2020-03-23

International Review Panel Report
For the
Atomic Energy of Canada Limited
Canadian Nuclear Laboratories
Near Surface Disposal Facility
Safety Case and Assessment Documents

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Executive Summary

An international subject matter expert panel led by the U.S. Department of Energy (DOE) was formed to provide an independent review of the Atomic Energy of Canada Limited (AECL) Canadian Nuclear Laboratories (CNL) safety case and assessment documents as of October 9, 2019 for the proposed near surface disposal facility (NSDF). This review report is provided to the AECL and CNL for consideration in determining the completeness and defensibility of the safety case and assessment documents. The review was conducted from June 24, 2019 through December 2019 and consisted of document reviews, an on-site visit, activity observations, webinars, and interviews.

The review scope was bounded by the Environmental Impact Statement (EIS) and Safety Case document, and the Postclosure Safety Assessment with all the referenced underpinning documents. The review panel evaluated the documents consistent with the non-binding expectations for a safety case and safety assessment from the International Atomic Energy Agency (IAEA) *Specific Safety Requirements on Disposal of Radioactive Waste*, SSR-5 and the IAEA *Specific Safety Guide on The Safety Case and Safety Assessment for the Disposal of Radioactive Waste*, SSG-23 as well as personal experience with their regulatory environment.

The panel commends the CNL staff and their support contractors for developing the analyses and documentation to support licensing of the NSDF. The staff proved to be well qualified and are applying tools with the necessary capabilities to support the license submittal. The CNL team's candor and openness in responding to specific information requests and queries was highly appreciated and proved beneficial to the review.

The panel identified 35 recommendations, 76 suggestions, and five good practices. Hereafter recommendations and suggestions will be referenced collectively as "observations." The review scope did not include a formal observation resolution process. The panel reviewed several "mature draft" documents (and in some cases multiple versions of the same document) but did not have the opportunity to review comment resolutions incorporated into the final integrated package to be submitted to the regulator. The iterative nature of the review provided opportunities for the panel to make observations beneficial for on-going work. For example, it was apparent in revised versions of the Safety Case and Postclosure Safety Assessment documents reviewed by the panel that changes were made to address specific observations.

Overall the panel believes that the facility is being conservatively designed to dispose of the planned radioactive inventory, and contingent on appropriate resolution of outstanding observations as identified the safety documentation provides reasonable assurance that appropriate safety standards could be met. The panel concluded that CNL has an adequate knowledge of the system at the current stage of repository development. However, the panel identified the following general observations:

- Document and justify assumptions where deliberate cautious or conservative bias or safety margins are introduced. This will help with discussions of defense-in-depth and communication of conclusions regarding compliance with regulatory criteria.

- Identify assumptions made in the absence of natural and engineered system understanding to inform future investigation and/or data collection.
- Clarify and justify the basis for selecting the barrier system design (e.g., cap design details).
- Justify the methods used to make radionuclide screening decisions.
- Document the connection between the safety case and the Waste Acceptance Criteria (WAC).
- Clarify the links between the Postclosure Safety Assessment results and other safety analyses and requirement development (e.g., WAC, design features, operational considerations, monitoring, research/characterization needs, etc.).

CNL should be commended for the following best practices identified by the panel:

- The quality assurance process described in the Quality Assurance Program was well developed, efficient and effective in meeting quality assurance objectives for data and models.
- The use of signature boxes within the data documentation sections of the Postclosure Safety Assessment provided evidence of the quality assurance checking process and that an appropriate Features, Events, and Processes-based method was being used to derive a reasonably comprehensive set of sensitivity cases for evaluation.
- The crosswalk of NSDF requirements to the document sections where they are addressed was an excellent tool for the reviewers and those seeking to understand how the assessment addresses requirements.
- The normal evolution and inadvertent intruder scenario assessments addition of As Low As Reasonably Achievable optimization considerations effectively provided additional evidence of protectiveness consistent with the defense in depth philosophy.

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Acronyms

AECL	Atomic Energy of Canada Limited
CNL	Canadian Nuclear Laboratories
CNSC	Canadian Nuclear Safety Commission
COPC	Constituent of Potential Concern
DOE	United States Department of Energy
EBS	Engineered Barrier System
ECM	Engineered Containment Mound
EIS	Environmental Impact Statement
$K_d s$	Effective Sorption Coefficient
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
LFRG	Low-Level Waste Disposal Facility Federal Review Group
LLW	Low-Level Radioactive Waste
NRC	United States Nuclear Regulatory Commission
NSDF	Near Surface Disposal Facility
PostSA	Postclosure Safety Assessment
US	United States of America
WAC	Waste Acceptance Criteria

1.0 Introduction

The Atomic Energy of Canada Limited (AECL) is the Government of Canada's Federal Crown Corporation responsible for managing the Government's legacy radioactive waste at several sites across Canada. AECL discharges its responsibilities for Canada's waste liabilities through an agreement with Canadian Nuclear Laboratories (CNL), which is privately owned and operated.

CNL has proposed a near surface disposal facility (NSDF) for the disposal of low- level radioactive waste (LLW) from AECL's sites, to be located within the Chalk River Laboratory site. Low-level radioactive waste as defined by the Canadian Nuclear Safety Commission is waste that contains material that is more radioactive than clearance levels and exemption quantities allow and loses most or all of its radioactivity within 300 years. AECL has accepted and supports CNL's proposal for an NSDF and considers it to be safe, environmentally responsible and an economical means to address AECL's LLW (the vast majority of which is already located at AECL's Chalk River site).

An international United States (US) Government-led expert panel was formed to provide an independent review of the CNL safety case and assessment documents as of October 9, 2019. This review report is provided to the AECL and CNL for consideration in determining the completeness and defensibility of the safety case and assessment documents. The review was conducted from June 24, 2019 through December 2019 and consisted of document reviews, an on-site visit, activity observations, webinars, and interviews. This report documents the results of the panel's review.

1.1 Review Scope

The review scope was bounded by the Environmental Impact Statement (EIS), Safety Case document, and the Postclosure Safety Assessment (PostSA) with all the referenced underpinning documents. The panel evaluated the documents consistent with the non-binding expectations for a safety case and safety assessment from the International Atomic Energy Agency (IAEA) *Specific Safety Requirements on Disposal of Radioactive Waste*, SSR-5 and the IAEA *Specific Safety Guide on The Safety Case and Safety Assessment for the Disposal of Radioactive Waste*, SSG-23 as well as typical expectations from personal experiences from their regulatory environment.

The review was focused on the descriptions and justifications for assumptions regarding:

1) the conceptualization of the natural and engineered system and any evolution over time.
2) the inventory and source term and
3) the exposure scenarios.

The reviewers evaluated the model results documentation and assessed the understanding of the system behavior. The assumptions used within the analyses with the greatest influence on conclusions were evaluated to ensure they have been identified and suitably addressed.

1.2 Approach

The review consisted of document reviews, subject matter expert interviews, technical discussions, conference calls, topic-specific webinars and an on-site visit. The panel was originally given four general lines of inquiry to evaluate if the EIS and supporting documentation addressed IAEA guidance, DOE Directives, and United States Nuclear Regulatory Commission (NRC) requirements and were logical and defensible. The panel reviewed several "mature draft" documents (and in some cases multiple versions of the same document) but did not have the opportunity to review the final integrated package to be submitted to the regulator. The panel provided real-time input, recommendations and suggestions for improving the documents reviewed. Good practices were also identified. Ultimately based on Canadian regulations, CNL will determine how to interpret and implement the observations.
The panel used the following definitions:

- Recommendations identified missing, incomplete, or inadequately implemented elements. Recommendations are designed to provide tangible improvements.
- Suggestions are not directly related to conformance with expectations or standards. Suggestions stimulate considering new or different approaches to technical, regulatory and policy issues that may enhance performance.
- A good practice recognizes an outstanding organization, arrangement, program or performance superior to those generally observed elsewhere. A good practice goes beyond the fulfilment of current requirements or expectations.

Hereafter recommendations and suggestions, when referenced together will be referred to as "observations." The preliminary observations were documented and used to guide the topic-specific webinars and on-site interviews. An on-site visit was conducted the week of 22 July 2019. The visit allowed the panel to interview subject matter experts, have in-depth topic specific discussions, and view the proposed NSDF site.

1.3 Panel Membership

The review was led by Dr. Justin Marble from the DOE Office of Waste Disposal. Dr. Marble was supported by Jhon Carilli from the DOE Nevada National Security Site and Gary Pyles from the DOE Richland Operations Office. The DOE federal staff was supported by experienced contractor staff with expertise in safety case documents identified below. Susan Krenzien from Inspection Experts, Inc. provided administrative and organizational support.

Name	Experience Summary
Roger Seitz	Inspection Experts Inc.; Overall International and DOE experience related to waste disposal operations, design and safety assessment.
Matt Kozak	Intera Inc.; International experience and modeling; safety assessments
Graham Smith	GMS Abingdon Ltd; International experience and dose, radiological assessment/biosphere assessor.
Andy Baker	Eden Nuclear and Environment Ltd.; Experience with technical management of the Safety Case for the LLW Waste Repository in the UK; extensive experience with other facilities.

Jay Rhoderick	Longenecker & Associates; Former DOE LLW Disposal Federal Review Group (LFRG) co-chair and DOE waste disposal experience
John Patterson	Strata-G; Extensive DOE experience at Oak Ridge with LFRG, Waste Acceptance Criteria (WAC), and DOE Directives
Steve Kenworthy	Strata-G; DOE experience in technical analysis of engineered systems, and surface and subsurface hydrology
Kearn Patrick Lee	Orano Federal Services, LLC; Extensive experience of modeling of long-term storage of radioactive waste
Laurie Judd	Longenecker & Associates; Program Manager

2.0 Technical Documents

Numerous technical documents were reviewed by the panel, and the following sections identify each document reviewed (including readiness stage) and a summary of the recommendations, suggestions, and/or good practices identified by the panel.

2.1 Design Requirements

The panel reviewed *Design Requirements*, 232-503212-DR-001, Revision 2, 2019 April (final). The document identifies general, functional, and performance requirements for each NSDF element including the Engineered Containment Mound (ECM), Wastewater treatment plant, Support Facilities, and Site infrastructure.

One recommendation and three suggestions were identified by the panel. The panel recommends including a discussion or emphasizing how the design and modeling processes are integrated to demonstrate how the safety assessment and safety case influence the design. The suggestions included:

- Including either the origin of the design requirements or their derivation.
- A description or explanation of the design requirement change management system would be beneficial.
- Text regarding the design life for the facility could be made more consistent with other technical documents.

2.2 Reference Inventory Report

The panel reviewed *NSDF Reference Inventory Report,* 232-508600-REPT-003, Revision 2D1, 2019 June (mature draft). The report establishes a representative radionuclide inventory by extrapolating existing waste packages, environmental remediation projects and decommissioning projects data and provides the source term for dose assessments. The panel identified two recommendations and one suggestion. Both recommendations are regarding the use of scaling factors:

- Discuss key uncertainties associated with the scaling factors and how to address those uncertainties in the dose assessments.
- Consider using alternative and/or complementary scaling and other investigative methods for other difficult to measure nuclides, not just Cs-137. Relevant references were suggested.

It is also suggested that when referencing the International Atomic Energy Agency chart of radionuclides website that the date accessed be identified, as the website is revised periodically. It was also suggested that radioactive decay products not in equilibrium should be included.

2.3 Non-Radiological Inventory of Constituents of Potential Concern

The panel reviewed *Near Surface Disposal Facility (NSDF) Non-Radiological Inventory of Constituents of Potential Concern (COPC),* 232-508600-TN-007, Revision 3, 2019 July (mature draft). This technical note provides an estimated inventory of non-radiological COPCs to inform modeling and safety assessments. The panel suggests identifying non-radiological contaminants that can impact NSDF barriers (e.g., change effective sorption coefficient (K_ds)) and discuss the uncertainties associated with using the data in the assessments.

2.4 Base Liner and Final cover

The panel reviewed *Base Liner and Final Cover Performance and Life Cycle Evaluation*. 232-508600-TN-006, Revision 0, 2017 March 31 (final). The study analyzed the hydraulic performance (i.e., leakage rate) of the proposed NSDF ECM base liner and final cover lining systems and provided evidence for whether the base liner and final cover system will meet life cycle requirements. The panel recommends that the potential for differential settlement be quantified, including a volume estimate of potential voids that degradation could produce and an associated quantification of the potential for subsidence.

2.5 Waste Acceptance Criteria

The panel reviewed *Waste Acceptance Criteria.* 232-508600-WAC-002, Revision 4, 2019 June (mature draft). The document defines the criteria for waste acceptance into the NSDF and provides limits and controls for the physical, chemical, and radiological properties of the waste. The panel identified three recommendations and eight suggestions. The recommendations are:

- Consider setting limits on graphite, beryllium and deuterated materials. See Nuclear Decommissioning Authority *Guidance on the control of fissile material in waste packages*, 2013 November.
- Justify the reduced radionuclide list (Table 6) and consider broadening the radiological data acquisition and recording. (This is a combination of a recommendation and suggestion.)
- Ensure references are available.

Three of the suggestions are editorial in nature, with the remaining 4 detailed below:

- Ensure lead shielding does not constitute improper disposal of hazardous waste.
- Justify the 10% voidage limit and clarify how the quantity of biodegradeable material is to be limited (this suggestion is related to the recommendation in Section 2.4 above).
- Clearly justify the WAC requirements and link them to references.
- Identify the form, format, and required information for waste profiles developed by generators to obtain approval for disposal.

2.6 Environmental Impact Statement

The panel reviewed *CNL Near Surface Disposal Facility Project Environmental Impact Statement.* 1547525, Revision 1D3, 2019 August (mature draft). The panel suggests that the protection objectives and model scenarios and assumptions be compared to the operational and

post-closure radiological assessment and provide an explanation of any differences. It is understood that the operational and postclosure regulatory and other protection objectives can be different; the point of the suggestion is to ensure that different interpretations of site understanding are not used in the respective assessments without reason.

2.7 Safety Case Document

The panel reviewed *Safety Assessment Report, Near Surface Disposal Facility Safety Case*. 232-03610-SAR-001, Revision D1, 2019 July (draft), therefore the recommendations and suggestions maybe preliminary in nature depending on the version. The two recommendations and one suggestion were focused on the overall structure and content of the draft document. A second suggestion regarded links to the WAC.

- The good safety case approach is being used, but the safety case is not well developed in terms of presenting and substantiating an 'integrated collection of safety arguments.'
- Include a structured discussion of the safety strategy
    - Identify the goals that the strategy is intended to meet.
        - (a) a high degree of safety for the public and the environment,
        - (b) high degree of safety for workers,
        - (c) addressing Canada's legacy waste in a timely way to avoid passing the legacy to the next generation, and
        - (d) being responsible stewards of Canadian tax dollars.
    - Address these goals in an optimum way. Describe in detail how the selected approach meets these goals by describing other options that have been considered and showing that the decisions made are the correct ones based on the graded approach. To argue this, some supporting points need to be made.
        - (i) the waste is relatively innocuous compared to other types of radwaste, so a graded approach should be used for ensuring the public and the environment are protected, addressing goal (a),
        - (ii) the waste volumes argue for a near surface design from both operational safety and cost, addressing both goals (b) and (d),
        - (iii) the near surface disposal design can be implemented more quickly than other designs considered, addressing both goals (c) and (d).
- The Safety Case could highlight that the NSDF analysis includes many assumptions intended to be cautiously biased to overestimate potential consequences, even with these biases results are expected to provide reasonable confidence that impacts will be below the dose standard, and therefore the facility may potentially safely accept more activity than evaluated in the PostSA and Inventory report.
- The Safety Case should include stronger statements related to implementation of the WAC:
    - the safety assessment has been used as the basis for an appropriate (preliminary?) set of waste acceptance criteria,
    - there is a robust plan for the application of those criteria and dealing with any variations,
    - a robust waste acceptance process is in place and
    - arrangements are in place for dealing with any non-conformances.

2.8 Quality Assurance Program

The panel reviewed *Project Quality Plan: Addendum #2 Performance Assessment for a Near Surface Disposal Facility Using AMBER Version 6.2*. 232-505210-PLA-002, Revision 0, 2018 October 24 (final). The panel recognized the document as a good practice with the QA process described as well developed, efficient and effective in meeting quality assurance objectives for data and models.

2.9 Reference Distribution Coefficient

The panel reviewed *Technical Note: Reference Distribution Coefficient and Calculation of the Effective Distribution Coefficient for the NSDF Engineered Containment Mound*. 232-508600-TN-008, Revision 0, 2018 February 23 (final). The panel recommends justifying the method for developing the K_ds. It was not clear that a weighted average based on mass was an appropriate method.

2.10 Postclosure Safety Assessment

Four different versions of the PostSA were reviewed by the panel. These included the second iteration (scoping study) and three drafts of the third iteration (early, model/data, and consolidated). The early and model/data drafts were combined for this report. The consolidated mature draft was available after the on-site visit. No formal effort was made to determine if earlier comments were incorporated in later iterations. It should be noted that, because of the nature of the PostSA, observations made regarding the PostSA may be addressed and incorporated in other documents as appropriate.

The document presents a quantitative assessment of the postclosure radiological and non-radiological safety of the proposed NSDF, identifies key uncertainties, addresses relevant Canadian requirements, and supports the EIS.

2.10.1 Second Iteration

The panel reviewed *Postclosure Safety Assessment Addendum #1*. 232-509240-ASD-002, Revision 0, 2019 January. The panel recommended that the assumptions where deliberate cautious bias or safety margins were introduced be clearly identified and documented.

2.10.2 Third early and model/data Iteration

The panel reviewed *Postclosure Safety Assessment Introduction – Phase II. 351294-008, Revision #3*, 2019 July and *Postclosure Safety Assessment*. 351294-006, Revision #3, 2019 July (section 5 only). The panel identified 12 recommendations, 35 suggestions, and 2 good practices. Given the number of suggestions on this early draft, they are not summarized in this report.

The recommendations included:

- Discuss the multiple lines of defense in the ECM performance using key parameter sensitivities.
- For perspective, consider providing information comparing doses from naturally occurring radioactive material in the waste to natural background doses

- Resolve inconsistencies between the discussion regarding Engineered Barrier System (EBS) failure and the conceptual model implemented.
- The links between the safety assessment and the WAC are not adequately described
- Resolve inconsistencies that exist between waste type descriptions
- Gas generation rates need to be justified and the uncertainties evaluated.
- Deliberate cautious assumptions and data choices should be clearly identified and documented as such to identify the intent and support defense-in-depth discussions.
- The presentation and justification of the WAC should include:
    - the derivation of maximum radionuclide specific limits taking account of impacts from each pathway or scenario;
    - limits based on both specific activity (e.g. for human intrusion) and total inventory (e.g. for the groundwater pathway);
    - an explanation of the approach to capacity management;
    - an explanation of what would happen if any limits were exceeded (on a container and/or total inventory basis);
    - a justification of the approach.
- The cap design needs additional substantiation
- Optimization of the cap design should be identified
    - demonstration that design alternatives have been considered and that definitive design choices have been made taking account of radiological impacts as well as other factors such as long-term durability;
    - demonstrating that design choices conform with good practice;
    - explaining how design requirements link to the repository safety case.
- The near field flow model requires discussion on assumptions, implications, and uncertainties.
- The representation of the closure cap during the postclosure period is not clearly justified considering the AECL expert elicitation.

The good practices identified regarded signature boxes within the data documentation sections providing evidence of the quality assurance checking process and that an appropriate Features, Events, and Processes-based method was used to derive a reasonably comprehensive set of sensitivity cases for evaluation.

2.10.3 Third Consolidated Iteration

The panel reviewed *Postclosure Safety Assessment Introduction – Phase II*. 351294-008, Revision #3, 2019 October. The panel identified 11 recommendations, 23 suggestions and two good practices.

The recommendations included:

- The conclusions should emphasize:
    - the generally low radiological hazard associated with the waste and the facility, in operation and post-closure
    - radiation doses have been calculated using cautious models and assume the use by future communities of local contaminated resources

    - An assessment approach has been followed consistent with international recommendations and guidance as implemented in many countries and recognized as best practice
    - doses are much lower than background
    - assessed doses are lower than the regulatory criteria for all but two scenarios; however, these two exceptions may be considered both very unlikely and involving overly conservative combinations of assumptions.
- Clarify how the gas pathway for C-14 was modelled
- Document the connection between the safety case and the WAC
- Include introductory material explaining what the model represents, which pathways are addressed and identify the key processes
- Document nearby source terms and calculate potential cumulative doses
- Document the rational for Ra chemical properties used since different than other radioisotopes
- Use less conservative assessments in the analysis and demonstrate that there is considerable margin of safety in the facility
- Discuss the assumed criterion for human intrusion of 1 mSv y^{-1} in the context of International Commission on Radiological Protection (ICRP) and IAEA guidance for human intrusion (i.e., 1 mSv is at the very low end of the scale (1-20 mSv)). IAEA and ICRP recommend optimization for doses in that range, so discuss examples of how the facility will help reduce the potential for this scenario for doses slightly above 1 mSv (i.e., a calculated dose slightly above 1 mSv is not necessarily an indication of a non-compliance).
- Review and consider revision of dosimetric data
- Recognize that some construction aspects of the cover design may be difficult to execute in field conditions.

One good practice identified was the crosswalk of NSDF requirements to the document sections where they are addressed, this was an excellent tool for the reviewers and those seeking to understand how the assessment addresses requirements. The other good practice was the normal evolution and inadvertent intruder scenario assessments addition of As Low As Reasonably Achievable to provide an additional layer of protection consistent with the defense in depth philosophy.

3.0 Other Recommendation

The panel identified one recommendation that concerns the reference inventory, WAC, and safety assessment. The basis for not reporting certain radionuclides is related to their significance in the post closure safety assessment using the reference inventory. This leaves a potential vulnerability if there are waste streams with quantities greater than analyzed in the reference inventory, but that don't require reporting. It is recommended that CNL confirm that inventories are less than the reference inventory for all waste streams. Consider developing an internal document with concentration and/or inventory limits for all the radionuclides in the reference inventory linked to non-exceedance of an annual dose of 0.3 mSv. This will provide perspective on the allowable amounts of each radionuclide based on the assumptions in the SA.

4.0 Conclusions

The panel commends the CNL staff and their support contractors for developing the analyses and documentation to support licensing of the NSDF. The staff proved to be well qualified and are applying tools with the necessary capabilities to support the license submittal. The CNL team's candor and openness in responding to specific information requests and queries was highly appreciated and proved beneficial to the review.

The panel identified 35 recommendations, 76 suggestions, and five good practices. The panel is not involved in resolving observations with CNL and any resulting document revisions were not reviewed by the panel. The panel reviewed several "mature draft" documents but did not have the opportunity to review comment resolutions incorporated into the final integrated package to be submitted to the regulator. The iterative nature of the review provided opportunities for the panel to make observations beneficial for on-going work. For example, it was apparent in revised versions of the Safety Case and PostSA document reviewed by the panel that changes were made to address specific observations.

Overall the panel believes that the facility is being conservatively designed to dispose of the planned radioactive inventory, and contingent on appropriate resolution of outstanding observations as identified the safety documentation provides reasonable assurance that appropriate safety standards could be met. The panel concluded that CNL has an adequate knowledge of the system at the current stage of repository development. However, the panel identified the following general comments:

- Document and justify assumptions where deliberate cautious or conservative bias or safety margins are introduced. This will help with discussions of defense-in-depth and communication of conclusions regarding compliance with regulatory criteria.
- Identify assumptions made in the absence of natural and engineered system understanding to inform future investigation and/or data collection.
- Clarify and justify the basis for selecting the barrier system design (e.g., cap design details).
- Justify the methods used to make radionuclide screening decisions
- Document the connection between the safety case and the WAC.
- Clarify the links between the PostSA results and other safety analyses and requirement development (e.g., WAC, design features, operational considerations, monitoring, research/characterization needs, etc.).

Finally, CNL should be commended for the following best practices identified by the panel:

- The quality assurance process described in the Quality Assurance Program was well developed, efficient and effective in meeting quality assurance objectives for data and models.
- The use of signature boxes within the data documentation sections of the Postclosure Safety Assessment provided evidence of the quality assurance checking process and that an appropriate Features, Events, and Processes-based method was being used to derive a reasonably comprehensive set of sensitivity cases for evaluation.

- The crosswalk of NSDF requirements to the document sections where they are addressed was an excellent tool for the reviewers and those seeking to understand how the assessment addresses requirements.
- The normal evolution and inadvertent intruder scenario assessments addition of As Low As Reasonably Achievable optimization considerations effectively provided additional evidence of protectiveness consistent with the defense in depth philosophy.