potential shortfalls that I will follow-up during Step 3 of GDA:

- Barrier Substantiation, as reported in the UK HPR1000 GDA Step 2 Internal Hazards Assessment Report (Ref. 16). This will benefit from consideration of multidisciplinary lessons learned from previous GDA projects reported in Ref 41.

4.3.4 Conclusions

70. Based on the outcome of my Step 2 assessment of civil engineering analysis and design methodologies, I have concluded that subject to appropriate resolution of the shortfalls the RP has demonstrated that they are likely able to meet ONR expectations. I am satisfied that through implementation of these methodologies, the structural analysis can be carried out to support the design and demonstrate that structures can fulfil their safety functional requirements. I recognise that these methodologies should be able to deliver designs consistent with the expectations for the defined classification and categorisation of nuclear-safety-related structures.

4.4 Application of Codes and Standards

4.4.1 Assessment

71. My assessment is based on the PSR–Chapter 16 (Ref. 12); the response to RQ-UKHPR1000-0011 (Ref. 25) & supporting information (Ref. 26); and The Approach to Codes and Standards for Civil Engineering (Ref. 18)

72. Information presented in the PSR relates to the Chinese codes and standards used for the design of civil structures on FCG3. Through discussions with the RP I have established that the Chinese Civil Engineering codes used for FCG3 are based on older, non-current versions of the American codes (e.g. ACI, ASCE and ASME codes). Comparative studies between the FCG3 codes and current American codes have been submitted to ONR (Ref. 26), but not assessed as they have limited value for GDA.

73. The RP submitted their approach to Codes & Standards for the UK HPR1000 (Ref. 18). Following an optioneering exercise, where the RP has claimed the use of ALARP principles, they have established the final position on Civil Engineering codes and standards for the UK HPR1000 as follows:

- Adopt the most current American codes for strength design (the Ultimate Limit State).
- Adopt a combination of the most current American and European codes for serviceability design.
- Material specification is in accordance with European and British codes through comparison between relevant American and European codes. Note: that the RP has not yet undertaken this work.

74. I consider that the application of the latest internationally recognised and accepted Civil Engineering nuclear-specific codes and standards meets the intent of SAP ECS.3

4.4.2 Strengths

75. During my GDA Step 2 assessment of Civil Engineering codes and standards I have noted the following areas of strength:

- The RP will adopt the latest internationally recognised and accepted nuclear-specific codes and standards and this should lead to a conservative analysis, commensurate with the importance of the safety function(s) being performed and reflect RGP.

4.4.3 Items that Require Follow-up

76. During my GDA Step 2 assessment of Civil Engineering codes and standards I have identified the following additional potential shortfalls that I will follow-up during Step 3 of GDA:

- Combining of codes and standards needs to be adequately justified and their mutual compatibility demonstrated, particularly when using British or European material parameters in American design codes.

4.4.4 Conclusions

77. Based on the information supplied I am satisfied that nuclear-safety-related structures will be designed, manufactured, constructed, installed, commissioned, quality assured, maintained, tested and inspected to the appropriate codes and standards.

4.5 ALARP Considerations

78. ONR's overall assessment of ALARP is being coordinated by the Project Technical Inspector and is reported in (Ref. 13). The principal RP submissions on the ALARP topic are "ALARP & BAT - Principles & Requirements for UK HPR1000 GDA" (Ref. 21) and "ALARP Methodology" (Ref. 22).

79. Evidence of ALARP in the Civil Engineering topic has been limited to implementation of their ALARP principles with respect to selection of Civil Engineering codes and standards in Ref. 18. This submission considers various options available to the RP,

impact on nuclear safety and the use of the RGP. Based on this submission I am satisfied that the RP understands the principles set out in NS-TAST-GD-005 - Demonstration of ALARP (Ref. 3).

80. During my Step 2 assessment I have not identified any areas of strength or items for follow-up in relation to ALARP Civil Engineering considerations. I will assess the application of the RP's ALARP principles in Civil Engineering during Steps 3 and 4 of GDA.

4.6 Aircraft Impact Safety Case

4.6.1 Assessment

81. My assessment is based on the PSR (Ref. 12); the partial response to RQ-0087 (Ref. 31); and the response to RQ-0112 (Ref. 37). For the aircraft impact topic ONR issued a letter to GNS (Ref. 11), which sets out ONR's expectations for the design of new nuclear power reactors against the threat from malicious aircraft impact. This letter serves as a benchmark for assessment.

82. Information presented in the PSR regarding aircraft impact is limited to identifying which structures are protected from aircraft crashes (i.e. within the aircraft impact shell). The partial response to RQ-UKHPR1000-0087 (Ref. 31) details a generic aircraft impact safety case production strategy, identifies an initial list of future deliverables and identifies other work packages that the RP will undertake to produce an overall generic aircraft impact safety case.

83. The PSR (Ref. 12) identifies that the following buildings are protected from aircraft crashes (see Section 4, Figure 1 for reference general layout):

- Reactor Building (BRX)
- Safeguard Buildings (BSX)
- Fuel Buildings (BFX)
- Emergency Diesel Generators (BDA, BDB & BDC).

84. In addition, Ref. 37 notes that the following buildings also have aircraft impact shells:

- Nuclear Auxiliary Building (BNX),
- Radioactive Waste Treatment Building (BWX),
- Station Blackout Diesel Generator Buildings (BDU & BDV)
- Extra Cooling System & Fire-fighting System Building (BEJ)

85. There is a clear discrepancy between information provided in the PSR (Ref. 12) and the response to RQ-UKHPR1000-0112 (Ref. 37) which needs to be explored further.

86. In addition, the response to RQ-UKHPR1000-0112 (Ref. 37) states that two levels of aircraft impact shell are proposed; dependant on whether it is providing protection against design basis loads or beyond design basis loads. I am unclear on the two levels of aircraft protection and will explore this further in Steps 3 and 4 of GDA.

87. Whilst the bulk of the work to produce a generic aircraft impact safety case has yet to be completed, the RP has a clear strategy in place. I am satisfied that the strategy, if implemented throughout GDA, should meet ONR's expectations letter as defined in Ref. 11 and paragraphs 251 and 252 of SAP EHA.8.

88. During my site visits to two HPR1000 plants under construction in China, I was able to see sections through the external containment. Whilst the design of the UK HPR1000 external containment is yet to be submitted to ONR for formal assessment, based on my observations from these site visits, it was clear there is attention drawn to reinforcement density, concrete mixes and flow properties. This has provided some

confidence that the design is suitable for construction and will likely satisfy the intent of SAP ECE.16.

4.6.2 Strengths

89. During my GDA Step 2 assessment of aircraft impact I have noted the following areas of strength:

- Planned assessment work will be undertaken using guidance from NEI 07-13, Revision 8P. This guidance is recognised as RGP in the UK, having precedence with previous reactor designs that have undergone GDA.
- The RP has established an Aircraft Impact Multi-Disciplinary Working Group. The main purpose of the Working Group is to oversee and coordinate the activities required for the Aircraft Impact topic.
- The RP has established a clear Civil Engineering Safety Case document hierarchy and list of deliverables for ONR's assessment later in GDA, which will enable production of a generic aircraft impact safety case.

4.6.3 Items that Require Follow-up

90. During my GDA Step 2 assessment of aircraft impact I have identified the following additional potential shortfalls that I will follow-up during Step 3 of GDA:

- Definition of the malicious aircraft load case (work is being led by the RP External Hazards team) has not yet been completed.
- Safety demonstration as described in ONR's expectations letter on Aircraft Impact (Ref. 11) has not yet started.
- A gap analysis between National Nuclear Safety Administration (NNSA) and ONR's expectations has not yet been undertaken by the RP. Supporting work is due to be submitted to ONR later in Step 2, but falls outside formal assessment window for my Step 2 report. The outcome of this work may have implications on future work in this area.
- The RP has identified that two types of aircraft impact shell exist for the HPR1000. I consider this a novel concept for the UK and the implications for the Civil Engineering assessment and generic aircraft impact safety case need to be further explored.

4.6.4 Conclusions

91. Based on the outcome of my Step 2 assessment of aircraft impact, I have concluded that sufficient information has been presented to provide confidence that a generic aircraft impact safety case for UK HPR1000 should be achievable. The bulk of the work to produce the safety case has not yet been submitted to ONR, but will be submitted by the RP and assessed by ONR during Steps 3 and 4.

4.7 Compliance with Relevant Regulations

92. My assessment is based on the PSR–Chapter 16 (Ref. 12).

93. Information presented in the PSR is limited to a paragraph stating that the design of UK HPR1000 will be compliant with Construction (Design and Management) Regulations (CDM) 2015. The assessment of CDM is led by the Conventional Health & Safety Inspector and reported in Ref. 40.

94. Information presented in the PSR states that Building Regulations 2010 will be considered for specific requirements on structural instability and disproportionate collapse.

95. During my Step 2 assessment I have not identified any areas of strength or items for follow-up in relation to compliance with regulation.

4.8 Out of Scope Items

96. The following items have been left outside the scope of my GDA Step 2 assessment of the UK HPR1000 Civil Engineering:

- Basis of Safety Case Documents. The reason for leaving this matter out of the scope of my GDA Step 2 assessment is that they are being provided during GDA Step 3.
- Application of methodologies. The reason for leaving this matter out of the scope of my GDA Step 2 assessment is that they are being provided during GDA Step 3. Various methodology options have been discussed with the RP during GDA Step 2.
- Basis of Design Reports. The reason for leaving this matter out of the scope of my GDA Step 2 assessment is that they are being provided during GDA Step 3.
- Supporting analysis, design and substantiation reports. The reason for leaving this matter out of the scope of my GDA Step 2 assessment is that they are being provided during Step 4 o GDA.
- Any information relating to the analysis and design of the Turbine Building. The reason for leaving this mater out of the scope of my GDA Step 2 assessment is that the RP has stated that it is out of scope for GDA.

97. It should be noted that the above omissions do not invalidate the conclusions from my GDA Step 2 assessment. During my GDA Step 3 assessment I will follow-up the above out-of-scope items as appropriate; I will capture this within my GDA Step 3 Assessment Plan.

4.9 Comparison with Standards, Guidance and Relevant Good Practice

98. In Section 2.2, above, I have listed the standards and criteria I have used during my GDA Step 2 assessment of the UK UKHPR1000 Civil Engineering, to judge the adequacy of the preliminary safety case. In this regard, my overall conclusions can be summarised as follows:

- SAPs: At this stage in GDA, it is difficult to establish the degree to which the expectations presented in the relevant SAPs may be fully satisfied, as the RP's PSR is based on the FCG3 plant and the majority of supporting evidence (based on the UK HPR1000 design) is due to be submitted during Steps 3 and 4 of GDA. However, I consider that overall satisfaction of the relevant SAPs is likely to be achieved as GDA progresses. This is because confidence has been provided by the RP in the Step 2 submissions I have received and assessed to date, and the contents of their proposed Civil Engineering safety case strategy appear broadly in-line with expectations. I have used the SAPs to inform and guide my Step 2 assessment. Annex 1 provides further details on their application to the UK HPR1000 and my judgement on the degree to which the expectations set out within them have been satisfied by the RP during Step 2 of GDA.
- TAGs: The RP's PSR satisfies the principles of applicable parts of the relevant TAG, which are appropriate for GDA Step 2. Namely, Section 5 of the TAG which identifies key elements which need to be considered and expands on information presented in the SAPs, WENRA Reference Levels (Ref. 5) and IAEA Guidance (Ref. 4).

4.10 Interactions with Other Regulators

99. During GDA Step 2 I attended the first meeting of the Multinational Design Evaluation Programme (MDEP) HPR1000 Working Group, 26 - 29 March 2018 in Beijing. The interactions focussed on:

- Programme of key NNSA milestones for all HPR1000 reactors under construction in China.
- Design changes to FCG Units 3 & 4 and FQ Units 5 & 6 since the start of construction.
- Various design features for the HPR1000.

100. Of particular interest to Civil Engineering was that NNSA notified ONR that a design change to the FCG Units 3 & 4 containment prestressing system was made after start of construction. ONR have not yet received any detailed information on the inner containment, but this will be explored further during Steps 3 and 4 of GDA.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

101. During Step 2 of GDA the RP submitted a PSR and other supporting references, which outline a preliminary nuclear safety case for the UK HPR1000. These documents have been formally assessed by ONR. The PSR together with its supporting references present, at a high-level, the claims in the area of Civil Engineering that underpin the safety of the UK HPR1000.

102. During Step 2 of GDA I have targeted my assessment at the content of the PSR and its references that is of most relevance to the area of Civil Engineering; against the expectations of ONR's SAPs and TAGs and other guidance which ONR regards as RGP. From the UK HPR1000 assessment done so far, I conclude the following:

- I believe that the claims made are reasonable for Step 2 of GDA with regard to Civil Engineering and they will evolve as GDA progresses. It is apparent that the RP understands the links between the SFRs and engineering evidence, but has not yet been able to demonstrate this in the preliminary safety case presented during Step 2. However, the Programme of Schedule Delivery (Ref. 17) provides the intended safety case document hierarchy for future Civil Engineering submissions which will be made to ONR later in GDA, to substantiate the claims with suitable arguments and evidence. This provides some confidence the complete "golden thread" is likely to become fully established as the generic safety case develops.
- I have identified a number of potential shortfalls that I will follow up in Steps 3 and 4 of GDA.
- As GDA progresses to the more detailed assessment Steps, I will need to increase my familiarity with the Civil Engineering aspects of the UK HPR1000. At present, I am aware of with the RP's high-level safety claims, which is commensurate with the level of detail required for Step 2 assessment. However, as GDA progresses, I will need to become fully familiar with all of the Civil Engineering specific safety functions and the RP's application of relevant methodologies to nuclear safety-related structures.

103. Overall, during my GDA Step 2 assessment, I have not identified any fundamental safety shortfalls in the area of Civil Engineering that might prevent the issue of a Design Acceptance Confirmation (DAC) for the UK HPR1000 design.

5.2 Recommendations

104. My recommendations are as follows.

- Recommendation 1: ONR should consider the findings of my assessment in deciding whether to proceed to Step 3 of GDA for the UK HPR1000.
- Recommendation 2: All the items identified in Step 2 as important to be followed up should be included in ONR's GDA Step 3 Civil Engineering Assessment Plan for the UK HPR1000.
- Recommendation 3: All the relevant out-of-scope items identified in Section 4.8 of this report should be included in ONR's GDA Step 3 Civil Engineering Assessment Plan for the UK HPR1000.

6 REFERENCES

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4. IAEA Standards and Guidance

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   - IAEA Safety Standards: Fundamental Safety Principles; SF-1; 2006
   - IAEA Safety Standards: Safety Assessment for Facilities and Activities General Safety Requirements Part 4; GSR Part 4; 2016
   - IAEA Safety Standards: Seismic Design and Qualification for Nuclear Power Plants, Safety Guide; NS-G-1.6; 2003
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5. Western European Nuclear Regulators' Association.

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12. GNS, UK HPR1000 GDA Project, Preliminary Safety Report Chapters 1-27, HPR/GDA/PSR/0001 Revision 0, October 2017; TRIM Ref. 2018/14773

13. ONR, Summary of the Step 2 Assessment of the UK HPR1000 Reactor, ONR-GDA-UKHPR1000-AR-18-020; TRIM 2018/238474

14. ONR, GDA Step 2 Assessment of Fault Studies of the UK HPR1000 Reactor, ONR-GDA-UKHPR1000-AR-18-010; TRIM 2018/237156

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16. ONR, GDA Step 2 Assessment of Internal Hazards of the UK HPR1000 Reactor, ONR-GDA-UKHPR1000-AR-18-003; TRIM 2018/208486

17. GNS, GDA for UK HPR1000, Programme of Schedule Delivery for Civil Engineering Schedule, Rev A, 22 May 2018; TRIM 2018/171585

18. GNS, The Approach to Codes and Standards for Civil Engineering, GH X NIX10 010 DWJG 42 GN, 15/03/2018; TRIM 2018/178182

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22. GNS, ALARP Methodology, GDA-REC-CGN-001428 GHX00100051DOZJ03GN Rev A, 31 May 2018; TRIM 2018/181415

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31. RQ-UKHPR1000-0087 Partial Response, Aircraft Impact Assessment Safety Case Strategy, 7 June 2018; TRIM 2018/188656

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34. GNS, Seismic Analysis Methodology Presentation, GDA-REC-CGN-001744, 14 June 2018; TRIM 2018/199061

35. RO-UKHPR1000-0002, Demonstration that the UK HPR1000 Design is Suitably Aligned with the Generic Site Envelope, 13 March 2018; TRIM 2018/43924

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40. GDA Step 2 Assessment of Conventional Health & Safety of the UK HPR1000 Reactor, ONR-GDA-UKHPR1000-AR-18-012; TRIM 2018/253631

41. "Design of nuclear safety related concrete structures against hazard combinations: Regulatory perspectives on multi-discipline challenges", International Conference on Technical Innovations in Nuclear Civil Engineering (TINCE 2018), August 29-31 2018, Paris, France

Annex 1

Relevant Safety Assessment Principles Considered During the Assessment

SAP No.	SAP Title	Description	Comment
SC.4	The regulatory assessment of safety cases. Safety case characteristics.	A safety case should be accurate, objective and demonstrably complete for its intended purpose	Addressed in Section 4.1 of this report. The submitted PSR does present sufficient information for the Civil Engineering Safety Case. However, the programme of schedule delivery for Civil Engineering shows a document structure that when delivered should satisfy intent. Hence, this SAP is not yet demonstrated.
EKP.1	Engineering principles: key principles. Inherent safety.	The underpinning safety aim for any nuclear facility should be an inherently safe design, consistent with the operational purposes of the facility.	Not assessed explicitly within the report. Will be assessed by future GDA submissions.
EKP.2	Engineering principles: key principles. Fault tolerance.	The sensitivity of the facility to potential faults should be minimised.	Not assessed explicitly within the report. Will be assessed by future GDA submissions.
EKP.3	Engineering principles: key principles. Defence in depth.	Nuclear facilities should be designed and operated so that defence in depth against potentially significant faults or failures is achieved by the provision of multiple independent barriers to fault progression.	Addressed in Section 4.1 of this report. Application of defence in depth on the Spent Fuel Pool sampled. Arguments presented for the containment function of the SFP presented do not currently meet ONR expectations for defence in depth. Hence, this SAP is not demonstrated.
EKP.4	Engineering principles: key principles. Safety function.	The safety function(s) to be delivered within the facility should be identified by a structured analysis.	Addressed throughout Section 4 of this report. The PSR states high level safety functions and supplementary information has been provided through RQ-UKHPR1000-0097. Applicability to the UK HPR1000 will be examined through the Basis of Safety Case documents due to be submitted during Step 3. Hence, this SAP is partly demonstrated.

ECS.1	Engineering principles: safety classification and standards. Safety categorisation.	The safety functions to be delivered within the facility, both during normal operation and in the event of a fault or accident, should be identified and then categorised based on their significance with regard to safety.	Addressed in Section 4.2 of this report. The PSR states the Categorisation and Classification for FCG3 structures. The Methodology of Safety Categorisation and Classification submission and information provided through RQ-UKHPR1000-0097 show intent to meet the SAP. Hence, this SAP is partly demonstrated.
ECS.2	Engineering principles: safety classification and standards. Safety classification of structures, systems and components.	Structures, systems and components that have to deliver safety functions should be identified and classified on the basis of those functions and their significance to safety.	See ECS.1
ECS.3	Engineering principles: safety classification and standards. Codes and standards.	Structures, systems and components that are important to safety should be designed, manufactured, constructed, installed, commissioned, quality assured, maintained, tested and inspected to the appropriate codes and standards.	Addressed in Sections 4.2 and 4.4 of this report. The PSR states the Categorisation and Classification for structures. The Approach to Codes and Standards for Civil Engineering submission and information provided through RQ-UKHPR1000-0097 show intent to meet the SAP. Hence, this SAP is partly demonstrated.
EDR.1	Engineering principles: design for reliability. Failure to safety.	Due account should be taken of the need for structures, systems and components to be designed to be inherently safe, or to fail in a safe manner, and potential failure modes should be identified, using a formal analysis where appropriate.	Not possible to assess during Step 2. Will be covered by future GDA submissions; principally the basis of design and various design reports. Hence, this SAP is not yet demonstrated.
ERL.1	Engineering principles: reliability claims. Form of claims.	The reliability claimed for any structure, system or component should take into account its novelty, experience relevant to its proposed environment, and uncertainties in operating and fault conditions, physical data and design methods.	See EDR.1
ERL.2	Engineering principles: reliability claims. Measures to achieve reliability	The measures whereby the claimed reliability of systems and components will be achieved in practice should be stated.	See EDR.1

EMT.1	Engineering principles: maintenance, inspection and testing. Identification of requirements	Safety requirements for in-service testing, inspection and other maintenance procedures and frequencies should be identified in the safety case.	Not possible to assess during Step 2. Will be covered by future GDA submissions; principally the Examination, maintenance, inspection and testing for civil engineering submission. Hence, this SAP is not yet demonstrated
EAD.1	Engineering principles: ageing and degradation. Safe working life.	The safe working life of structures, systems and components that are important to safety should be evaluated and defined at the design stage.	Not assessed explicitly within the report. Operational and service life claims considered in PSR. The validity of these claims will be validated through future submissions; principally, the basis of safety case, the basis of design and supporting analysis/design submissions. Hence, this SAP is not yet demonstrated.
EAD.2	Engineering principles: ageing and degradation. Lifetime margins	Adequate margins should exist throughout the life of a facility to allow for the effects of materials ageing and degradation processes on structures, systems and components.	See EAD.1
ELO.4	Engineering principles: layout. Minimisation of the effects of incidents.	The design and layout of the site, its facilities (including enclosed plant), support facilities and services should be such that the effects of faults and accidents are minimised.	Not assessed explicitly within the report. Will be covered by future GDA submissions and assessed in conjunction with Internal and External Hazards teams. The principal submission for assessment is the Overview of the UK HPR1000 civil works and structures. Hence, this SAP is not yet demonstrated.
EHA.7	Engineering principles: external and internal hazards. 'Cliff-edge' effects.	A small change in design basis fault or event assumptions should not lead to a disproportionate increase in radiological consequences.	Not assessed explicitly within the report. The PSR recognises Beyond Design Basis load conditions. The application to assess cliff-edge effects will be covered by a topic report which is scheduled to be delivered later during GDA. Hence, this SAP is not yet demonstrated.

EHA.8	Engineering principles: external and internal hazards. Aircraft crash.	The total predicted frequency of aircraft crash, including helicopters and other airborne vehicles, on or near any facility housing structures, systems and components should be determined.	Addressed in Section 4.5 of this report. Sufficient information has been presented to provide confidence that a generic aircraft impact safety case for UK HPR1000 should be achievable. The bulk of the work has not yet been submitted to ONR, but will be submitted by the RP and assessed by ONR during Steps 3 and 4. Hence, this SAP is partially demonstrated.
EHA.18	Engineering principles: external and internal hazards. Beyond design basis events.	Fault sequences initiated by internal and external hazards beyond the design basis should be analysed applying an appropriate combination of engineering, deterministic and probabilistic assessments.	See EHA.7
ECE.1	Engineering Principles: Civil Engineering. Functional Performance	The required safety functions and structural performance of the civil engineering structures under normal operating, fault and accident conditions should be specified.	Addressed in Section 4.1 of this report. RP understands the links between the engineering evidence and SFRs but has not yet been able to demonstrate this through the safety case. Hence, this SAP is partially demonstrated.
ECE.2	Engineering Principles: Civil Engineering. Independent Arguments	For structures requiring the highest levels of reliability, multiple independent and diverse arguments should be provided in the safety case.	See EKP.3
ECE.3	Engineering Principles: Civil Engineering. Defects	It should be demonstrated that structures important to safety are sufficiently free of defects so that their safety functions are not compromised, that identified defects can be tolerated, and that the existence of defects that could compromise safety functions can be established through their lifecycle.	See EKP.3
ECE.4	Engineering Principles: Civil Engineering. Natural Site Materials	Investigations should be carried out to determine the suitability of the natural site materials to support the foundation loadings specified for normal operation and fault conditions.	Addressed in Section 4.3 of this report. Insufficient investigation work has been undertaken to produce a generic design envelope. Hence, this SAP is not demonstrated.
ECE.5	Engineering Principles: Civil Engineering. Geotechnical Investigation	The design of foundations and sub-surface structures should utilise information derived from geotechnical site investigation.	See ECE.4

ECE.6	Engineering Principles: Civil Engineering. Loadings	Load development and a schedule of load combinations, together with their frequencies, should be used as the basis for structural design. Loadings during normal operating, testing, design basis fault and accident conditions should be included.	Addressed in Section 4.3 of this report. The RP has an existing civil analysis and design which will need to be revised for the UK HPR1000. The bulk of the work for the civil analysis and design has yet to be completed but, the RP has a strong starting position; coupled with a planned structure of deliverables for the Civil Engineering Safety Case. Hence, this SAP is partly demonstrated
ECE.7	Engineering Principles: Civil Engineering. Foundations	The foundations and sub-surface structures should be designed to meet their safety functional requirements specified for normal operation and fault conditions with an absence of cliff edge effects beyond the design basis.	Not possible to assess during Step 2. Will be covered by future GDA submissions; principally the basis of design and supporting analysis/design submissions. Hence, this SAP is not yet demonstrated.
ECE.8	Engineering Principles: Civil Engineering. Inspectability	Designs should allow key load-bearing elements to be inspected and, where necessary, maintained.	Not possible to assess during Step 2. Will be covered by future GDA submissions; principally the Examination, maintenance, inspection and testing for civil engineering submission and supporting analysis/design submissions. Hence, this SAP is not yet demonstrated.
ECE.9	Engineering Principles: Civil Engineering. Earthworks	The design of embankments, natural and excavated slopes, river levees and sea defences close to the facility should not jeopardise the safety of the facility.	This SAP will be assessed primarily during the site specific phase following GDA; however excavation assumptions will be covered in GDA. Not possible to assess during Step 2. Will be covered by future GDA submissions; principally the basis of design and supporting analysis/design submissions. Hence, this SAP is not yet demonstrated.
ECE.10	Engineering Principles: Civil Engineering. Groundwater	The design should be such that the facility remains stable against possible changes in the groundwater conditions.	See ECE.9
ECE.11	Engineering Principles: Civil Engineering. Naturally Occurring Explosive Gases	The design should take account of the possible presence of naturally occurring explosive, asphyxiant or toxic gases or vapours in underground structures such as tunnels, trenches and basements.	Not applicable for GDA.

ECE.12	Engineering Principles: Civil Engineering: Structural Analysis And Model Testing.	Structural analysis and/or model testing should be carried out to support the design and should demonstrate that the structure can fulfil its safety functional requirements over the full range of loading for the lifetime of the facility.	See ECE.6
ECE.13	Engineering Principles: Civil Engineering: Structural Analysis And Model Testing. Use Of Data	The data used in structural analysis should be selected or applied so that the analysis is demonstrably conservative.	Not possible to assess during Step 2. Will be covered by future GDA submissions; principally the basis of design and supporting analysis/design submissions. Hence, this SAP is not yet demonstrated.
ECE.14	Engineering Principles: Civil Engineering: Structural Analysis And Model Testing. Sensitivity Studies	Studies should be carried out to determine the sensitivity of analytical results to the assumptions made, the data used, and the methods of calculation.	Not possible to assess during Step 2. Will be covered by future GDA submissions. Hence, this SAP is not yet demonstrated.
ECE.15	Engineering Principles: Civil Engineering: Structural Analysis And Model Testing. Validation Of Methods	Where analyses have been carried out on civil structures to derive static and dynamic structural loadings for the design, the methods used should be adequately validated and the data verified.	Not possible to assess during Step 2. Will be covered by future GDA submissions, principally the verification and validation for the software used in Civil Engineering submission. Hence, this SAP is not yet demonstrated.
ECE.16	Engineering Principles: Civil Engineering: Construction. Materials	The construction materials used should comply with the design methodologies employed, and be shown to be suitable for enabling the design to be constructed and then operated, inspected and maintained throughout the life of the facility.	Assessed in Section 4.4 of this report. The RP recognises issues with material specification and plans to undertake comparative studies between relevant American and European codes. Hence, this SAP is partly demonstrated
ECE.17	Engineering Principles: Civil Engineering: Construction. Prevention Of Defects	The construction should use appropriate materials, proven techniques and a quality management system to minimise defects that might affect the required integrity of structures.	See ECE.16
ECE.18	Engineering Principles: Civil Engineering: Construction. Inspection During Construction	Provision should be made for inspection and testing during construction to demonstrate that appropriate standards of workmanship etc have been achieved.	Not applicable for GDA.
ECE.19	Engineering Principles: Civil Engineering: Construction. Non-Conformities	Where construction non-conformities or identified defects are judged to have a significant detrimental effect on integrity, remedial measures should be applied to ensure the original design intent is still achieved.	Not applicable for GDA.

ECE.20	Engineering Principles: Civil Engineering: In-Service Inspection And Testing. Inspection, Testing And Monitoring	Provision should be made for inspection, testing and monitoring during normal operations aimed at demonstrating that the structure continues to meet its safety functional requirements. Due account should be taken of the periodicity of the activities.	Not possible to assess during Step 2. Will be covered by future GDA submissions; principally the Examination, maintenance, inspection and testing for civil engineering submission. Hence, this SAP is not yet demonstrated
ECE.21	Engineering Principles: Civil Engineering: In-Service Inspection And Testing. Proof Pressure Tests	Pre-stressed concrete pressure vessels and containment structures should be subjected to a proof pressure test, which may be repeated during the life of the facility.	Not possible to assess during Step 2. Will be covered by future GDA submissions; principally the Examination, maintenance, inspection and testing for civil engineering submission and Justification of prestressing system submissions. Hence, this SAP is not yet demonstrated.
ECE.22	Engineering Principles: Civil Engineering: In-Service Inspection And Testing. Leak Tightness	Civil engineering structures that retain or prevent leakage should be tested for leak tightness prior to operation.	Sampled through RQ-UKHPR1000-0013 for containment structures in Section 4.1 of this report. Hence, this SAP is partly demonstrated.
ECE.23	Engineering Principles: Civil Engineering: In-Service Inspection And Testing. Inspection Of Sea And River Flood Defences	Provision should be made for the routine inspection of sea and river flood defences to determine their continued fitness for purpose.	Not applicable for GDA.
ECE.24	Engineering Principles: Civil Engineering: In-Service Inspection And Testing. Settlement	There should be arrangements to monitor civil engineering structures during and after construction to check the validity of predictions of performance made during the design and for feedback into design reviews.	Not possible to assess during Step 2. Will be covered by future GDA submissions; principally the Examination, maintenance, inspection and testing for civil engineering submission and supporting analysis/design submissions. Hence, this SAP is not yet demonstrated.
ECE.25	Engineering Principles: Civil Engineering. Provision For Construction	Items important to safety should be designed so that they can be manufactured, constructed, assembled, installed and erected in accordance with established processes that ensure the achievement of the design specifications and the required level of safety. The effects of construction hazards on any nearby safety-related SSCs should be taken into account.	Not possible to assess during Step 2. Will be covered by future GDA submissions; principally the analysis/design submissions and construction report. Hence, this SAP is not yet demonstrated.
ECE.26	Engineering Principles: Civil Engineering. Provision For Decommissioning	Special consideration should be given at the design stage to the incorporation of features to facilitate radioactive waste management and the future decommissioning and dismantling of the facility.	See ECE.25

Annex 2

Principal RQs and ROs of relevance to Civil Engineering

RQ Number	Description	Issue Date	TRIM Ref.	Response Date	TRIM Ref.
RQ-UKHPR1000-0011	UK Context of Civil Engineering	08/12/2017	2017/454167	15/02/2018	2018/58423
RQ-UKHPR1000-0012	Early Visibility of Civil Engineering GDA Scope	08/12/2017	2017/454188	09/02/2018	2018/52223
RQ-UKHPR1000-0013	Steel Lined Concrete Structures	08/12/2017	2017/454204	09/02/2018	2018/52256
RQ-UKHPR1000-0096	Ground Bearing Capacity in Generic Site Report	09/05/2018	2018/156362	25/06/2018	2018/208136
RQ-UKHPR1000-0097	Safety Claims and Approach to Analysis & Design	09/05/2018	2018/156373	14/06/2018	2018/198894 2018/199061
RQ-UKHPR1000-0087*	Aircraft Impact Assessment Safety Case Strategy	23/05/2018	2018/148440	07/06/2018	2018/188656
RQ-UKHPR1000-0112*	Clarification of information provided in 9-12 May workshop (external hazards)	29/05/2018	2018/178126	22/06/2018	2018/207291
RO-UKHPR1000-0002*	Demonstration that the UK HPR1000 Design is Suitably Aligned with the Generic Site Envelope	13/03/2018	2018/43924	25/05/2018 (Resolution Plan)	2018/177171 (Resolution Plan)

* *Item being led by External Hazards but considered of significance to Civil Engineering*