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ALTERNATIVE MEANS ASSESSMENT REPORT

NPD CLOSURE PROJECT

64-509200-ASD-002

Revision 1

Accepted by:

Brian Wilcox
Director Reactor Decommissioning (NPD
&WR-1)

2020/03/28

Date


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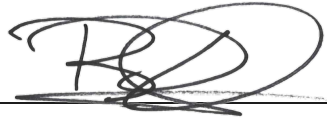
REVISION 1

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A large orange geometric graphic consisting of a triangle and a rectangle. The triangle is on the right side, with its hypotenuse on the left. A horizontal line extends from the left edge of the page, passing through the triangle and ending at the right edge. The rectangle is on the left side, with its right edge on the hypotenuse of the triangle.

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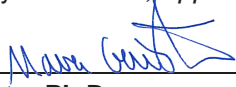
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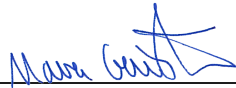
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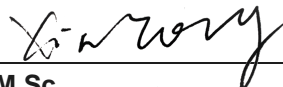
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ALTERNATIVE MEANS ASSESSMENT

REVISION 1

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Revision History				
Revision		Details of Revision	Author	Reviewer
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0	2016/11/10	Original Report	N. Garisto, J.G. Gilbert	L. H. Johnson
1		Updated to address the comments from the Federal and Provincial Review Team, as well as the public and indigenous groups. Major change is the assumption of availability of off-site disposal for waste being sent to CRL for storage.	N. Garisto, S. McKee	X. Tong, R. Kovacs

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1.0 INTRODUCTION

1.1 Background

Following permanent shutdown of the Nuclear Power Demonstration (NPD) Nuclear Generating Station, all process systems not required during safe storage were drained and shut down, including the heavy water moderator and heat transport system. The spent fuel was transferred to fuel storage facilities at another CNL site. Demineralizer equipment was removed for re-use, and the entire turbine system, control room and support facilities were cleared out and demolished where possible. Some hazardous materials have been removed such as portions of the asbestos insulation and floor tiles. Any redundant buildings and non-nuclear systems were removed (i.e., power house components). The Nuclear Power Demonstration Waste Facility (NPDWF) currently consists of a limited number of structures including the main building storing the reactor and its associated systems, a diesel-generator, the ventilation stack and the guardhouse.

At the time of NPD Nuclear Generating Station permanent shutdown, the preferred decommissioning strategy for the station was one of deferred decommissioning. A deferment period allowed the significant reduction of radiation fields emanating from the reactor and associated process systems as a result of the decay of radioactive isotopes.

In 1988, after the facility was shut down, total residual radioactivity in the NPD reactor system was estimated to be 2×10^{15} Bq. Since shut down, 31 years of radioactive decay have reduced radioactivity considerably. The total radiological inventory of the NPD reactor system in 2019 was estimated at 7.51×10^{13} Bq (McVeigh 2019).

The decommissioning of the NPDWF has been proposed using the In-Situ Disposal approach triggering an Environmental Assessment. An alternative means assessment is a required input to the Environmental Impact Statement (EIS) as defined in the *Canadian Environmental Assessment Act* (2012), the CNSC “Generic Guidelines for the Preparation of an Environmental Impact Statement” (2016), REGDOC 2.9.1 (2017), and the CEAA Operational Policy Statement: Addressing “Purpose of” and “Alternative Means” under the *Canadian Environmental Assessment Act, 2012* (2015). This report provides the alternative means assessment for the decommissioning of the NPDWF.

1.2 Problem Statement

The NPD reactor has been removed from service and placed in a permanent shutdown state; however, a radiological inventory of contaminants remains and represents a risk of future release to the environment. The Government of Canada has requested CNL accelerate efforts to reduce the overall legacy liability and complete the closure of the NPD Site. The NPDWF needs to be decommissioned in an expeditious manner to safely render the hazards into a condition that meets the prescribed dose constraints to the public and the environment. Additionally, Canada does not currently have disposal capabilities for the reactor systems and components present at NPD.

1.3 Objective

The objective of this report is to provide a qualitative analysis of the environmental risks (including health) of alternative decommissioning techniques, as specified in the Project Description (Titterington 2016). This analysis will allow for the selection of a preferred method for carrying out the project. The approach involves comparison of the risk of the alternative means with the risk from current operations of the facility, that is, relative to continued Storage with Surveillance (SwS). This latter risk is evaluated in detail in Athauda-Arachchige (2015) and the specific baseline risks to each environmental component are discussed in the applicable section. The risk for the alternative means is evaluated with respect to the Valued Components (VCs) identified in the EIS. In addition to the relative environmental risks, this report also addresses absolute environmental risk. Together, these comparisons of environmental risk are used to select a preferred decommissioning technique.

1.4 Timeframes

Three timeframes were used for the analysis in this report to allow for clear analysis of the options, and their time-dependence. The three timeframes are:

- **Decommissioning Execution:** the expected active decommissioning phase of the project. This is when workers are expected to be on-site, undertaking activities associated with the decommissioning of the facility.
- **Institutional Controls:** the monitoring period of the project. This is the timeframe where institutional controls are in effect, and there are a small number of workers e.g., monitoring the surroundings to ensure that there are no unexpected releases. Expected duration: for planning purposes, the Institutional Control period is at least 100 years, though institutional controls will continue for as long as necessary.
- **Post-Institutional Controls:** this timeframe follows the expected cessation of Institutional Controls. This timeframe includes all long-term effects of the facility.

1.5 Overview

As discussed above, the objective of this report is to provide a qualitative analysis of the environmental risks (including health) of alternative decommissioning techniques and select a preferred means. The process of this selection follows the framework laid out in the CEAA Operational Policy Statement: Addressing “Purpose of” and “Alternative Means” under the Canadian Environmental Assessment Act, 2012 (CEAA 2015). The results of this report will feed into the EIS. A list of Valued Components (VCs) has been developed as part of the EIS, and this same list is used in this report, as discussed in Section 3.1. The potential impacts of each alternative on each VC group, through the environmental components, are assessed qualitatively and compared.

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Figure 1.5-1 shows the overall structure and approach used in this report. Following the *CEAA* Operational Policy Statement (*CEAA* 2015), the first step is to identify technically and economically feasible alternative means. This includes the selection of feasibility criteria and the definition of the alternative means. Following this, the assessment of the alternative means against the criteria is presented to determine which alternative means are technically and economically feasible, and should be carried through to the next step. This information is presented in Section 2 and the four alternatives can be seen on the flow chart.

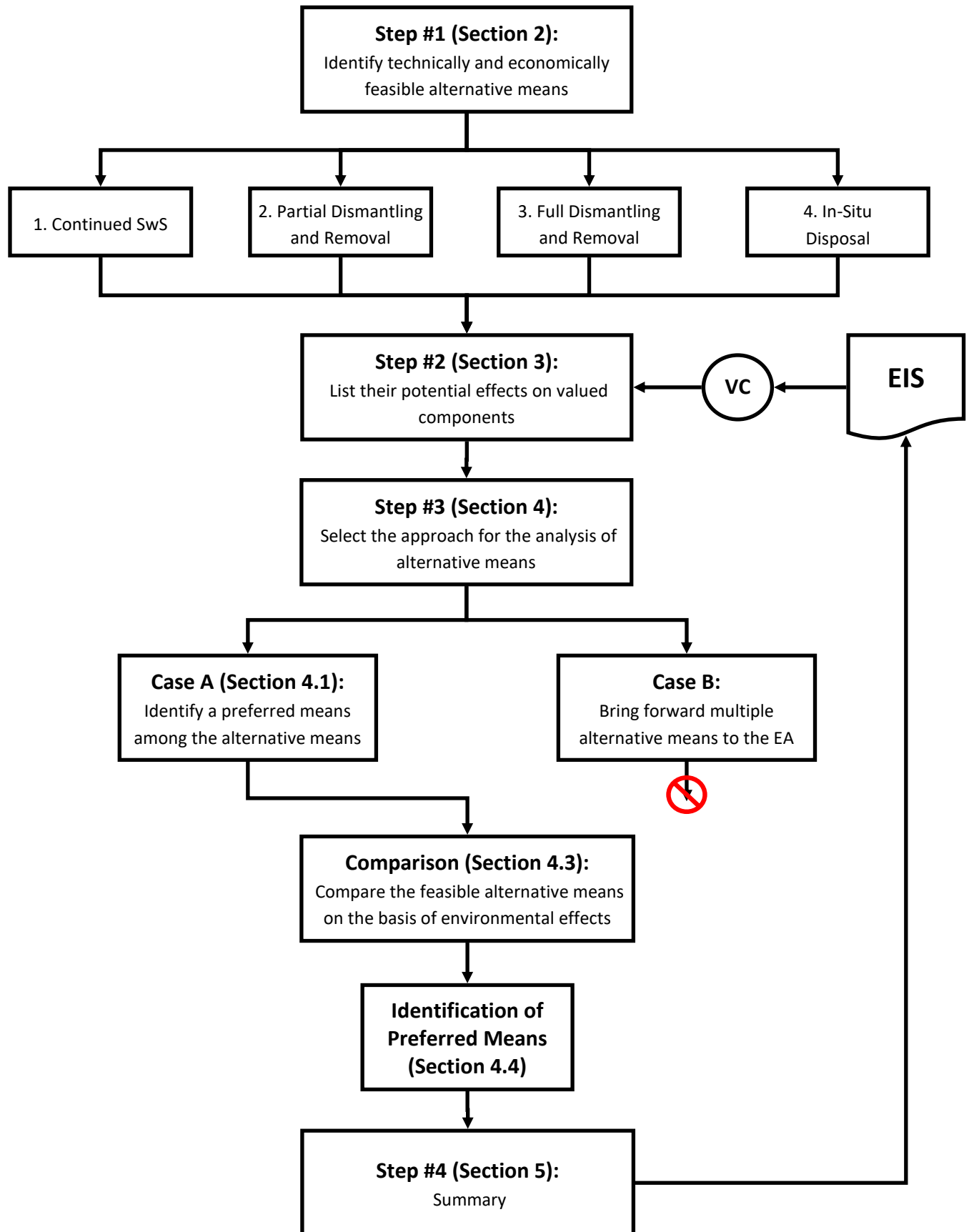
These alternatives feed into the second step, which is to list the potential effects on VCs. The VCs assessed in this report are based on those VCs identified in the EIS, and are listed by environmental component in Section 3.1. Finally, a set of interaction matrices, which show the potential impact of each alternative means on the environmental components, can be found in Section 3.2.

This information then feeds into step three, where the analysis approach moving forward is selected. Section 4.1 explains that *CEAA* “Case A” is being pursued for this project. A methodology is then explained in Section 4.2, which will structure the analysis performed. Following this, in Section 4.3, the four alternative means are assessed and compared for their effect on the key VCs. Additionally, in Section 4.3.6, a quantitative analysis of radiological dose and injury to workers was undertaken. Based on the environmental impacts and the effects on the VCs, a preferred means can be selected.

Section 5 provides a standalone summary which feeds into the EIS. This summary discusses the alternative means that has been selected as the preferred means, and a concise explanation of how this decision was made.

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Figure 1.5-1 Overview Flow Chart



2.0 IDENTIFICATION OF FEASIBLE ALTERNATIVE MEANS

This section provides Step #1 of the *CEAA* Operational Policy Statement: Addressing “Purpose of” and “Alternative Means” under the Canadian Environmental Assessment Act, 2012 (*CEAA* 2015). In the context of *CEAA* (2015), feasibility includes technical and economic aspects.

In addition to these aspects, *CEAA* also highlights sustainability as a consideration in the EA process. REGDOC-2.9.1 (CNSC 2017) defines sustainable development as development that meets the needs of the present, without compromising the ability of future generations to meet their own needs. As outlined in subsequent sections, this Alternative Means Assessment assesses alternative means over three different timeframes. In this way, aspects of sustainability over the expected life of the waste are inherently considered.

2.1 Criteria for Feasibility

The *CEAA* Operational Policy Statement: Addressing “Purpose of” and “Alternative Means” under the Canadian Environmental Assessment Act, 2012 (*CEAA* 2015) identifies that the first step in performing an alternative means assessment is the identification of technically and economically feasible alternative means. Two sets of feasibility criteria were developed to aid in determining which alternative means to carry through the assessment.

As discussed above, aspects of sustainability over the expected life of the waste are inherently considered. Therefore, explicit criteria related to sustainability are not required.

2.1.1 Technical Feasibility

The criteria that are used in this report to assess the technical feasibility of the alternative means are:

- Reliable Technology, i.e. does the alternative means use a previously demonstrated technology?
- Regulatory Compliance, i.e. does the alternative means meet regulatory requirements?

2.1.2 Economic Feasibility

Given that this is a decommissioning project, and there will be no CNL income associated with it, the criteria that are used to assess the economic feasibility of the alternative means are:

- Cost, i.e. is the alternative within the financial guarantee limit from NRCan?

2.2 Definition of Alternative Means

Several alternative means are provided in the Project Description (Titterington 2016). It is worth noting that some of these alternative means will require further action at some later time. For example, alternatives involving the removal of waste from the NPD Site require the consideration of future disposal, i.e., off-site disposal facilities for low-level waste (LLW) and intermediate-level waste (ILW). This assessment includes

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consideration of the activities related to disposal of this waste specifically, however does not include consideration of the construction, operation, decommissioning, and long-term care and maintenance of such facilities. The Project Description (Titterington 2016) provides four alternative means for decommissioning that are being assessed. These alternative means are:

1. Continued Storage with Surveillance (SwS);
2. Partial Dismantling and Removal;
3. Full Dismantling and Removal;
4. In-Situ Disposal.

Each of these four alternative means are described in more detail below, along with a pictographic representation of the approach. The legend for the pictographs can be found at the bottom of this section.

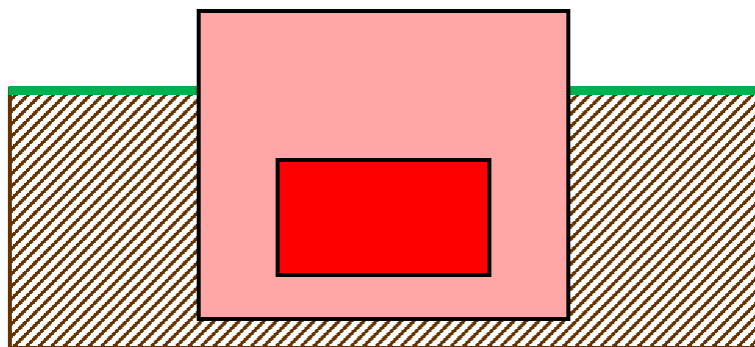
1. Continued Storage with Surveillance (SwS)








“Continue with a deferred decommissioning approach which includes maintaining the NPDWF in the Storage with Surveillance phase to allow for further radioactive decay.” (Titterington 2016)

For this analysis it has been assumed that this approach involves continuing to defer decommissioning by maintaining the NPDWF in the SwS phase, thereby allowing for further radioactive decay. This will involve continued maintenance, monitoring and yearly reporting in the form of annual compliance reports. Specific activities may change over time as the state of the facility changes.

Continued SwS serves as a baseline case against which the other alternative means are compared.

NPD Site



	Low Level Radioactive Material (LLW)		Grouted Low Level Radioactive Material
	Reactor System and Components (ILW)		Grouted Reactor System and Components
	Ground		Grass
			Clean Concrete

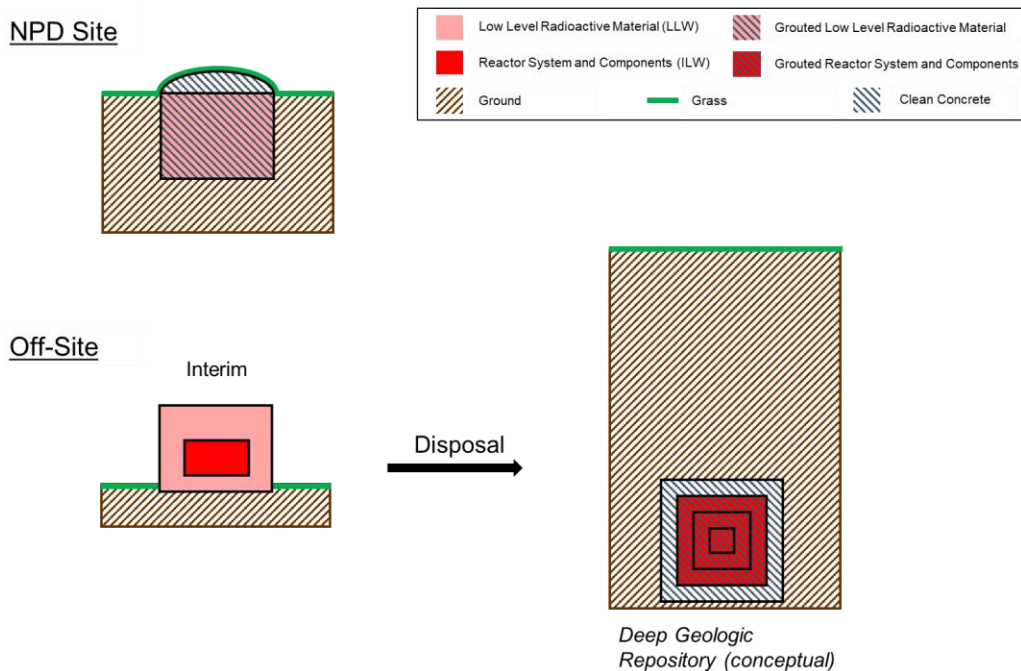
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2. Partial Dismantling and Removal

“Partial removal of the source term (i.e., reactor systems and components) for interim storage at the Chalk River Laboratories (CRL) site until the waste undergoes final disposal at the CRL site. The remaining facility systems, structures and components will remain in-situ.” (Titterington 2016)

This alternative means is a combination of the in-situ disposal and full removal alternatives, and involves removal of the reactor system and components. The feeders, pressure tubes, calandria tubes, calandria and associated bioshielding will be removed, and the fuel handling room will be decommissioned. This waste would be packaged in containers for transport and storage. Additionally, a few drums of waste from the spent fuel bay cleanup would likely also be removed. This waste would be temporarily stored at the CRL site, prior to final disposal. It is assumed that a disposal facility for ILW will become available at CRL at some point during the Institutional Controls phase. Activities associated with the construction of such a facility are not considered in this assessment; only disposal-related activities (e.g., transportation, handling, emplacement) are considered. The remaining facility systems, structures, and components will remain in-situ, and will be decommissioned in the same manner as for “4. In-Situ Disposal”. The above ground structures will be demolished and the rubble emplaced in the below grade structures prior to grouting. A concrete cap and engineered barriers would cover the facility and the surrounding area would be remediated. The stack would remain intact to continue serving as a habitat for chimney swifts.

During the Institutional Controls phase, surveillance, inspection, maintenance, and monitoring activities will be undertaken at the NPD site. These activities will include inspection of the integrity of the disposal facility, i.e., concrete cap and engineered barrier, and maintenance such as re-grading and removing trees and deep-rooted plants. The specific monitoring activities would be developed in compliance with applicable CSA N288 series documents for groundwater, effluent, and environmental monitoring.



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3. Full Dismantling and Removal

“Full dismantling and removal of all systems, structures and components for interim storage at the CRL site, until the waste undergoes final disposal at the CRL site.” (Titterington 2016)

For this analysis it has been assumed that this alternative means involves removing all radioactive material from the site and storing it temporarily at CRL, until a final disposal location is available. It is assumed that disposal facilities for both low-level waste (LLW) and intermediate-level waste (ILW) will become available at CRL during the Institutional Controls phase. The activities associated with the construction of these facilities is not in the scope of this assessment; only the disposal-related activities (e.g., transportation, handling, emplacement) are considered.

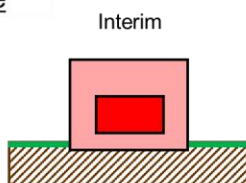
All structures on-site would be demolished and removed from the site, along with any nuclear or hazardous waste. This would include the removal of the reactor and the associated systems. It would also include removal of the stack and construction of a replacement roosting structure. The site would be remediated following the removal of all structures. It has also been assumed that the waste will be stored in containers within a building at the CRL site due to the lack of a disposal facility at the time of waste removal.

During the Institutional Controls phase, it is assumed that minimal surveillance, inspection, and maintenance activities will be undertaken at the NPD site. It is expected that monitoring activities will continue to demonstrate the enhancement of the site following removal of the facility. Similarly, monitoring of the chimney swift population and use of the roosting structure will be required. General maintenance of the property will also be required (e.g., surface condition of roads and landfills).

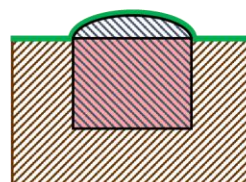
NPD Site



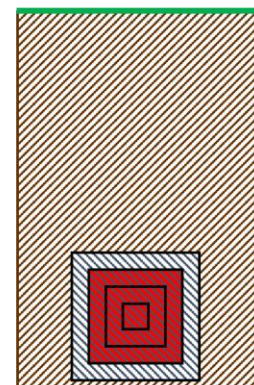
Off-Site



Disposal →



Near Surface Disposal Facility (conceptual)



Deep Geologic Repository (conceptual)

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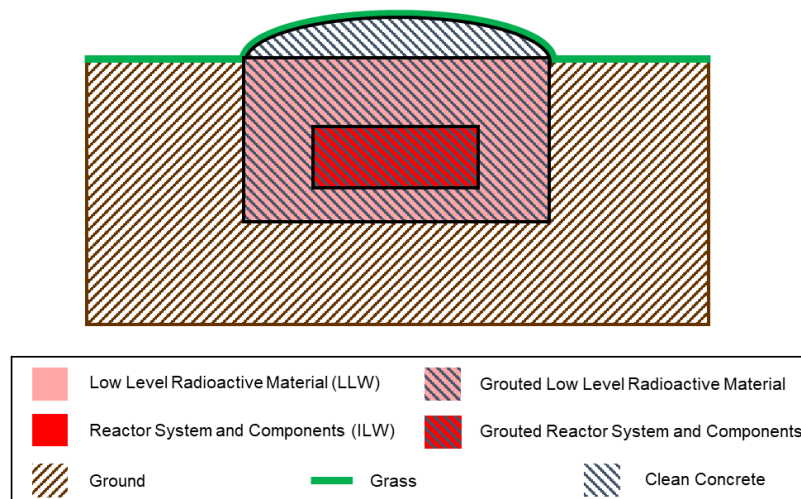
4. In-Situ Disposal

“In-situ disposal where the source term will be isolated inside the below grade structure and systems to allow for continued radioactive decay.” (Titterington 2016)

For this analysis it has been assumed that this alternative means involves grouting the reactor and associated systems in place within the building as a means of decommissioning. The above ground structures will be demolished, and the rubble will also be grouted within the below grade structures. The stack would not be demolished, as it will be left as a habitat for chimney swifts. Finally, a concrete cap and engineered barrier system would be placed over the facility to close it and the site will be remediated.

During the Institutional Controls phase, surveillance, inspection, maintenance, and monitoring activities will be undertaken at the NPD site. These activities will include inspection of the integrity of the disposal facility, i.e., concrete cap and engineered barrier, and maintenance such as re-grading and removing trees and deep-rooted plants. A draft follow-up program has been developed in compliance with applicable CSA N288 series documents for groundwater, effluent, and environmental monitoring to be undertaken during both the Decommissioning Execution and Institutional Controls phases.

NPD Site



2.3 Feasibility of Alternative Means

2.3.1 Technical Feasibility

As discussed in Section 2.1, the criteria that are used to assess the technical feasibility of the alternative means are:

- Reliable Technology, i.e. does the alternative means use a previously demonstrated technology?
- Regulatory Compliance, i.e. does the alternative means meet regulatory requirements?

Table 2.3-1 below shows the assessment of the four alternative means against the feasibility criteria.

Table 2.3-1 Technical Feasibility Assessment

Alternative Means	Assessment of Feasibility	Criteria Met?
Reliable Technology, i.e. does the alternative means use a previously demonstrated technology?		
1. Continued SwS	<p>Storage with Surveillance (SwS) is the current operating state. For the Decommissioning Execution timeframe the techniques and technologies used will not change from those that have already been successfully demonstrated.</p> <p>For the Institutional Controls timeframe, as time passes, and the facility continues to age and degrade, the task of maintaining the facility will become increasingly more complex, but feasible based on CNL experience at Chalk River Laboratories (CRL).</p> <p>In the Post-Institutional Controls timeframe, given the uncertainty in the end state of this alternative means, institutional control will be required indefinitely, unless a disposal approach can be found. This is deemed feasible, albeit, complex.</p>	Y
2. Partial Dismantling and Removal	As a combination of aspects from the alternatives “3. Full Dismantling & Removal” and “4. In-Situ Disposal”, this alternative will use the same demonstrated technologies as described for those alternative means.	Y
3. Full Dismantling and Removal	During the Decommissioning Execution Phase, the removal of components from the facility is not a new technology, and has been performed in the past. Transfers of waste are routinely done in Canada i.e. from reactor sites to the Western Waste Management Facility. This alternative means uses the technology and approaches demonstrated through these past works.	Y

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Alternative Means	Assessment of Feasibility	Criteria Met?
	<p>During the Institutional Controls phase, interim storage of waste at the CRL Site will involve monitoring and maintenance as needed. The eventual disposal of waste will require the development and construction of disposal facilities for both low- and intermediate-level waste. Although quite complex, this is deemed to be technically feasible.</p> <p>During the Post-Institutional Controls phase, maintenance and monitoring activities will be required at the disposal facilities. The complexity of these activities is low.</p>	
4. In-Situ Disposal	<p>In-Situ disposal has been successfully implemented in a number of locations and projects across North America and the European Union. See Appendix A for further information.</p> <p>In the Institutional Controls timeframe, following the closure of the facility, only monitoring will be required, and the waste will be safely within the grouted monolith.</p> <p>In the Post-Institutional Controls timeframe, ongoing institutional control may not be required. As a result, the complexity of this alternative is very low. While there is a potential risk of human intrusion in the long term, this risk is low due to the fact that the facility is grouted.</p>	Y
Regulatory Compliance, i.e. does the alternative means meet regulatory requirements?		
1. Continued SwS	<p>Continuing with the existing operations would not require licensing changes and experience with the current regulatory compliance could be applied.</p> <p>However, in the Institutional and Post-Institutional Control phases, there is considerable uncertainty regarding the end state of this alternative, and the potential impacts that could have on the VCs. This uncertainty carries with it a large regulatory risk (e.g., inability to obtain a Licence to Abandon, or similar type of licensing activity). Additionally, the regulatory regime could also change, and a more permanent alternative means may be required.</p>	Y
2. Partial Dismantling and Removal	As a combination of aspects from the alternatives “3. Full Dismantling & Removal” and “4. In-Situ Disposal”, this alternative will have similar regulatory compliance consideration as described for these alternative means.	Y

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Alternative Means	Assessment of Feasibility	Criteria Met?
	<p>This alternative will require an ILW disposal facility; there is regulatory uncertainty associated with both the approval and timing of the availability of such a facility.</p> <p>A Licence to Abandon, or similar type of licensing activity, for the off-site disposal facility would be required to undertake cessation of institutional controls and would likely be contingent on decommissioning and environmental monitoring results.</p>	
<p>3. Full Dismantling and Removal</p>	<p>During the Decommissioning Execution timeframe, this alternative will require regulatory approval for the decommissioning of the facility, and potentially for transportation of waste to, and interim storage at, a new location. Additionally, removal of the stack would require a replacement habitat to be built for the chimney swifts, however if the swifts do not move to the replacement habitat, there is a risk that CNL would not be authorized by regulators to remove the stack.</p> <p>During the Institutional Controls phase, the eventual disposal of waste will require disposal facilities for both low- and intermediate-level waste. There is some uncertainty with respect to the licensing/approval, as well as the timing of the availability, of these disposal facilities. This uncertainty carries some risk.</p> <p>A Licence to Abandon, or similar type of licensing activity, for the off-site disposal facilities would be required to undertake cessation of institutional controls and would likely be contingent on decommissioning and environmental monitoring results.</p>	<p>Y</p>
<p>4. In-Situ Disposal</p>	<p>During the Decommissioning Execution timeframe, this decommissioning approach will carry some regulatory risk, as it will be the first time this approach has been used in Canada outside of the uranium mining industry.</p> <p>A Licence to Abandon, or similar type of licensing activity, would be required to undertake cessation of institutional controls and would likely be contingent on decommissioning and environmental monitoring results.</p>	<p>Y</p>

2.3.2 Economic Feasibility

As discussed in Section 2.1, the criteria that are used to assess the economic feasibility of the alternative means are:

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- Cost, i.e. is the alternative within the financial guarantee limit from NRCan?

Table 2.3-2 shows the estimated costs of four alternative means. The costs presented in this table are in Canadian dollars. It is also important to note that none of the costs include off-site storage or eventual disposal costs (for the stored waste). Furthermore, “1. Continued SwS” will require periodic capital investment to replace infrastructure, which has also not been included in the cost.

The primary costs for “2. Partial Dismantling & Removal”, “3. Full Dismantling & Removal”, and “4. In-Situ Disposal” are all during the Decommissioning Execution timeframe. This is because these alternative means all involve increased work in the short term to limit requirement for future interactions. It can also be seen that “4. In-Situ Disposal” is significantly less expensive than “2. Partial Dismantling & Removal” or “3. Full Dismantling & Removal”. This is because “4. In-Situ Disposal” does not involve the removal and transportation of any waste.

Alternative “3. Full Dismantling & Removal” is the bounding case, as it involves the largest initial investment, and is within CNL’s guarantee, and therefore feasible. Given that the bounding case is feasible, all of the alternative means are therefore feasible.

Table 2.3-2 Overall Project Costs

Timeframe	1. Continued SwS	2. Partial Dismantling & Removal	3. Full Dismantling & Removal	4. In-Situ Disposal
Decommissioning Execution	\$4.5 M/yr. + periodic infrastructure improvement	\$70-90 M + storage costs + eventual final disposal costs	\$125-150 M + storage costs + eventual final disposal costs	\$60-80 M, including institutional control activities

3.0 POTENTIAL IMPACTS ON VALUED COMPONENTS

This section follows Step #2 of the CEEA Operational Policy Statement: Addressing “Purpose of” and “Alternative Means” under the Canadian Environmental Assessment Act, 2012 (CEAA 2015).

3.1 Valued Component Identification

The Valued Components (VCs) that are used in this analysis are those identified in the EIS. Table 3.1-1 below shows the key VCs that were selected for each environmental component, based on the master list of candidate VC species. The table also identifies pathways for the transfer of effects. Note: Shaded cells represent pathways to VCs in other environmental components.

Although selected for the “4. In-Situ Disposal” alternative, the VCs are applicable to all of the alternatives. Furthermore, “2. Partial Dismantling and Removal” and “3. Full Dismantling & Removal”, are both currently assumed to store the waste at the Chalk River Laboratories (CRL) site nearby. Considering the proximity of the sites, the key VCs that have been identified for the NPD site are also indicative of the key VCs for the CRL site.

Table 3.1-1 VCs for the Nuclear Power Demonstration Closure Project

Environmental Component	VC or Pathway	Rationale
Atmospheric Environment	Pathway to human health	The effects on humans associated with changes in atmospheric conditions (radiological and chemical releases and concentrations) will be considered in the human health component.
	Pathway to non-human biota health	The effects on non-human biota associated with changes in atmospheric conditions (radiological and chemical releases and concentrations) will be considered in the aquatic and terrestrial environmental components.
	Pathway to VCs in other environmental components	The effects on VCs in other environmental components associated with changes in atmospheric conditions (e.g. noise) will be considered in the applicable environmental components.
Surface Water Environment	Pathway to human health	The effects on humans associated with changes in site drainage and surface water quality (radiological and chemical releases and concentrations) will be considered in the Human Health component.
	Pathway to non-human biota health	The effects on non-human biota associated with changes in site drainage and surface water quality (radiological and chemical releases and concentrations) will be considered in the aquatic and terrestrial environmental components.
	Pathway to VCs in other environmental components	The effects on VCs in other environmental components associated with changes in site drainage and surface water quality (e.g., water levels) will be considered in the applicable environmental components.

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Environmental Component	VC or Pathway	Rationale
Aquatic Environment	Aquatic vegetation	Represents a fundamental element of ecosystem health and function.
	Benthic invertebrates	Macroinvertebrates occupy the sediment and are an important food source for benthivorous fish species. They are used to evaluate overall ecosystem health.
	Emerald shiner	Numerically important pelagic forage species.
	Lake Sturgeon	Benthivorous/bottom-dwelling fish. Lake Sturgeon has been subject to fishery exploitation in the past, before population declines. It is the largest, longest-living freshwater fish in Ontario. In the stretch of the Ottawa River that includes NPD, the Lake Sturgeon is more abundant than elsewhere in the river.
	White sucker	Abundant benthivorous/bottom dwelling fish, an important component of that community with available data.
Terrestrial Environment	Bald eagle	Large raptor. Cultural and ecological significance. Known nest in the local study area.
	Black bear	Large terrestrial omnivore. Cultural significance and public interest. Black bear is included and also intended to be representative of other large mammals, such as moose.
	Blanding's turtle	THR (SARA status) turtle. The Blanding's turtle has been sighted near the NPD Site, and travels great distances over land.
	Chimney swift	THR (SARA status) migratory insectivorous bird. There is a chimney swift super roost in the vent stack at NPD which is in close proximity to site activities and may be impacted.
	Eastern milksnake	SC (SARA status) snake present at NPD.
	Eastern wolf	SC (SARA status) large terrestrial carnivore. Regional presence.
	Great blue heron	Large wading piscivorous bird. Great blue herons are sensitive to human disturbance. Regional presence. Great blue herons often return to their nesting colonies for many consecutive years, and are sensitive to habitat destruction or disturbance.
	Green frog	The green frog is abundant and is present in wetlands at NPD.
	Little brown myotis Eastern small-footed myotis Northern myotis Tri-coloured bat	Bat species known to be present at NPD. All are listed as END (SARA status) except for eastern small-footed myotis which is unlisted. While each listed species is a VC, the little brown myotis (in bold) is used as a surrogate for the others.
	Mallard	The Ottawa River is in the heart of the Atlantic Flyway, and is an important stopover for migrating waterfowl such as the mallard.

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Environmental Component	VC or Pathway	Rationale
		Regional presence.
	Meadow vole	Soil-dwelling, small herbivore. Burrowing is an important exposure pathway.
	Monarch butterfly	SC (SARA status) – Monarchs are migrants and are sensitive to habitat fragmentation and disturbance. Found in the site study area.
	Muskrat	Aquatic piscivore/herbivore. Regional presence.
	Red Maple	Upland/wetland deciduous tree common at NPD.
	Ruffed grouse	Ground-dwelling non-migratory omnivorous bird. Present at NPD.
	Soil Invertebrates	Soil-dwelling invertebrates (e.g. earthworm). Exposure from soil.
	Short-tailed shrew	Abundant carnivorous small mammal. Burrowing is an important exposure pathway. Sufficient data availability.
Geological and Hydrogeological Environment	Pathway to human health	The effects on humans associated with changes in soil and groundwater conditions (radiological and chemical releases and concentrations, and noise) as well as groundwater flow and other physical parameters will be considered in the human health environmental component.
	Pathway to non-human biota health	The effects on non-human biota associated with changes in soil and groundwater conditions (radiological and chemical releases and concentrations, and noise) as well as groundwater flow and other physical parameters will be considered in the aquatic and terrestrial environmental components.
	Pathway to VCs in other environmental components	The effects on VCs in other environmental components associated with changes in soil and groundwater conditions (radiological and chemical releases and concentrations) as well as groundwater flow and other physical parameters will be considered in the applicable environmental components.
Radiation and Radioactivity Environment	Pathway to human health	The effects on humans associated with changes in radioactivity in the environment will be considered in the human health component.
	Pathway to non-human biota health	The effects on non-human biota associated with changes in radioactivity in the environment will be considered in the Non-Human Biota Health component.
	Pathway to VCs in other environmental components	The effects on non-human biota associated with changes in radioactivity in the environment will be considered in the aquatic and terrestrial environmental components.
Land Use	Land Use and Planning Regime	The proposed project may allow for redesignation of some or all of the NPD property for another use following closure.

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Environmental Component	VC or Pathway	Rationale
	Landscape and Visual Setting	The project activity may impact the quality of views from the Ottawa River. It is not visible from Highway 17.
	Highway 17	Project-related increases in traffic may impact capacity and safety of the Highway. Transportation-related accidents represent a risk to human health and safety, as well as a risk to the natural environment.
Physical and Cultural Heritage Resources	No direct corresponding VC	VCs not Identified.
Socio-Economic Conditions	Walleye	Socio-economic importance as a sportfish.
	White-tailed deer	Socio-economic importance as a game species.
	Residents – Use/Enjoyment of Property	There may be disruption to use and enjoyment of property because of nuisance-related effects (e.g., dust, noise, traffic) during the Execution phase for residents living in the Local Study Area.
Indigenous Rights and Interests	No direct VCs Identified	Identification of VCs is ongoing. This assessment considers effects to Indigenous Peoples' communities, traditional land and resource use, and ceremonial sites and significant features. Impact on Aboriginal health is addressed under human health.
Health	Human	Public: The general public may be exposed to health risk as a result of the project. The effects on humans associated with changes in atmospheric, surface water, geological and hydrogeological conditions (radiological and chemical releases and concentrations), and external gamma radiation are considered. The effect of ingestion of foodstuffs such as honey and berries is also considered.
		Worker: Workers may be exposed to health risk as a result of performing their duties relative to the project. The effects on humans associated with changes in atmospheric, surface water, geological and hydrogeological conditions (radiological and chemical releases and concentrations) and external gamma radiation are considered.
	Non-human Biota	Terrestrial Vegetation (see above).
		Soil Invertebrates (see above).
		Birds (see above).
		Mammals (see above).
		Amphibians and Reptiles (see above).
		Aquatic plants (see above).
		Benthic invertebrates (see above).
		Fish (see above).

THR – Threatened, SC – Special Concern, END – Endangered

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A qualitative assessment of relative risk to environmental components from the four alternative means is being carried out. Environmental components (e.g. atmospheric environment, surface water environment) are the column heading of the interactions matrix (See EIS Section 4.2). These environmental components are assessed in the EIS by representative VCs. Therefore, we also assess the risk of the four alternative means to the corresponding VCs within each component. See a list of the environmental components and corresponding VCs in Table 3.1-2.

Thus, the environmental components that are being analyzed are:

1. Environmental Effects
 - 1.1. Atmospheric Environment
 - 1.2. Surface Water Environment
 - 1.3. Aquatic Environment
 - 1.4. Terrestrial Environment
 - 1.5. Geological and Hydrogeological Environment
 - 1.6. Radiation & Radioactivity Environment
2. Miscellaneous Physical Effects
 - 2.1. Land Use
 - 2.2. Traffic and Transportation
 - 2.3. Physical and Cultural Heritage Resources
3. Socioeconomic Effects
 - 3.1. Socioeconomic Effects
4. Effects on Indigenous People
 - 4.1. Effects on Indigenous Peoples' Rights and Interests
5. Health Effects
 - 5.1. Public Health
 - 5.2. Worker Health
 - 5.3. Non-Human Biota

Please note that there are some minor differences between this VC list and that in the EIS. For example, traffic and transportation is being assessed separately from land use, as compared to the EIS which assesses them as within the same component. This was done due to large discrepancies found when assessing these two as one component. For example, the alternative means that are beneficial for Land Use (such as alternative "3. Full Dismantling and Removal) generally have larger impacts on Traffic and Transportation.

With the environmental components and associated VCs defined, a clear definition of each environmental component was needed. This is done to ensure that there is no double counting of the same effect. For example, terrestrial environment does not include the effects to the health of the animals because this has been counted in the non-human biota component. Table 3.1-2, below, shows each component, the specific scope of each component, and the related VCs. Some of the environmental components are classified as pathways, meaning that they feed into another component, which will in turn directly impact a VC. These pathways are shaded grey to differentiate them from the components which have direct impacts on VCs.

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Table 3.1-2 Scope of Environmental Components

	Environmental Component	Scope	VCs
1	Environmental Effects		
1.1	Atmospheric Environment	Includes: <ul style="list-style-type: none"> Air Quality (Radiological, Chemical and Physical (e.g. Particulate Matter) Releases and Concentrations) Noise 	Pathway to: <ul style="list-style-type: none"> Human Health Non-Human Biota Health VCs in Other Environmental Components
1.2	Surface Water Environment	Includes: <ul style="list-style-type: none"> Site Drainage Surface Water Quality (Radiological and Chemical Releases and Concentrations) Flows and Levels Shoreline Processes 	Pathway to: <ul style="list-style-type: none"> Human Health Non-Human Biota Health VCs in Other Environmental Components
1.3	Aquatic Environment	Includes: <ul style="list-style-type: none"> Aquatic Habitat Aquatic Biota (fish, benthic invertebrates, etc.) Excludes: <ul style="list-style-type: none"> Non-Human Biota (Chemical and Radiological, see #5.3) 	<ul style="list-style-type: none"> Aquatic vegetation Benthic invertebrates Emerald shiner Lake sturgeon White sucker
1.4	Terrestrial Environment	Includes: <ul style="list-style-type: none"> Vegetation Birds Terrestrial Invertebrates Amphibians and Reptiles Mammals Landscape Connectivity Excludes: <ul style="list-style-type: none"> Non-Human Biota (Chemical and Radiological, see #5.3) 	<ul style="list-style-type: none"> Bald eagle Black bear Blanding's turtle Chimney swift Eastern milksnake Eastern wolf Great blue heron Green frog Little brown myotis Mallard Meadow vole Monarch butterfly Muskrat Red Maple Ruffed grouse Soil invertebrates Short-tailed shrew

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	Environmental Component	Scope	VCs
1.5	Geological and Hydrogeological Environment	Includes: <ul style="list-style-type: none"> • Soil Quality (Radiological and Chemical Releases and Concentrations) • Groundwater Quality (Radiological and Chemical Releases and Concentrations) • Groundwater Flow 	Pathway to: <ul style="list-style-type: none"> • Human Health • Non-Human Biota Health • VCs in Other Environmental Components
1.6	Radiation and Radioactivity Environment	Includes: <ul style="list-style-type: none"> • External Gamma Radiation Excludes: <ul style="list-style-type: none"> • Radioactivity in atmospheric, surface water, aquatic and geological and hydrogeological environments (covered within those components) 	Pathway to: <ul style="list-style-type: none"> • Human Health • Non-Human Biota Health
2	Miscellaneous Physical Effects		
2.1	Land Use	Includes: <ul style="list-style-type: none"> • Land Use in Study Area • Landscape and Visual Setting 	<ul style="list-style-type: none"> • Land Use and Planning Regime • Landscape and Visual Setting
2.2	Traffic and Transportation	Notes: <ul style="list-style-type: none"> • This has been separated from Land Use to simplify the analysis Includes: <ul style="list-style-type: none"> • Transportation System Operation • Transportation System Safety 	<ul style="list-style-type: none"> • Highway 17
2.3	Physical and Cultural Heritage Resources	Includes: <ul style="list-style-type: none"> • Archaeological Resources • Built Heritage/Cultural Landscape • Cultural Resources Excludes: <ul style="list-style-type: none"> • Effects on Indigenous Peoples' Rights and Interests (See #4.1) 	<ul style="list-style-type: none"> • No direct VCs identified
3	Socioeconomic Effects		
3.1	Socioeconomic Effects	Includes: <ul style="list-style-type: none"> • Resource/Human Uses of the Land • Physical Assets Exclude <ul style="list-style-type: none"> • Land Use (See #2.1) 	<ul style="list-style-type: none"> • Walleye • White-tailed deer • Residents – Use/Enjoyment of Property

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	Environmental Component	Scope	VCs
4	Effects on Indigenous People		
4.1	Effects on Indigenous Peoples' Rights and Interests	<p>Includes:</p> <ul style="list-style-type: none"> • Indigenous Peoples' Communities <ul style="list-style-type: none"> ○ First Nations ○ Métis • Traditional Land and Resource Use • Ceremonial Sites and Significant Features 	<ul style="list-style-type: none"> • Identification of VCs is ongoing. This assessment considers effects to Indigenous Peoples' communities, traditional land and resource use, and ceremonial sites and significant features. Impact on Aboriginal health is addressed under human health.
5	Health Effects and Non-Human Biota		
5.1	Public Health	<p>Includes:</p> <ul style="list-style-type: none"> • Normal operational exposure of the public to <ul style="list-style-type: none"> ○ Radiation ○ Chemical Contaminants ○ Noise • Malfunctions • Accidents • Disruptive Events • Glaciation <p>Excludes:</p> <ul style="list-style-type: none"> • Transportation (see #2.1) 	<ul style="list-style-type: none"> • Human Health
5.2	Worker Health	<p>Includes:</p> <ul style="list-style-type: none"> • Normal operational exposure of workers to <ul style="list-style-type: none"> ○ Radiation ○ Chemical Contaminants ○ Noise • Malfunctions • Accidents <p>Excludes:</p> <ul style="list-style-type: none"> • Transportation (see #2.1) 	<ul style="list-style-type: none"> • Human Health
5.3	Non-Human Biota	<p>Includes:</p> <ul style="list-style-type: none"> • Normal operational exposure of VCs to <ul style="list-style-type: none"> ○ Radiation ○ Chemical Contaminants ○ Noise • Malfunctions • Accidents • Disruptive Events • Glaciation <p>Excludes:</p> <ul style="list-style-type: none"> • Transportation (see #2.1) 	<p>Non-Human Biota (See Table 3.1-1)</p> <ul style="list-style-type: none"> • Terrestrial vegetation • Soil invertebrates • Birds • Mammals • Amphibians and reptiles • Aquatic plants • Benthic invertebrates • Fish

3.2 Potential Effects on VCs

Table 3.2-1 to Table 3.2-4 show a high-level, compacted, interaction matrix for each of the four alternative means. These interaction matrices show the areas of potential effect from the project on the VCs. The interaction matrix for the In-Situ Disposal alternative is consistent with the full interaction matrix in the EIS. The interaction matrix addresses all phases of the project for each alternative. It was derived taking into account Features, Events, and Processes that may affect the project (Arcadis and Quintessa 2017). It has been compacted to a higher level, both in the activities and in the environmental components, to facilitate a direct comparison with the other alternatives. Any indicated interaction represents that at least one of the sub-components, or sub activities, has an interaction, but it does not represent that all sub components are affected.

In addition to the interaction matrices, a set of comparison matrices have been prepared. These allow for all four alternatives to be directly compared, by presenting all four alternatives, and their interactions on one matrix. Because each different alternative has different activities associated with it, they have been simplified further to allow for comparison. Table 3.2-5 shows the four alternatives and their interactions on the environmental components for the Decommissioning Execution timeframe. Table 3.2-6 shows the interactions for the Institutional Control timeframe. Table 3.2-7 shows the interactions during Post-Institutional Control period (>100 years). Interactions have been marked for each alternative if that alternative has at least one interaction in the corresponding period.

For all interaction matrices please note:

- ◆ represents a potential interaction on the NPD Site
- ○ represents a potential interaction at the off-site storage location (assumed to be CRL)
- ■ represents a potential interaction that is expected to have beneficial effects
- If multiple symbols appear in the same cell in the comparison matrices it is to show that some activities have potential impacts, on on-site and/or off-site, and some activities have potential impacts that are expected to have beneficial effects
- Any activity that has an interaction has also been assumed to interact with social effects, as it may impact hunting.
- Marked cells indicate a potential interaction on at least one of the sub-categories of the assessment criteria, not all sub-categories are affected
- The timeframe headings have been shortened to fit:
 - DE – Decommissioning Execution
 - IC – Institutional Controls
 - PIC – Post-Institutional Controls

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Table 3.2-1 Continued SwS Interaction Matrix

		1. Continued SwS	Environmental Effects					Miscellaneous Physical Effects			Socio-economic Effects	Effects on Indigenous People	Health Effects (Normal)			
Timeframe	Activity #	Project Activities	Atmospheric Environment	Surface Water Environment	Aquatic Environment	Terrestrial Environment	Geological and Hydrogeological Environment	Radiation and Radioactivity Environment	Land Use	Traffic and Transportation	Physical and Cultural Heritage Resources	Socioeconomic Effects	Effects on Indigenous Peoples' Rights and Interests	Public Health	Worker Health	Non-Human Biota
DE/IC ¹	1	Ongoing Maintenance and Monitoring	◆	◆				◆	◆			◆	◆	◆	◆	◆
PIC	2	Long Term Effect (Assuming Cessation of Maintenance)	◆	◆			◆	◆	◆			◆	◆	◆		◆

Notes: 1 – For this alternative means the Decommissioning Execution and Institutional Controls are the same

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Table 3.2-2 Partial Dismantling and Removal Interaction Matrix

		2. Partial Dismantling and Removal	Environmental Effects					Miscellaneous Physical Effects			Socio-economic Effects	Effects on Indigenous People	Health Effects (Normal)			
Timeframe	Activity #	Project Activities	Atmospheric Environment	Surface Water Environment	Aquatic Environment	Terrestrial Environment	Geological and Hydrogeological Environment	Radiation and Radioactivity Environment	Land Use	Traffic and Transportation	Physical and Cultural Heritage Resources	Socioeconomic Effects	Effects on Indigenous Peoples' Rights and Interests	Public Health	Worker Health	Non-Human Biota
DE	1	Removal of Reactor System and Components	◆	◆ ¹			◆	◆	◆ ¹			◆	◆	◆	◆	◆
	2	Transport Waste to Another CNL Site (Including Accidents)	○	○				○		○		○	◆	○	○	○
	3	Batch Mixing Plant	◆	◆		◆		◆ ²	◆	◆		◆	◆	◆	◆	◆
	4	Removal of Above Ground Structures and Grouting of the Whole Facility	◆	◆		◆	◆	◆	◆	◆		◆	◆	◆	◆	◆
	5	Install Cap and Engineered Barrier	◆	◆			◆						◆		◆	
	6	Final Site Restoration	◆	◆		■			■	◆	■	◆	◆		◆	
IC	7	Long term Care and Maintenance (of Monolith)								■		◆				
	8	Storage, Monitoring, and Eventual Disposal of Waste Off-Site	○	○			○	○				○	◆	○	○	○
PIC	9	Facility performance during the Post-Institutional Controls phase	◆ ○	◆ ○			◆ ○	◆ ○	■		◆	◆ ○	◆	◆ ○		◆ ○

Notes: 1 – Lay down area 2 – Creating access for the slip pipes has the potential to release radioactive material

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Table 3.2-3 Full Dismantling and Removal Interaction Matrix

		3. Full Dismantling and Removal	Environmental Effects					Miscellaneous Physical Effects			Socio-economic Effects	Effects on Indigenous People	Health Effects (Normal)			
Timeframe	Activity #	Project Activities	Atmospheric Environment	Surface Water Environment	Aquatic Environment	Terrestrial Environment	Geological and Hydrogeological Environment	Radiation and Radioactivity Environment	Land Use	Traffic and Transportation	Physical and Cultural Heritage Resources	Socioeconomic Effects	Effects on Indigenous Peoples' Rights and Interests	Public Health	Worker Health	Non-Human Biota
DE	1	Removal of Reactor System and Components	◆	◆ ¹			◆	◆	◆ ¹			◆	◆	◆	◆	◆
	2	Removal of Structures and Low Level Components	◆	◆		◆	◆	◆	◆	◆		◆	◆	◆	◆	◆
	3	Final Site Restoration	◆	◆		■			■	◆	■		◆		◆	
	4	Transport Waste to Another CNL Site (Including Accidents)	○	○				○		○		○	◆	○	○	○
IC	5	Release of NPD site						■		■		■				
	6	Storage, Monitoring, and Eventual Disposal of Waste Off-Site	○	○			○	○				○	◆	○	○	○
PIC	6	Facility performance during the Post-Institutional Controls phase	○	○			○	○	■		◆	○	◆	○		○

Notes: 1 – Lay down area

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Table 3.2-4 In-Situ Disposal Interaction Matrix

		4. In-Situ Disposal	Environmental Effects					Miscellaneous Physical Effects			Socio-economic Effects	Effects on Indigenous People	Health Effects (Normal)			
Timeframe	Activity #	Project Activities	Atmospheric Environment	Surface Water Environment	Aquatic Environment	Terrestrial Environment	Geological and Hydrogeological Environment	Radiation and Radioactivity Environment	Land Use	Traffic and Transportation	Physical and Cultural Heritage Resources	Socioeconomic Effects	Effects on Indigenous Peoples' Rights and Interests	Public Health	Worker Health	Non-Human Biota
DE	1	Batch Mixing Plant	◆	◆		◆		◆ ¹	◆	◆		◆	◆	◆	◆	◆
	2	Grouting of Below Grade Structure	◆	◆				◆		◆		◆	◆	◆	◆	◆
	3	Removal and Grouting of Above Ground Structures	◆	◆		◆	◆	◆		◆		◆	◆	◆	◆	◆
	4	Install Cap and Engineered Barrier	◆	◆			◆						◆		◆	
	5	Final Site Restoration	◆	◆		■			■		■	◆	◆		◆	
IC	6	Care and Maintenance										◆				
PIC	7	Facility performance during the Post-Institutional Controls phase	◆	◆			◆	◆	■			◆	◆	◆		◆

Notes: 1 – Creating access for the slip pipes has the potential to release radioactive material

Decommissioning Execution Timeframe

Table 3.2-5 Decommissioning Execution Timeframe Comparison Matrix

Alternative Means	Environmental Effects						Miscellaneous Physical Effects			Socio-economic Effects	Effects on Indigenous People	Health Effects (Normal)		
	Atmospheric Environment	Surface Water Environment	Aquatic Environment	Terrestrial Environment	Geological and Hydrogeological Environment	Radiation and Radioactivity Environment	Land Use	Traffic and Transportation	Physical and Cultural Heritage Resources	Socioeconomic Effects	Effects on Indigenous Peoples' Rights and Interests	Public Health	Worker Health	Non-Human Biota
1. Continued SwS	◆	◆				◆	◆	◆		◆	◆	◆	◆	◆
2. Partial Dismantling and Removal	◆ ○	◆ ○		◆ ■	◆	◆ ○	◆ ■	◆ ○	■	◆ ○	◆	◆ ○	◆ ○	◆ ○
3. Full Dismantling and Removal	◆ ○	◆ ○		◆ ■	◆	◆ ○	◆ ■	◆ ○	■	◆ ○	◆	◆ ○	◆ ○	◆ ○
4. In-Situ Disposal	◆	◆		◆ ■	◆	◆	◆ ■	◆	■	◆	◆	◆	◆	◆

Institutional Controls Timeframe

Table 3.2-6 Institutional Controls Timeframe Comparison Matrix

Alternative Means	Environmental Effects						Miscellaneous Physical Effects			Socio-economic Effects	Effects on Indigenous People	Health Effects (Normal)		
	Atmospheric Environment	Surface Water Environment	Aquatic Environment	Terrestrial Environment	Geological and Hydrogeological Environment	Radiation and Radioactivity Environment	Land Use	Traffic and Transportation	Physical and Cultural Heritage Resources	Socioeconomic Effects	Effects on Indigenous Peoples' Rights and Interests	Public Health	Worker Health	Non-Human Biota
1. Continued SWS	◆	◆				◆	◆	◆		◆	◆	◆	◆	◆
2. Partial Dismantling and Removal	○	○			○	○				○	◆	○	○	○
3. Full Dismantling and Removal	○	○			○	○				○	◆	○	○	○
4. In-Situ Disposal											◆			

Post-Institutional Controls Timeframe

Table 3.2-7 Post-Institutional Controls Timeframe Comparison Matrix

Alternative Means	Environmental Effects						Miscellaneous Physical Effects			Socio-economic Effects	Effects on Indigenous People	Health Effects (Normal)		
	Atmospheric Environment	Surface Water Environment	Aquatic Environment	Terrestrial Environment	Geological and Hydrogeological Environment	Radiation and Radioactivity Environment	Land Use	Traffic and Transportation	Physical and Cultural Heritage Resources	Socioeconomic Effects	Effects on Indigenous Peoples' Rights and Interests	Public Health	Worker Health	Non-Human Biota
1. Continued SWS	◆	◆	◆		◆	◆	◆			◆	◆	◆		◆
2. Partial Dismantling and Removal	◆ ○	◆ ○			◆ ○	◆ ○	■		◆	◆ ○	◆	◆ ○		◆ ○
3. Full Dismantling and Removal	○	○			○	○	■		◆	○	◆	○		○
4. In-Situ Disposal	◆	◆			◆	◆	■		◆	◆	◆	◆		◆

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These comparison matrices show that for the Decommissioning Execution timeframe, the interactions with the environment are similar between the alternatives. This does not account for the likelihood or severity of these interactions, and will require further analysis to decide on a preferred method. For the Post-Institutional Controls timeframe, there is still too much similarity to be able to select a preferred method, however it can be seen that continuing with SwS has some drawbacks. Further analysis is done below, on all timeframes, to determine the preferred alternative means.

4.0 ANALYSIS OF ALTERNATIVE MEANS

This section provides Step #3 of the CEEA Operational Policy Statement: Addressing “Purpose of” and “Alternative Means” under the *Canadian Environmental Assessment Act*, 2012 (CEAA 2015).

4.1 Selection of Approach

The CEEA Operational Policy Statement (CEAA 2015) identifies 2 cases which can be selected for the EIS:

- Case A: Identify a preferred means in the EIS
- Case B: Bring forward multiple alternative means into the EIS

In this report the four alternative means are compared so that it can be determined which is the preferred means for carrying out the project. Given that there is sufficient information available to be able to select a single alternative means to carry forward in our analysis Case A of CEAA (2015) has been selected. Section 4.4.4 will identify the preferred alternate means that has been selected.

4.2 Methodology

The comparison was conducted for three timeframes (discussed in Section 1.4) and each environmental component. Environmental components were analysed as either pathways to other components, or as components containing VCs. As with Table 3.1-2, any components that are pathways are shaded in grey to differentiate them. For the sake of simplicity, the analysis used groups of VCs, as opposed to individual VCs.

4.2.1 Relative Risk Comparison

For each environmental component, at each timeframe, a table is presented. This table shows each of the 4 alternatives, their risk relative to the baseline case, and an explanation of the key factors that affect that risk. In the each of these tables, “1. Continued SwS” is the baseline case, and any comparison to the baseline or baseline case is referring to this alternative means and its associated risks. Table 4.2-1 shows the relative risk icons used in the analysis.

The assignment of relative risk arrows was based on the experience and professional judgement of technical specialists. Although subjective in scale, the arrows consider aspects such as magnitude, spatial extent, impact to human and non-human biota health.

Table 4.2-1 Relative Risk Scale

Symbol	Explanation
↑↑ Risk	Alternative is associated with more risk than baseline.
↑ Risk	Alternative is associated with slightly more risk than baseline
≈ Risk	Alternative is associated with approximately same risk as baseline.
↓ Risk	Alternative is associated with slightly less risk than baseline.
↓↓ Risk	Alternative is associated with less risk than baseline.

4.3 Environmental Effects of Alternative Means

4.3.1 Environmental Effects

4.3.1.1 Atmospheric Environment

Atmospheric Environment	
Includes/Excludes	VCs
Includes: <ul style="list-style-type: none"> Air Quality (Radiological, Chemical and Physical (e.g. Particulate Matter) Releases and Concentrations) Noise 	Pathway to: <ul style="list-style-type: none"> Human Health Non-Human Biota Health VCs in Other Environmental Components

Timeframe: Decommissioning Execution			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↑↑ Risk	↑↑ Risk	↑ Risk
<p>Continued SwS activities are not expected to have any large emission to the atmospheric environment.</p> <p>Occasional releases will continue to be released through the monitored, HEPA filtered, ventilation system as required for maintenance.</p>	<p>Given the increased activities that will take place as part of decommissioning, there is expected to be a much higher risk of effect on the atmospheric environment. Specifically, heavy vehicles and equipment, demolition, and the batch mixing plant are expected to increase the amount of air emissions and noise.</p> <p>Additionally, there is the potential for releases of radioactive material as part of these activities.</p>	<p>Given the increased activities that will take place as part of decommissioning, there is expected to be a much higher risk of effect on the atmospheric environment. Specifically, the heavy vehicles and equipment and demolition are expected to increase the amount of air emissions and noise.</p> <p>Additionally, there is the potential for releases of radioactive material as part of these activities.</p>	<p>Given the increased activities that will take place as part of decommissioning, there is expected to be a higher risk of effect on the atmospheric environment. Specifically, the heavy vehicles needed for demolition, and the batch mixing plant are expected to increase the amount of air emissions and noise. However, this alternative will require less demolition and heavy vehicle and equipment activity.</p> <p>Additionally, there is the potential for releases of radioactive material as part of these activities, however no radioactive components are being removed as part of this alternative.</p> <p>Overall, due to the reduced amount of demolition required and the fact that no radiological material is being removed, the risk for this alternative would be less than “2. Partial Dismantling and Removal” and “3. Full Dismantling & Removal”.</p>

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Atmospheric Environment			
Timeframe: Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↓ Risk	↓ Risk	↓↓ Risk
<p>Emissions during this timeframe will be similar to the Decommissioning Execution timeframe.</p>	<p>On-Site: Following the partial dismantling and removal of the facility, the in-situ site will behave similarly to “4. In-Situ Disposal”.</p> <p>Interim Storage at CRL: The emissions during interim storage at the CRL site are expected to be slightly lower than those from “1. Continued SwS” as the waste will be stored in containers, thereby limiting releases (as discussed in Section 2.2).</p> <p>Disposal Activities at CRL: There will also be some atmospheric emissions from additional handling and transportation (e.g., vehicle emissions) associated with emplacement and disposal.</p> <p>Final Disposal at CRL: Following final disposal at the CRL site, this alternative will behave similarly to “4. In-Situ Disposal”.</p> <p>Overall: the risk to the atmospheric environment is expected to be slightly lower than the baseline case.</p>	<p>On-Site: Following the full dismantling and removal of the facility, there will no longer be any waste on-site. Thus, no impacts to the atmospheric environment are expected at the NPD site.</p> <p>Interim Storage at CRL: The emissions at the CRL site are expected to be slightly lower than those from “1. Continued SwS” as the waste will be stored in containers, thereby limiting releases (as discussed in Section 2.2).</p> <p>Disposal Activities at CRL: There will also be emissions from additional handling and transportation (e.g., vehicle emissions) associated with emplacement and disposal.</p> <p>Final Disposal at CRL: Following final disposal at the CRL site, this alternative will behave similarly to “4. In-Situ Disposal”.</p> <p>Overall: the risk to the atmospheric environment is expected to be slightly lower than the baseline case.</p>	<p>On-Site: Once the facility is fully closed, there should not be any immediate emissions, and eventual volatilization through the cap is expected to be minimal.</p> <p>Overall the risk to atmospheric environment will be greatly reduced relative to “1. Continued SwS”.</p>

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Atmospheric Environment			
Timeframe: Post-Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↓↓ Risk	↓↓ Risk	↓↓ Risk
<p>With time, as the system degrades and groundwater seeps in, there will be the potential for releases of both radioactive and chemical contaminants.</p>	<p>Although the waste will be apportioned to two disposal facilities (the NPD disposal facility, and an ILW disposal facility), the total inventory is the same as for “1. Continued SwS”.</p> <p>It is assumed that the releases to the atmosphere during the post-institutional controls phase would be very low for an ILW facility (e.g., for a deep geological disposal facility). Therefore, the overall risk for this alternative is the same as for “4. In-Situ Disposal”.</p>	<p>Although the waste will be apportioned to two disposal facilities (for both LLW and ILW), the total inventory is the same as for “1. Continued SwS”.</p> <p>It is assumed that the releases to the atmosphere during the post-institutional controls phase would be very low for an ILW facility (e.g., for a deep geological disposal facility), and that releases from an LLW disposal facility would be similar to in-situ disposal. Therefore, the overall risk for this alternative is the same as for “4. In-Situ Disposal”.</p>	<p>While there is the potential for atmospheric releases of contaminants, this is unlikely, due to the grout and cap system. Even in the case where atmospheric emissions occur, they would be delayed, and as such be of a much smaller risk, as compared to the baseline case.</p> <p>Overall the risk is much lower than the baseline case.</p>

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4.3.1.2 Surface Water Environment

Surface Water Environment	
Includes/Excludes	VCs
Includes: <ul style="list-style-type: none"> • Site Drainage • Surface Water Quality (Radiological and Chemical Releases and Concentrations) • Flows and Levels • Shoreline Processes 	Pathway to: <ul style="list-style-type: none"> • Human Health • Non-Human Biota Health • VCs in Other Environmental Components

Timeframe: Decommissioning Execution			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↑↑ Risk	↑↑ Risk	↑ Risk
Continued activities are not expected to lead to significant emissions to the surface water environment.	Given the increased activities that will take place as part of partial dismantling and removal, there is expected to be a higher risk of effect on the surface water environment. Specifically, any rainwater runoff of contaminants will be of key importance, however, these effects should be localized to the site and have negligible effects on the Ottawa River. Additionally, there is the potential for releases of contaminated water as a result of decontamination activities following the removal of the reactor system and components.	Given the high level of activity that will take place as part of full dismantling and removal, there is expected to be a much higher risk of effect on the surface water environment. Specifically, any rainwater runoff of contaminants will be of key importance however, these effects should be localized to the site and have negligible effects on the Ottawa River. Additionally, there is the potential for releases of contaminated water as a result of decontamination activities following the removal of components.	Given the increased activities that will take place as part of decommissioning there is expected to be a higher risk of effect on the surface water environment. Specifically, any rainwater runoff of contaminants will be of key importance, however, these effects should be localized to the site and have negligible effects on the Ottawa River.

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Surface Water Environment			
Timeframe: Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↓ Risk	↓ Risk	↓↓ Risk
<p>Emissions during this timeframe will be similar to the Decommissioning Execution timeframe.</p>	<p>On-Site: Following the partial dismantling and removal of the facility, the in-situ site will behave similarly to “4. In-Situ Disposal”.</p> <p>Interim Storage at CRL: During interim storage at the CRL site, the risk to surface water will likely be slightly lower than “1. Continued SwS” as the waste will be stored in containers, thereby limiting releases.</p> <p>Disposal Activities at CRL: Additional handling, transportation, and emplacement of waste will result in emissions and subsequent deposition, which may cause a change in surface water quality.</p> <p>Final Disposal at CRL: Following final disposal at the CRL site, this waste will behave similar to “4. In-Situ Disposal”.</p> <p>Overall: the risk to the surface water environment is lower than the baseline case due to the delay of contaminant release.</p>	<p>On-Site: Following the full dismantling and removal of the facility, there will no longer be any waste on-site. Thus, no impacts to the surface water environment are expected at the NPD site.</p> <p>Interim Storage at CRL: During interim storage at the CRL site, the risk to surface water will likely be slightly lower than “1. Continued SwS” as the waste will be stored in containers, thereby limiting releases.</p> <p>Disposal Activities at CRL: Additional handling, transportation, and emplacement of waste will result in emissions and subsequent deposition, which may cause a change in surface water quality.</p> <p>Final Disposal at CRL: Following final disposal at the CRL site, this waste will behave similar to “4. In-Situ Disposal”.</p> <p>Overall: Overall the risk to the surface water environment is lower than the baseline case due to the delay of contaminant release.</p>	<p>On-Site: The concrete cap will reduce the amount of precipitation that infiltrates the facility and hence will reduce the advective flow in the facility. Therefore, the rate of mobilization of contaminants will be reduced compared to the base case.</p> <p>Furthermore, the grout will also reduce the advective flow and will sorb contaminants. The relatively high pH of the grout could enhance the precipitation of some released contaminants (e.g. Pb).</p> <p>The slower release rates will reduce the risk compared to the base case. For radionuclides, this will also allow for more decay within the system, and hence reduced risk.</p>

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Surface Water Environment			
Timeframe: Post-Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↓↓ Risk	↓↓ Risk	↓↓ Risk
<p>It is assumed that the facility will not be maintained once institutional controls are removed.</p> <p>With time, water will seep into the facility, mobilize contaminants, and gradually release them from the waste into groundwater and into the receiving environment, including surface water (Ottawa River).</p>	<p>Although the waste will be apportioned to two disposal facilities (the NPD disposal facility, and an ILW disposal facility), the total inventory is the same as for “1. Continued SwS”.</p> <p>It is assumed that the releases to surface water during the post institutional controls phase would be very low for an ILW facility (e.g., for a deep geological disposal facility). Therefore, the overall risk for this alternative is the same as for “4. In-Situ Disposal”.</p>	<p>Although the waste will be apportioned to two disposal facilities (for both LLW and ILW), the total inventory is the same as for “1. Continued SwS”.</p> <p>It is assumed that the releases to surface water during the post-institutional controls phase would be very low for an ILW facility (e.g., for a deep geological disposal facility), and that an LLW disposal facility would be similar to in-situ disposal. Therefore, the overall risk for this alternative is the same as for “4. In-Situ Disposal”.</p>	<p>This will continue to behave as described in the Institutional Controls phase.</p>

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4.3.1.3 Aquatic Environment

Aquatic Environment	
Includes/Excludes	VCs
<p>Includes:</p> <ul style="list-style-type: none"> • Aquatic Habitat • Aquatic Biota (fish, benthic invertebrates, etc.) <p>Excludes:</p> <ul style="list-style-type: none"> • Non-Human Biota (see Environmental Component #5.3 (Section 4.3.5.3)) 	<ul style="list-style-type: none"> • Aquatic vegetation • Benthic invertebrates • Emerald shiner • Lake Sturgeon • White sucker

Timeframe: Decommissioning Execution			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	≈ Risk	≈ Risk	≈ Risk
Continued SwS is not expected to have any impacts on aquatic environment VCs.	<p>As there are no activities expected to occur in or near the water, there are no effects predicted on the aquatic environment VCs.</p> <p>Water required for grouting or dust suppression may be drawn from the Ottawa River using existing infrastructure, however due to the low velocity of water drawing and hydrant design features, no impingement or entrainment risk is expected.</p>	<p>As there are no activities expected to occur in or near the water, there are no effects predicted on the aquatic environment VCs.</p> <p>Water required for dust suppression may be drawn from the Ottawa River using existing infrastructure, however due to the low velocity of water drawing and hydrant design features, no impingement or entrainment risk is expected.</p>	<p>As there are no activities expected to occur in or near the water, there are no effects predicted on the aquatic environment VCs.</p> <p>Water required for grouting or dust suppression may be drawn from the Ottawa River using existing infrastructure, however due to the low velocity of water drawing and hydrant design features, no impingement or entrainment risk is expected.</p>

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Aquatic Environment			
Timeframe: Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	≈ Risk	≈ Risk	≈ Risk
<p>Effects during this timeframe will be similar to the Decommissioning Execution timeframe.</p>	<p>On-Site: No project works will be undertaken in or near water, therefore no effects are expected on aquatic habitat.</p> <p>Following the partial dismantling and removal of the facility, the in-situ site will behave similarly to “4. In-Situ Disposal”.</p> <p>Interim Storage at CRL: The impact to the aquatic environment as a result of interim storage at CRL is expected to be negligible.</p> <p>Disposal activities at CRL: It is expected that the emissions from disposal activities will not impact the aquatic environment.</p> <p>Final Disposal at CRL: Following final disposal at the CRL site, this alternative will behave similarly to “4. In-Situ Disposal”.</p> <p>Overall: Given that no effects to the aquatic environment are expected as part of “1. Continued SwS”, this is not expected to change for “2. Partial Dismantling and Removal”.</p>	<p>On-Site: No project works will be undertaken in or near water, therefore no effects are expected on aquatic habitat.</p> <p>Following the full dismantling and removal of the facility, there will no longer be any waste on-site. Thus, no impacts to the aquatic environment are expected at the NPD site.</p> <p>Interim Storage at CRL: The impact to the aquatic environment as a result of interim storage at CRL is expected to be negligible.</p> <p>Disposal activities at CRL: It is expected that the emissions from disposal activities will not impact the aquatic environment.</p> <p>Final Disposal at CRL: Following final disposal at the CRL site, this alternative will behave similarly to “4. In-Situ Disposal”.</p> <p>Overall: Given that no effects to the aquatic environment are expected as part of “1. Continued SwS”, this is not expected to change for “3. Full Dismantling and Removal”.</p>	<p>No project works will be undertaken in or near water, therefore no effects are expected on aquatic habitat.</p> <p>As discussed in Section 4.3.1.2, the concrete cap is expected to reduce the amount of water that is able to get into the facility, thereby also limiting the releases of contaminated water from the facility. Additionally, the grout within the facility will slow the release of any contaminants.</p> <p>Given that no effects to the aquatic environment are expected as part of “1. Continued SwS”, this is not expected to change for “4. In-Situ Disposal”.</p>

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Aquatic Environment			
Timeframe: Post-Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↓↓ Risk	↓↓ Risk	↓↓ Risk
<p>As discussed in Section 4.3.1.2, as the facility degrades it will release chemicals and contaminants to the surface water environment VCs. These chemicals and contaminants will degrade the habitability of the water, and impact the habitats of the aquatic biota. This impact will be proportional to the release, and therefore the risk is proportional to the risk discussed in the surface water comparison above.</p>	<p>Although the waste will be apportioned to two disposal facilities (the NPD disposal facility, and an ILW disposal facility), the total inventory is the same as for “1. Continued SwS”. These two sites, with lower inventory, are expected to have a similar level of risk to the aquatic environment as “4. In-Situ Disposal”.</p>	<p>Although the waste will be apportioned to two disposal facilities (for both LLW and ILW), the total inventory is the same as for “1. Continued SwS”. These two sites, with lower inventory, are expected to have a similar level of risk to the aquatic environment as “4. In-Situ Disposal”.</p>	<p>As discussed in Section 4.3.1.2, as the facility has water slowly leach in, and subsequently leach out, it will release chemicals and contaminants to the surface water environment VCs. These chemicals and contaminants will degrade the habitability of the water, and impact the habitats of the aquatic biota. This impact will be proportional to the release, which is shown in Section 4.3.1.2 to be very small. Therefore, the risk is proportional to the risk discussed in the surface water comparison above.</p>

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4.3.1.4 Terrestrial Environment

Terrestrial Environment	
Includes/Excludes	VCs
<p>Includes:</p> <ul style="list-style-type: none"> • Vegetation • Birds • Terrestrial Invertebrates • Amphibians and Reptiles • Mammals • Landscape Connectivity <p>Excludes:</p> <ul style="list-style-type: none"> • Non-Human Biota (see Environmental Component #5.3 (Section 4.3.5.3)) 	<ul style="list-style-type: none"> • Bald eagle • Black bear • Blanding’s turtle • Chimney swift • Eastern milksnake • Eastern wolf • Great blue heron • Green frog • Little brown myotis • Mallard • Meadow vole • Monarch butterfly • Muskrat • Red Maple • Ruffed grouse • Soil Invertebrates • Short-tailed shrew

Timeframe: Decommissioning Execution			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↑↑ Risk	↑↑ Risk	↑↑ Risk
<p>The existing facility is not known to provide habitat for animals with the exception of a roosting colony of chimney swifts. The fence around the facility limits animal use of the area, as well as the connectivity of the area.</p>	<p>During the active decommissioning of the facility, the need for laydown areas and the batch mixing plant will result in a potential risk to the terrestrial environment VCs.</p> <p>A VC of specific concern is the chimney swifts that roost within the ventilation stack. In this alternative, the stack will remain in place, and the effect on chimney swifts is expected to be minimal.</p> <p>Grouting and demolition will remove the residence/hibernaculum of SAR bats and may result in incidental kill of a small number of bats.</p>	<p>During the active decommissioning of the facility, the need for laydown areas will result in a potential risk to the terrestrial environment VCs.</p> <p>This alternative includes the demolition of the ventilation stack. A replacement habitat would be designed and constructed, and the existing stack would only be removed once the chimney swifts are established in the new habitat. However, there is a risk that chimney swifts do not select the replacement habitat, and that the stack cannot be removed.</p> <p>Demolition will remove the residence/hibernaculum of SAR bats and may result in incidental kill of a small number of bats.</p>	<p>During the active decommissioning of the facility, the need for laydown areas and the batch mixing plant will result in a potential risk to the terrestrial environment VCs.</p> <p>A VC of specific concern is the chimney swifts that roost within the ventilation stack. In this alternative, the stack will remain in place, and the effect on chimney swifts is expected to be minimal.</p> <p>Grouting and demolition will remove the residence/hibernaculum of SAR bats and may result in incidental kill of a small number of bats.</p>

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Terrestrial Environment			
Timeframe: Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↓ Risk	↓ Risk	↓↓ Risk
<p>The existing facility is not known to provide any habitats for animals with the exception of a colony of chimney swifts. The fence around the facility limits animal use of the area, as well as the connectivity of the area.</p> <p>Overall, the facility occupies a small area within the surrounding natural areas.</p>	<p>On-Site: The removal of the above grade facility and the decrease of the area that is fenced in will allow renaturalization of a portion of the site, improve the land connectivity, and decrease the impact on terrestrial communities.</p> <p>As discussed in the Decommissioning Execution timeframe, the ventilation stack will be left in place, and no effects are expected to chimney swifts.</p> <p>Interim Storage at CRL: Effects of stored waste at the CRL Site to the terrestrial environment will be limited by containment.</p> <p>Disposal Activities at CRL: Disposal activities, e.g., handling, transportation, and emplacement, are expected to result in physical nuisance effects (noise, vibration, encroachment) to terrestrial VCs.</p> <p>Final Disposal at CRL: Following final disposal at the CRL site, this waste will be similar to “4. In-Situ Disposal”.</p> <p>Overall: the risk is slightly lower than the baseline.</p>	<p>On-Site: The removal of the facility and fencing will allow renaturalization of the site, improve the land connectivity, and decrease the impact on terrestrial communities.</p> <p>As discussed for the Decommissioning Execution phase, this alternative includes the demolition of the ventilation stack. A replacement habitat would be designed and constructed, and the existing stack would only be removed once the chimney swifts are established in the new habitat. However, there is a risk that chimney swifts do not select the replacement habitat, and that the stack cannot be removed.</p> <p>Interim Storage at CRL: Effects to the terrestrial environment will be limited by containment of waste stored at the CRL Site.</p> <p>Disposal Activities at CRL: Disposal activities, e.g., handling, transportation, and emplacement, are expected to result in physical nuisance effects (noise, vibration, encroachment) to terrestrial VCs.</p> <p>Final Disposal at CRL: Following final disposal at the CRL site, this waste will be similar to “4. In-Situ Disposal”.</p> <p>Overall: the risk is slightly lower than the baseline.</p>	<p>The removal of the above grade facility and the decrease of the fenced area will allow renaturalization of a portion of the site, improve the land connectivity, and decrease the impact on terrestrial communities.</p> <p>As discussed in the Decommissioning Execution timeframe, the ventilation stack will be left in place, and no effects are expected to chimney swifts.</p>

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Terrestrial Environment			
Timeframe: Post-Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↓↓ Risk	↓↓ Risk	↓↓ Risk
<p>Following the loss of institutional control, the facility could be left to degrade. This will continue to have an impact on the terrestrial environment VCs.</p>	<p>Although the waste will be apportioned to two disposal facilities (the NPD disposal facility, and an ILW disposal facility), given that the total inventory is the same, the risk associated with this alternative will be similar to “4. In-Situ Disposal”.</p> <p>Following the cessation of institutional controls, the remaining fencing will likely be removed and the site will eventually renaturalize and be potentially become entirely available for wildlife.</p>	<p>Although the waste will be apportioned to two disposal facilities (for both LLW and ILW), given that the total inventory is the same, the risk associated with this alternative will be similar to “4. In-Situ Disposal”.</p> <p>Following the cessation of institutional controls, the site will continue to renaturalize and potentially become entirely available for wildlife.</p>	<p>Groundwater will flow into the eventually degraded grouted disposal facility on-site. Contaminated groundwater will flow out and eventually into the Ottawa river, which could be transferred to soil (e.g., via irrigation) and terrestrial biota. These releases are expected to be very low, and negligible.</p> <p>Following institutional control, the remaining fencing will likely be removed and the site will eventually renaturalize and potentially become entirely available for wildlife.</p>

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4.3.1.5 Geological and Hydrogeological Environment

Geological and Hydrogeological Environment	
Includes/Excludes	VCs
Includes: <ul style="list-style-type: none"> • Soil Quality (Radiological and Chemical Releases and Concentrations) • Groundwater Quality (Radiological and Chemical Releases and Concentrations) • Groundwater Flow 	Pathway to: <ul style="list-style-type: none"> • Human Health • Non-Human Biota Health • VCs in Other Environmental Components

Timeframe: Decommissioning Execution			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↑ Risk	↑↑ Risk	↑ Risk
Releases to groundwater during SwS are minimal as all water that seeps into the facility is pumped out, and released to surface water after being monitored.	<p>There is a possibility of water leaching some contaminants into the groundwater during the closure processes.</p> <p>During the removal of the reactor system and components there is also the possibility of the soil around the facility being contaminated. This should be minimal and localized to the area directly around the facility, and is therefore not expected to have a large effect.</p>	<p>There is a possibility of water leaching some contaminants into the groundwater during the closure processes.</p> <p>Additionally, the removal of the facility could affect the site groundwater flow patterns, but these effects are not expected to affect the Ottawa River.</p> <p>During the removal of the facility there is also the possibility of the soil around the facility being contaminated.</p>	<p>There is a possibility of water leaching some contaminants into the groundwater during the closure processes.</p>

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Geological and Hydrogeological Environment			
Timeframe: Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↓ Risk	↓ Risk	↓↓ Risk
<p>Releases to groundwater during SwS are minimal as all water that seeps into the facility is pumped out, and released to surface water after being monitored.</p> <p>As the system degrades there is increased possibility of water leaching contamination out of the facility without being monitored.</p>	<p>On-Site: Following the partial dismantling and removal of the facility, the in-situ site will behave similarly to “4. In-Situ Disposal”.</p> <p>Interim Storage at CRL: The emissions during interim storage at the CRL site are expected to be slightly lower than those in “1. Continued SwS” as the waste will be stored in containers, thereby limiting releases.</p> <p>Disposal Activities at CRL: Material handling and transportation will result in emissions, and the resulting deposition may affect soil quality.</p> <p>Final Disposal: the disposed wastes will have a similar risk to “4. In-Situ Disposal”.</p> <p>Overall: This alternative means has slightly lower risk than the baseline case.</p>	<p>On-Site: Following the full dismantling and removal of the facility, there will no longer be any waste on-site. Thus, no impacts to the geological and hydrogeological environment are expected at the NPD site.</p> <p>Interim Storage at CRL: The emissions during interim storage at the CRL site are expected to be slightly lower than those in “1. Continued SwS” as the waste will be stored in containers, thereby limiting releases.</p> <p>Disposal Activities at CRL: Material handling and transportation will result in emissions, and the resulting deposition may affect soil quality.</p> <p>Final Disposal: The disposed wastes will have a similar risk to “4. In-Situ Disposal”.</p> <p>Overall: this alternative means has slightly lower risk than the baseline case.</p>	<p>The concrete cap will reduce the amount of precipitation that infiltrates the facility and hence will reduce the advective flow in the facility. Therefore, the rate of mobilization of contaminants will be reduced compared to the base case. Furthermore, the grout will also reduce the advective flow and will sorb contaminants. The relatively high pH of the grout could enhance the precipitation of some released contaminants (e.g., Pb).</p> <p>The slower release rates will reduce the risk compared to the base case.</p>

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Geological and Hydrogeological Environment			
Timeframe: Post-Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↓↓ Risk	↓↓ Risk	↓↓ Risk
<p>In the Post- Institutional Controls phase, the water will no longer be pumped out, and once water has entered the building it will eventually leach out, potentially carrying contaminants with it.</p> <p>Furthermore, the waste could be released and contaminate the soil around the facility.</p>	<p>Although the waste will be apportioned to two disposal facilities (the NPD disposal facility, and an ILW disposal facility), given that the total inventory is unchanged, the risk associated with this alternative will be similar to “4. In-Situ Disposal”.</p>	<p>Although the waste will be apportioned to two disposal facilities (for both LLW and ILW), given that the total inventory is the unchanged, the risk associated with this alternative will be similar to “4. In-Situ Disposal”.</p>	<p>Similar to the Institutional Controls phase, the cap on the NPD disposal facility will limit water inflow and the grout will delay the release of contaminants.</p>

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4.3.1.6 Radiation and Radioactivity Environment

Radiation and Radioactivity Environment	
Includes/Excludes	VCs
<p>Includes:</p> <ul style="list-style-type: none"> • External Gamma Radiation <p>Excludes:</p> <ul style="list-style-type: none"> • Radioactivity in atmospheric, surface water, aquatic and geological and hydrogeological environments (covered within those components) 	<p>Pathway to:</p> <ul style="list-style-type: none"> • Human Health • Non-Human Biota Health

Timeframe: Decommissioning Execution			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↑↑ Risk	↑↑ Risk	↑ Risk
<p>External gamma fields will continue to be present around the facility, however, these fields are expected to remain low, as they have been in the past (Primeau 2015).</p>	<p>During the active decommissioning of the facility it is possible that the ambient radiation field could be elevated as compared to baseline, due to the removal of the reactor system and components from the building. It is expected that this will be a localized effect though. Specifically, the breaching of the reactor and primary systems could result in much higher ambient radiation fields.</p>	<p>During the active decommissioning of the facility it is possible that the ambient radiation field could be elevated as compared to baseline, due to the removal of the radioactive material from the building. It is expected that this will be a localized effect though. Specifically, the breaching of the reactor and primary systems could result in much higher ambient radiation fields.</p>	<p>During the decommissioning the reactor and primary systems are expected to remain intact, and not be breached. However, the displacement of air via grouting, and release of surface contamination via material sizing will have a minor effect on radiation and radioactivity environment.</p>

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Radiation and Radioactivity Environment			
Timeframe: Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↓ Risk	↓ Risk	↓↓ Risk
<p>As with the Decommissioning Execution timeframe, external gamma fields will continue to be present around the facility, however, these fields are expected to remain low, as they have been in the past (Primeau 2015).</p>	<p>On-site: Following the partial dismantling and removal of the facility, the gamma fields at the NPD site will behave similarly to “4. In-Situ Disposal”.</p> <p>Interim Storage at CRL: It is expected that the gamma fields will be increased relative to “1. Continued SwS”, because there will be less shielding around the reactor system and components (container thickness), however this will be localized to the storage building. Additionally, the multiple handling of waste would increase the external gamma fields.</p> <p>Disposal Activities at CRL: Disposal activities are not expected to result in any changes to radiation and the radioactivity environment.</p> <p>Final Disposal: Following final disposal, this alternative will be similar to “4. In-Situ Disposal”.</p> <p>Overall: the risk from the external gamma fields is expected to be slightly lower than the baseline case.</p>	<p>On-Site: Following the full dismantling and removal of the facility, there will be no radioactive material remaining and therefore the external gamma fields should be reduced to background. Thus, no impacts to radiation and the radioactivity environment are expected at the NPD site.</p> <p>Interim Storage at CRL: it is expected that the gamma fields will be increased relative to “1. Continued SwS”, because there will be less shielding around the reactor system and components (container thickness), however this will be localized to the storage building. Additionally, the multiple handling of waste would increase the external gamma fields.</p> <p>Disposal Activities at CRL: Disposal activities are not expected to result in any changes to radiation and the radioactivity environment.</p> <p>Final Disposal: Following final disposal, this alternative will be similar to “4. In-Situ Disposal”.</p> <p>Overall: the risk from the external gamma fields is expected to be slightly lower than the baseline case.</p>	<p>Once the facility is fully closed the primary effect on external gamma fields will be due to radionuclide emission and accumulation. See discussion in Section 4.3.1.1, 4.3.1.2, and 4.3.1.5.</p> <p>It is expected that the containment offered by this alternative will reduce the external gamma fields relative to baseline.</p>

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Radiation and Radioactivity Environment			
Timeframe: Post-Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↓↓ Risk	↓↓ Risk	↓↓ Risk
<p>Following the loss of institutional control, it is possible that the emissions of radionuclides to the environment could increase as discussed in Section 4.3.1.1, 4.3.1.2, and 4.3.1.5. An increase in the release of radionuclides will likely result in an increase in the external gamma fields as well.</p>	<p>Although the waste will be apportioned to two disposal facilities (the NPD disposal facility, and an ILW disposal facility), the risk associated with the disposed waste will be similar to “4. In-Situ Disposal”.</p>	<p>Although the waste will be apportioned to two disposal facilities (for both LLW and ILW), the risk associated with the disposed waste will be similar to “4. In-Situ Disposal”.</p>	<p>Once the facility is fully closed the primary effect on external gamma fields will be due to radionuclide emission and accumulation. See discussion in Section 4.3.1.1, 4.3.1.2, and 4.3.1.5.</p> <p>It is expected that this alternative will reduce the external gamma fields relative to “1. Continued SwS”.</p>

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4.3.2 Miscellaneous Physical Effects

4.3.2.1 Land Use

Land Use	
Includes/Excludes	VCs
Includes: <ul style="list-style-type: none"> • Land Use in Study Area • Landscape and Visual Setting 	<ul style="list-style-type: none"> • Land Use and Planning Regime • Landscape and Visual Setting

Land Use			
Timeframe: Decommissioning Execution			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	≈ Risk	≈ Risk	≈ Risk
In continuing SwS operations there will be no change to the current land usage. The fencing will remain up, and there will be no public use of the land.	During the active decommissioning it is expected that the land use will not change substantially.	During the active decommissioning it is expected that the land use will not change substantially.	During the active decommissioning it is expected that the land use will not change substantially.

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Land Use			
Timeframe: Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↓ Risk	↓↓ Risk	↓ Risk
<p>In continuing SwS operations there will be no change to the current land usage. The fencing will remain up, and there will be no public use the land.</p>	<p>On-Site: Following the closure of the facility, the fenced area will decrease in size to cover only the decommissioned facility area. The remaining area, specifically the buffer zone, can be released. This will improve land use.</p> <p>Interim Storage at CRL: Land use at the interim storage location will be similar to land use at the base case.</p> <p>Disposal Activities at CRL: Undertaking disposal activities will not change land use at the CRL Site.</p> <p>Final Disposal: Final disposal will not change land use at the CRL Site.</p> <p>Overall: There is a slight benefit to land use at the NPD Site, and no change to land use at the CRL Site.</p>	<p>On-Site: Once the facility has been fully removed, the site will be able to be restored, and could be released.</p> <p>Interim Storage at CRL: Land use at the interim storage location will be similar to land usage in the base case.</p> <p>Disposal Activities at CRL: Undertaking disposal activities will not change land use at the CRL Site.</p> <p>Final Disposal: Final disposal will not change land use at the CRL Site.</p> <p>Overall: There is a benefit to land use at the NPD Site, and no change to land use at the CRL Site.</p>	<p>Following the closure of the facility, the fenced area will decrease in size to cover only the decommissioned facility area. The remaining area, specifically the buffer zone, can be released. This will improve land use. Overall, there is a slight benefit to land use.</p>

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Land Use			
Timeframe: Post-Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↓↓ Risk	↓↓ Risk	↓↓ Risk
<p>As for Institutional Controls, there will be no change from current land usage. The fencing will remain, and there will be limited ability to use the land. However, there will no longer be institutional controls to maintain the boundary.</p>	<p>On-Site: Following the cessation of institutional controls, the land is expected to be released, and all fencing will be removed.</p> <p>Off-Site: At the CRL Site, no changes to land use are expected.</p>	<p>On-Site: As with the Institutional Controls timeframe, the land will be restored, and freely accessible.</p> <p>Off-Site: At the CRL Site, no changes to land use are expected.</p>	<p>Following the cessation of institutional controls, the land is expected to be released, and all fencing will be removed.</p>

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4.3.2.2 Traffic and Transportation

Traffic and Transportation	
Includes/Excludes	VCs
Includes: <ul style="list-style-type: none"> • Transportation System Operation • Transportation System Safety 	<ul style="list-style-type: none"> • Highway 17

Timeframe: Decommissioning Execution			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↑↑ Risk	↑↑ Risk	↑ Risk
There are not any changes expected to the traffic and transportation.	There will be increased traffic on the road due to the increased activity, need for heavy machinery, and transportation of waste to the CRL Site. Members of the public near the transportation routes may be exposed to elevated noise/dust levels as a result of the increased traffic, but this should be small. Specifically, the transportation of the reactor vessel would require special transportation packaging, and may result in traffic limitations during the transportation of the reactor vessel, due to the large size. Furthermore, this activity could result in higher radiation exposures for the public during the transportation.	There will be increased traffic on the road due to the increased activity, need for heavy machinery, and transportation of waste to the CRL Site. Members of the public near the transportation routes may be exposed to elevated noise/dust levels as a result of the increased traffic, but this should be small. Specifically, the transportation of the reactor vessel would require special transportation packaging, and may result in traffic limitations during the transportation of the reactor vessel, due to the large size. Furthermore, this activity could result in higher radiation exposures for the public during the transportation.	There will be increased traffic on the road due to the increased activity, and need for heavy machinery, however, no hazardous materials are expected to be transported.

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Traffic and Transportation			
Timeframe: Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↑ Risk	↑ Risk	≈ Risk
There are not any changes expected to the traffic and transportation.	<p>On-Site: There are no expected effects to traffic during the monitoring period.</p> <p>Off-Site: During disposal activities, there will be increased traffic on the CRL Site between the interim storage location and the final disposal locations. This increases the potential for traffic accidents and other transportation-related risks (i.e., transportation safety related to hazardous substances).</p>	<p>On-Site: There are no expected effects to traffic during the monitoring period.</p> <p>Off-Site: During disposal activities, there will be increased traffic on the CRL Site between the interim storage location and the final disposal locations. This increases the potential for traffic accidents and other transportation-related risks (i.e., transportation safety related to hazardous substances).</p>	There are no expected effects to traffic during the monitoring period.

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Traffic and Transportation			
Timeframe: Post-Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	≈ Risk	≈ Risk	≈ Risk
There are no traffic effects anticipated beyond the institutional control period.	There are no traffic effects anticipated beyond the institutional control period.	There are no traffic effects anticipated beyond the institutional control period.	There are no traffic effects anticipated beyond the institutional control period.

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4.3.2.3 Physical and Cultural Heritage Resources

Physical and Cultural Heritage Resources	
Includes/Excludes	VCs
<p>Includes:</p> <ul style="list-style-type: none"> • Archaeological Resources • Built Heritage/Cultural Landscape • Cultural Resources <p>Excludes:</p> <ul style="list-style-type: none"> • Effects on Indigenous Peoples’ Rights and Interests (See Environmental Component #4.1 (Section 4.3.4.1)) 	No direct VCs identified

Timeframe: Decommissioning Execution			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	≈ Risk	≈ Risk	≈ Risk
<p>There will be no change to the physical and cultural heritage resources.</p>	<p>On-Site: Involves no activity that disturbs any potential underground archaeological resources at the site.</p> <p>There will be no change in risk to built heritage because "the area that will be affected by decommissioning activities has no archaeological potential (Kinickinick Heritage Consulting 2017).</p> <p>Off-Site: It is assumed that the interim storage or final disposal locations at the CRL site have no physical and cultural heritage resources.</p> <p>Therefore, there is no risk to physical and cultural heritage resources.</p>	<p>On-Site: Involves no activity that disturbs any potential underground archaeological resources at the site.</p> <p>There will be no change in risk to built heritage because "the area that will be affected by decommissioning activities has no archaeological potential (Kinickinick Heritage Consulting 2017).</p> <p>Off-Site: It is assumed that the interim storage or final disposal locations at the CRL site have no physical and cultural heritage resources.</p> <p>Therefore, there is no risk to physical and cultural heritage resources.</p>	<p>Involves no activity that disturbs any potential underground archaeological resources at the site.</p> <p>There will be no change in risk to built heritage because "the area that will be affected by decommissioning activities has no archaeological potential (Kinickinick Heritage Consulting 2017).</p>

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Physical and Cultural Heritage Resources			
Timeframe: Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	≈ Risk	≈ Risk	≈ Risk
There will be no change to the physical and cultural heritage resources.	There will be no change to the physical and cultural heritage resources.	There will be no change to the physical and cultural heritage resources.	There will be no change to the physical and cultural heritage resources.

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Physical and Cultural Heritage Resources			
Timeframe: Post-Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↓ Risk	↓ Risk	↓ Risk
<p>As with the Institutional Controls timeframe, there will be no change to physical and cultural heritage resources. The gradual degradation of the facility has no physical or cultural heritage effect.</p>	<p>On-Site: As the location of Canada’s first nuclear power reactor, the site may become recognized as a historical site.</p> <p>Off-Site: It is assumed that the final disposal locations at the CRL site have no physical and cultural heritage resources.</p> <p>Therefore, there is no risk to physical and cultural heritage resources on the CRL site.</p>	<p>On-Site: As the location of Canada’s first nuclear power reactor, the site may become recognized as a historical site.</p> <p>Off-Site: It is assumed that the interim storage and final disposal locations at the CRL site have no physical and cultural heritage resources.</p> <p>Therefore, there is no risk to physical and cultural heritage resources on the CRL site.</p>	<p>As the location of Canada’s first nuclear power reactor, the site may become recognized as a historical site.</p>

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4.3.3 Socioeconomic Effects

4.3.3.1 Socioeconomic Effects

Socioeconomic Effects	
Includes/Excludes	VCs
Includes: <ul style="list-style-type: none"> • Resource/Human Uses of the Land • Physical Assets Exclude <ul style="list-style-type: none"> • Land Use (See Environmental Component #2.1 (Section 4.3.2.1)) 	<ul style="list-style-type: none"> • Walleye • White-tailed deer • Residents – Use/Enjoyment of Property

Timeframe: Decommissioning Execution			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↑ Risk	↑ Risk	↑ Risk
It is anticipated that there will be no change to current socio-economic environment VCs.	The elevated noise and dust from decommissioning activities could negatively impact hunting and trapping surrounding the exclusion zone. However, these effects should be small given the large buffer zone. Proximity of decommissioning activities to the Ottawa River may also facilitate noise disturbance to boating, fishing and recreational activities/sites along the Ottawa River. Potential impacts to non-human biota could result in decreased hunting, fishing, trapping and recreational activities. Please see Section 4.3.5.3 for effects on non-human biota. Overall, this alternative means carries slightly more risk than the baseline case.	The elevated noise and dust from decommissioning activities could negatively impact hunting and trapping surrounding the exclusion zone. However, these effects should be small given the large buffer zone. Proximity of decommissioning activities to the Ottawa River may also facilitate noise disturbance to boating, fishing and recreational activities/sites along the Ottawa River. Potential impacts to non-human biota could result in decreased hunting, fishing, trapping and recreational activities. Please see Section 4.3.5.3 for effects on non-human biota. Overall, this alternative means carries slightly more risk than the baseline case.	The elevated noise and dust from decommissioning activities could negatively impact hunting and trapping surrounding the exclusion zone. However, these effects should be small given the large buffer zone. Proximity of decommissioning activities to the Ottawa River may also facilitate noise disturbance to boating, fishing and recreational activities/sites along the Ottawa River. Potential impacts to non-human biota could result in decreased hunting, fishing, trapping and recreational activities. Please see Section 4.3.5.3 for effects on non-human biota. Overall, this alternative means carries slightly more risk than the baseline case.

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Socioeconomic Effects			
Timeframe: Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↓ Risk	↓ Risk	↓ Risk
<p>It is anticipated that there will be no change to current socio-economic environment VCs, unless there is major change to the emission of contaminants, and therefore an impact on Non-Human Biota.</p>	<p>On-Site: Following the closure of the facility and decrease in the fenced area, the surrounding area can be released. This could result in a slight gain to wildlife habitat, hunting, trapping, recreational opportunities, and potentially to forestry.</p> <p>General: Potential effects to non-human biota, both on-site and at the CRL site, could result in decreased hunting, fishing, trapping and recreational opportunities. However, as discussed in Section 4.3.5.3, the effects on non-human biota are expected to be lower than those for the baseline case, and as such the potential risks to socioeconomic conditions are expected to be lower.</p> <p>Off-Site: Interim storage, transportation, and emplacement and disposal of waste will generate noise and dust, which could negatively impact hunting and trapping surrounding the exclusion zone. However, these effects should be negligible given the large buffer zone.</p> <p>Overall: this alternative means has slightly lower risk than the baseline case.</p>	<p>On-Site: Following the closure of the facility and removal of fencing, the site can be released. This could result in a slight gain in wildlife habitat, hunting, trapping, recreational opportunities, and potentially to forestry.</p> <p>General: Potential effects to non-human biota, both on-site and at the CRL site, could result in decreased hunting, fishing, trapping and recreational opportunities. However, as discussed in Section 4.3.5.3, the effects on non-human biota are expected to be lower than those for the baseline case, and as such the potential risks to socioeconomic conditions are expected to be lower.</p> <p>Off-Site: Interim storage, transportation, and emplacement and disposal of waste will generate noise and dust, which could negatively impact hunting and trapping surrounding the exclusion zone. However, these effects should be negligible given the large buffer zone.</p> <p>Overall: this alternative means has slightly lower risk than the baseline case.</p>	<p>Following the closure of the facility and decrease in the fenced area to cover only the decommissioned facility area, the area around the new licensed site can be released. This could result in a slight gain in wildlife habitat, hunting, trapping, recreational opportunities, and potentially to forestry.</p> <p>Potential effects to non-human biota could result in decreased hunting, fishing, trapping and recreational opportunities. However, as discussed in Section 4.3.5.3, the effects on non-human biota are expected to be lower than those for the baseline case, and as such the potential risks to socioeconomic conditions are expected to be lower.</p> <p>Overall, this alternative means has slightly lower risk than the baseline case.</p>

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Socioeconomic Effects			
Timeframe: Post-Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↓↓ Risk	↓↓ Risk	↓↓ Risk
<p>Effects to non-human biota could result in decreased hunting, fishing, trapping and recreational activities. Please see Section 4.3.5.3 for effects on Non-Human Biota.</p>	<p>Although the waste will be apportioned to two disposal facilities (the NPD disposal facility, and an ILW disposal facility), the combined risk of the disposed waste will be similar to “4. In-Situ Disposal”.</p>	<p>Although the waste will be apportioned to two disposal facilities (for both LLW and ILW), the combined risk of the disposed waste will be similar to “4. In-Situ Disposal”.</p>	<p>Potential effects to non-human biota could result in decreased hunting, fishing, trapping and recreational opportunities. However, as discussed in Section 4.3.5.3, the effects on non-human biota are expected to be much lower than those for the baseline case, and as such the potential risk to socioeconomic conditions is also expected to be much lower.</p> <p>Additionally, once the institutional controls have been removed and the site is released, there may be increases in area for recreational, hunting and trapping activities.</p> <p>Overall the risk to socioeconomic conditions is much lower than that of the baseline case.</p>

4.3.4 Effects on Indigenous Peoples

4.3.4.1 Effects on Indigenous Peoples’ Rights and Interests

Effects on Indigenous Peoples’ Rights and Interests	
Includes/Excludes	VCs
Includes: <ul style="list-style-type: none"> • Indigenous Peoples’ Communities <ul style="list-style-type: none"> ○ First Nations ○ Métis • Traditional Land and Resource Use • Ceremonial Sites and Significant Features 	No direct VCs identified

The Project occurs within a general area of traditional land and resource use for Indigenous peoples.

Timeframe: Decommissioning Execution			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↑ Risk	↑ Risk	↑ Risk
It is anticipated that there will be no effects on Indigenous Peoples’ rights and interests.	The elevated noise and dust from decommissioning activities could result in nuisance effects and negatively impact traditional land use. Potential effects on non-human biota could negatively affect Indigenous Peoples’ traditional land use. Please see Section 4.3.5.3 for effects on non-human biota.	The elevated noise and dust from decommissioning activities result in nuisance effects and negatively impact traditional land use. Potential effects on non-human biota could negatively affect Indigenous Peoples’ traditional land use. Please see Section 4.3.5.3 for effects on non-human biota.	The elevated noise and dust from decommissioning activities could negatively affect traditional land use. Effects on non-human biota could negatively affect Indigenous Peoples’ traditional land use. Please see Section 4.3.5.3 for effects on non-human biota.

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Effects on Indigenous Peoples’ Rights and Interests			
Timeframe: Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↓ Risk	↓ Risk	↓ Risk
<p>It is anticipated that there will be no effects on Indigenous Peoples’ rights and interests.</p>	<p>On-Site: Following the closure of the facility, and decrease in the fenced area, and some of the surrounding area could be released. This could result in a slight benefit to Indigenous Peoples’ traditional land use (e.g. hunting, fishing, trapping, gathering etc.).</p> <p>Off-site: It is expected that Indigenous Peoples’ rights and interests will remain unchanged as a result of interim storage and final disposal at the CRL Site.</p> <p>General: Potential effects on non-human biota could negatively affect Indigenous Peoples’ traditional land use. However, as discussed in Section 4.3.5.3, the effects to non-human biota are expected to be lower than for the baseline case, and as such the potential risk to Indigenous Peoples’ rights and interests is also expected to be lower.</p> <p>Overall: the risk to Indigenous Peoples’ rights and interests is lower than the baseline case.</p>	<p>On-Site: Following the removal of the facility, the site could be released. This could result in a benefit to Indigenous Peoples’ traditional land use (e.g. hunting, fishing, trapping, gathering etc.). The full removal of the facility may alleviate perceptible and intangible impacts to the land (e.g., avoidance of fishing near the NPD site).</p> <p>Off-site: It is expected that Indigenous Peoples’ rights and interests will remain unchanged as a result of interim storage and final disposal at the CRL Site.</p> <p>General: Potential effects on non-human biota could negatively affect Indigenous Peoples’ traditional land use. However, as discussed in Section 4.3.5.3, the effects to non-human biota are expected to be lower than for the baseline case, and as such the potential risk to Indigenous Peoples’ rights and interests is also expected to be lower.</p> <p>Overall: the risk to Indigenous Peoples’ rights and interests is lower than the baseline case.</p>	<p>Following the closure of the facility, and decrease in the fenced area, the surrounding area can be released. This could result in a slight benefit to Indigenous Peoples’ traditional land use (e.g. hunting, fishing, trapping, gathering etc.).</p> <p>Potential effects on non-human biota could negatively affect Indigenous Peoples’ traditional land use. However, as discussed in Section 4.3.5.3 the effects on non-human biota are expected to be lower than those for the baseline case, and as such the potential risk to Indigenous Peoples’ rights and interests is also expected to be lower.</p> <p>Overall the risk to Indigenous Peoples’ rights and interests is lower than the baseline case.</p>

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Effects on Indigenous Peoples’ Rights and Interests			
Timeframe: Post-Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↓↓ Risk	↓↓ Risk	↓↓ Risk
<p>Effects on non-human biota could negatively affect Indigenous Peoples’ traditional land use. Please see Section 4.3.5.3 for effects on Non-Human Biota.</p>	<p>On-Site: Following the cessation of institutional controls, the NPD Site land is expected to be released, and all fencing will be removed. This may increase the area available for Indigenous Peoples’ traditional land use.</p> <p>Off-site: It is expected that Indigenous Peoples’ rights and interests will remain unchanged as a result final disposal at the CRL Site.</p> <p>General: Potential effects on non-human biota could negatively affect Indigenous Peoples’ traditional land use. However, as discussed in Section 4.3.5.3, the effects on non-human biota are expected to be much lower than those for the baseline case during the post-institutional controls phase, and as such the potential risk to Indigenous Peoples’ rights and interests is also expected to be much lower.</p> <p>Overall: the risk to Indigenous Peoples’ rights and interests is much lower than the baseline case.</p>	<p>On-Site: As for the Institutional Controls phase, the NPD Site land will be restored and freely accessible.</p> <p>The full removal of the facility may alleviate perceptible and intangible impacts to the land (e.g., avoidance of fishing near the NPD site).</p> <p>Off-site: It is expected that Indigenous Peoples’ rights and interests will remain unchanged as a result final disposal at the CRL Site.</p> <p>General: Potential effects on non-human biota could negatively affect Indigenous Peoples’ traditional land use. However, as discussed in Section 4.3.5.3, the effects on non-human biota are expected to be much lower than those for the baseline case during the post-institutional controls phase, and as such the potential risk to Indigenous Peoples’ rights and interests is also expected to be much lower.</p> <p>Overall: the risk to Indigenous Peoples’ rights and interests is much lower than the baseline case.</p>	<p>Following the cessation of institutional controls, the NPD Site land is expected to be released, and all fencing will be removed. This may increase the area available for Indigenous Peoples’ traditional land use.</p> <p>Potential effects on non-human biota could negatively affect Indigenous Peoples’ traditional land use. However, as discussed in Section 4.3.5.3, the effects on non-human biota are expected to be much lower than those for the baseline case during the post-institutional controls phase, and as such the potential risk to Indigenous Peoples’ rights and interests is also expected to be much lower.</p> <p>Overall the risk to Indigenous Peoples’ rights and interests is much lower than the baseline case.</p>

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4.3.5 Health Effects

4.3.5.1 Public Health

Public Health	
Includes/Excludes	VCs
<p>Includes:</p> <ul style="list-style-type: none"> • Normal operational exposure of VCs to <ul style="list-style-type: none"> ○ Radiation ○ Chemical Contaminants ○ Noise • Safety <ul style="list-style-type: none"> ○ Malfunctions ○ Accidents ○ Disruptive Events <p>Excludes:</p> <ul style="list-style-type: none"> • Traffic Effects (see Environmental Component #2.1 (Section 4.3.2.1)) 	<ul style="list-style-type: none"> • Human Health

Timeframe: Decommissioning Execution			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↑↑ Risk	↑↑ Risk	↑ Risk
<p>Exposure to the public is not expected to change in this timeframe under normal operation conditions as well as under malfunctions and accidents. For example:</p> <p><u>Earthquake</u>: a design-basis earthquake impact may occur due to the gradual aging of the facility since its construction. However, the likelihood of a beyond-design basis earthquake occurring in the Decommissioning Execution period is negligible, and as such the risk is also negligible.</p>	<p>The removal and preparation of the reactor system and components for transportation, and the grouting of the remaining material in-situ could lead to releases to the geosphere and biosphere, and exposure to the public.</p> <p><u>Earthquake</u>: similar to “1. Continued SwS”.</p> <p><u>Severe Weather</u>: During the active decommissioning phase of the project, this alternative will behave very similarly to “4. In-Situ Disposal”.</p>	<p>The removal and preparation for transportation could lead to releases to the geosphere and biosphere, and exposure to the public.</p> <p><u>Earthquake</u>: similar to “1. Continued SwS”.</p> <p><u>Severe Weather</u>: During the active decommissioning phase of the project, this alternative will behave very similarly to the “4. In-Situ Disposal”.</p> <p>While the likelihood is small, there is the possibility that a tornado or similar event</p>	<p>As a result of the increase in activities taking place on site it is expected that there will be a higher risk of releases to the geosphere and biosphere, and exposure to the public.</p> <p><u>Earthquake</u>: similar to “1. Continued SwS”.</p> <p><u>Severe Weather</u>: During the active decommissioning phase of the project the system could be more susceptible to severe weather, as there is a higher likelihood of the facility being exposed to the weather.</p>

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Timeframe: Decommissioning Execution			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↑↑ Risk	↑↑ Risk	↑ Risk
<p><u>Severe Weather:</u> Extreme weather conditions involve high or low temperatures, excessive humidity, heavy precipitation including rain, snow, ice or hail, strong winds, and severe tornadoes.</p> <p>Extreme temperatures and humidity have no effect on the facility. Extreme precipitation could lead to the potential for flooding or with sufficient snow accumulation, could lead to collapse of the building, however this is highly unlikely. Furthermore, flooding could lead to releases of contaminants and therefore exposure of the VCs to these contaminants.</p> <p>Extreme winds or tornadoes could affect the above ground structures, either directly from the wind, or as a result of projectiles. This is also not expected to be likely due to the reinforced concrete walls and the steel beams supporting the roof.</p>	<p>While the likelihood is small, there is the possibility that a tornado or similar event could impact the waste as it is being transported. Depending on the method of transport this impact could be significant.</p> <p><u>Additional Risks:</u> the removal and breaching of the reactor vessel and other primary systems carries an increased risk of malfunctions and accidents, and could result in a higher exposure of the public.</p> <p>Overall, this option is higher risk than “1. Continued SwS”.</p>	<p>could affect the waste as it is being transported. Depending on the method of transport this effect could be large.</p> <p><u>Additional Risks:</u> the removal and breaching of the reactor vessel and other primary systems carries an increased risk of malfunctions and accidents, and could result in a higher exposure of the public.</p> <p>Overall, this option is higher risk than “1. Continued SwS”.</p>	<p>Specifically, if high winds or heavy precipitation were to occur while the above ground buildings were removed, but before final capping, this could result in increased releases.</p> <p>Overall, this option is slightly higher risk than “1. Continued SwS”.</p>

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Public Health			
Timeframe: Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↓ Risk	↓ Risk	↓↓ Risk
<p>As the facility begins to degrade with time there may be a need for more frequent maintenance, thereby resulting in potentially more releases. This could result in slightly higher exposure of the public.</p> <p><u>Earthquake:</u> as with the Decommissioning Execution phase, the potential impact from a DB earthquake is low, and the likelihood of a BDB earthquake occurring low, and as such the risk is negligible.</p> <p><u>Severe Weather:</u> the impacts of severe weather are the same as in the Decommissioning Execution phase.</p>	<p>On-Site: Following the partial dismantling and removal of the facility, the in-situ site will behave similarly to “4. In-Situ Disposal”.</p> <p>Interim Storage at CRL: During interim storage, the CRL site will have lower risks than “1. Continued SwS” as the waste will be stored in containers, thereby limiting releases.</p> <p>Disposal Activities at CRL: The handling, transportation, and emplacement of waste will increase the risk to public health slightly due to potential releases to the biophysical environment.</p> <p>Final Disposal: Following emplacement and disposal of waste at the CRL site, the risk to public health will be similar to “4. In-Situ Disposal”.</p> <p>Overall: the risk will be similar to “4. In-Situ Disposal”.</p>	<p>On-Site: Following the full dismantling and removal of the facility, there will no longer be any waste on-site. Thus, no impacts to the public health are expected at the NPD site.</p> <p>Interim Storage at CRL: During interim storage, the CRL site will have lower risks than “1. Continued SwS” as the waste will be stored in containers, thereby limiting releases.</p> <p>Disposal Activities at CRL: The handling, transportation, and emplacement of waste will increase the risk to public health slightly due to potential releases to the biophysical environment.</p> <p>Final Disposal: Following emplacement and disposal of waste at the CRL site, the risk to public health will be similar to “4. In-Situ Disposal”.</p> <p>Overall: the risk will be similar to “4. In-Situ Disposal”.</p>	<p>Once the facility has been closed, the risk to human health will be greatly reduced because the contaminant release will be delayed by the grouting.</p> <p><u>Earthquake:</u> If there is an earthquake of sufficient magnitude to damage the grout, there will be some contamination within the grout that will become exposed to groundwater. However, the surface area of these exposed fractures within the grout will be limited compared to an ungrouted source term. The risk, in case of an earthquake will therefore be much lower.</p> <p><u>Severe Weather:</u> with the entire facility being below ground and closed with the concrete cap, the impact of any severe weather will be mitigated to the point that the effects will be negligible.</p> <p>Overall the risk to public health will be much lower than the baseline.</p>

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Public Health			
Timeframe: Post-Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↓↓ Risk	↓↓ Risk	↓↓ Risk
<p>Current baseline exposure (radiation and chemical) is expected to increase with time due to gradual degradation of confinement systems (e.g. concrete walls), seepage of groundwater into the facility and gradual leaching of radionuclides and chemicals into the surrounding geosphere and biosphere. It is assumed that the potential loss of institutional controls in the long term will result in reduced maintenance and hence enhanced degradation with time.</p> <p><u>Earthquake:</u> With continued degradation of the facility with time, and the absence of maintenance activities in the time period beyond institutional controls, the risk will increase (compared to SwS under current conditions) because the facility will become more susceptible to</p>	<p>Although the waste will be apportioned to two disposal facilities (the NPD disposal facility, and an ILW disposal facility), the total inventory is unchanged, and the overall risk of exposure will be similar to “4. In-Situ Disposal”.</p> <p>The Postclosure Safety Assessment (PostSA) considers a scenario which assesses the removal of the reactor from the NPDWF prior to closure (i.e. representative of “2. Partial Dismantling and Removal”). This analysis indicates that, although removal of the reactor and contributing radionuclides results in a potential dose savings to the hunter receptor, the total dose to the site resident is only halved from 4E-05 mSv/yr to 2E-05 mSv/yr, as tritium would continue to be a key dose-contributing radionuclide.</p> <p>The probability of human intrusion is negligibly higher in this</p>	<p>Although the waste will be apportioned to two disposal facilities (for both LLW and ILW), the total inventory is unchanged, and the overall risk of exposure will be similar to “4. In-Situ Disposal”.</p> <p>The probability of human intrusion is negligibly higher in this alternative, due to the need for two disposal sites. This difference is negligible because the additional site is a deep geological repository with a very low probability of inadvertent human intrusion.</p>	<p>The long-term risk will be much lower, because the radionuclides and chemicals are grouted in place, thereby delaying their gradual release to the surrounding geosphere and biosphere. For the radioactive inventory, this additional barrier and associated delay will allow for continued decay within the system thereby reducing the risk of exposure.</p> <p><u>Earthquake:</u> If there is an earthquake of sufficient magnitude to damage the grout, there will be some contamination within the grout that will become exposed to groundwater. However, the surface area of these exposed fractures within the grout will be limited compared to an ungrouted source term. The risk, in case of an earthquake will therefore be much lower.</p>

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<p>structural damage as it degrades. The radioactive inventory however, will gradually decrease with time so that in the very long term, the risk will start to decrease.</p> <p><u>Severe Weather:</u> as the facility degrades it could also become more susceptible to severe weather impairment, and this could result in increased public exposure.</p>	<p>alternative, due to the need for two disposal sites. This difference is negligible because the additional site is a deep geological repository with a very low probability of inadvertent human intrusion.</p>		<p><u>Severe Weather:</u> as with the Institutional Controls phase, the risk of severe weather on the facility is extremely low due to the below ground emplacement and the concrete cap.</p> <p><u>Human Intrusion:</u> the likelihood for inadvertent human intrusion is lower than for ungrouted, above ground facilities due to the increased difficulty in accessing the waste.</p> <p>Overall the risk to public health is much lower than the base case.</p>
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4.3.5.2 Worker Health

Worker Health	
Includes/Excludes	VCs
<p>Includes:</p> <ul style="list-style-type: none"> • Normal operational exposure of VCs to <ul style="list-style-type: none"> ○ Radiation ○ Chemical Contaminants ○ Noise • Safety <ul style="list-style-type: none"> ○ Malfunctions ○ Accidents <p>Excludes:</p> <ul style="list-style-type: none"> • Traffic Effects (see Environmental Component #2.1 (Section 4.3.2.1)) 	<ul style="list-style-type: none"> • Human Health

Timeframe: Decommissioning Execution			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↑↑ Risk	↑↑ Risk	↑ Risk
<p>Current baseline exposure (radiation and chemical) is expected to continue at current levels during this timeframe.</p> <p><u>Earthquake</u>: the effects of earthquakes will be the same as described in public health for this timeframe.</p> <p><u>Severe Weather</u>: the effects of Severe Weather will also be the same as described in public health for this timeframe.</p> <p><u>Operational Impairment</u>: The regular maintenance and other activities, coupled with the age of the structures</p>	<p>The removal and preparation of the reactor system and components for transportation will lead to increased risk for high exposure to radiation.</p> <p>Demolition and grouting of remaining structures will increase exposure to chemicals, noise and dust.</p> <p>An estimated collective dose to perform this alternative is 300 person•mSv.</p> <p><u>Earthquake</u>: similar to "1. Continued SwS".</p> <p><u>Severe Weather</u>: During the active</p>	<p>The removal and preparation for transportation will lead to increased risk for high exposure to radiation, chemicals, noise and dust.</p> <p>Sorting waste into LLW and ILW for eventual storage and disposal will also result in an increase to worker dose. An estimated collective dose to perform this alternative is 761 person•mSv.</p> <p><u>Earthquake</u>: similar to "1. Continued SwS".</p> <p><u>Severe Weather</u>: During the active decommissioning phase of the project, this alternative will behave</p>	<p>As a result of the increase in activities taking place on site it is expected that there will be a higher risk of exposure to both radioactive material and chemicals.</p> <p>An estimated collective dose to perform this alternative is 14.7 person•mSv.</p> <p><u>Earthquake</u>: the effects of earthquakes will be the same as described in public health for this timeframe.</p> <p><u>Severe Weather</u>: the effects of Severe Weather will also be the same as described</p>

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Timeframe: Decommissioning Execution			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↑↑ Risk	↑↑ Risk	↑ Risk
<p>leaves the possibility for operational impairments (e.g. spills)</p>	<p>decommissioning phase of the project, this alternative will behave very similarly to “4. In-Situ Disposal”.</p> <p><u>Operational Impairment:</u> At the NPD site the risk of operational impairment will be higher than the baseline during this timeframe.</p> <p>At the storage site the risk will be slightly higher than “1. Continued SwS”, due to the operations associated with placing the waste into storage.</p> <p>It is worth noting that the transportation of waste carries some increase in risk as well.</p> <p>In addition to the risks discussed above, there is also the risk of industrial accidents, specifically given the extensive rigging and lifting that will be required. These activities carry significant risks to worker.</p> <p>Overall the risk is much larger than the baseline.</p>	<p>very similarly to “4. In-Situ Disposal”.</p> <p><u>Operational Impairment:</u> At the NPD site the risk of operational impairment will be higher than the baseline during this timeframe.</p> <p>At the storage site the risk will be slightly higher than “1. Continued SwS”, due to the operations associated with placing the waste into storage.</p> <p>It is worth noting that the transportation of waste carries some increase in risk as well.</p> <p>In addition to the risks discussed above, there is also the risk of industrial accidents, specifically given the extensive rigging and lifting that will be required. These activities carry significant risks to worker.</p> <p>Overall the risk is much larger than the baseline.</p>	<p>in public health for this timeframe.</p> <p><u>Operational Impairment:</u> during this timeframe, the risk from operational impairment is larger than the baseline, as a result of the increased activities.</p>

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Worker Health			
Timeframe: Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↓ Risk	↓ Risk	↓↓ Risk
<p>Current baseline exposure (radiation and chemical) is expected to increase with time due to increased need for maintenance and gradual degradation of confinement systems (e.g., concrete walls)</p> <p><u>Earthquake</u>: the effects of earthquakes will be the same as described in public health for this timeframe.</p> <p><u>Severe Weather</u>: the effects of severe weather will also be the same as described in public health for this timeframe.</p> <p><u>Operational Impairment</u>: The regular maintenance and other activities, coupled with the age of the structures leaves the possibility for operational impairments (e.g., spills)</p>	<p>On-Site: Following the partial dismantling and removal of the facility, effects to worker health at the in-situ site will be similar to “4. In-Situ Disposal”.</p> <p>Interim Storage and Disposal Activities: It is assumed that the waste is made ready for disposal during the Decommissioning Execution phase, thus, there are only minor dose implications to workers in this phase.</p> <p><u>Operational Impairment:</u> At the storage site there will be risks higher than those for “1. Continued SwS”.</p> <p>Final Disposal: Following disposal, the risk to worker health will be similar to “4. In-Situ Disposal”.</p>	<p>On-Site: With the entire facility removed, the risks will be limited to storage/disposal at the CRL site.</p> <p>Interim Storage and Disposal Activities: It is assumed that the waste is made ready for disposal (including sorting) during the Decommissioning Execution phase, thus, there are only minor dose implications to workers in this phase.</p> <p><u>Operational Impairment:</u> At the storage site there will be risks higher than those for “1. Continued SwS”.</p> <p>Final Disposal: Following disposal, the risk to worker health will be similar to “4. In-Situ Disposal”.</p>	<p>Once the facility is closed and capped, there will be very few workers present, with the exception of environmental monitoring, and potentially occasional security inspections. It is expected that the exposure will be minimal.</p> <p><u>Earthquake</u>: the effects of earthquakes will be the same as described in public health for this timeframe.</p> <p><u>Severe Weather</u>: the effects of severe weather will also be the same as described in public health for this timeframe.</p> <p><u>Operational Impairment:</u> during this timeframe, there will be limited, or no, risk from operational impairment, as the only operations taking place are the monitoring of the environment.</p>

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Worker Health			
Timeframe: Post-Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↑ Risk	↑ Risk	≈ Risk
As there are not expected to be workers present at the NPD site beyond 100 years, no health effects are expected.	<p>On-Site: As there are not expected to be workers present at the NPD site beyond 100 years, no health effects are expected.</p> <p>Off-Site: Once the disposal facilities at CRL are closed and capped, long-term care, maintenance, and monitoring activities at the CRL site are expected to continue into this phase. There will be very few workers present, and worker exposure will be minimal.</p>	<p>On-Site: As there are not expected to be workers present at the NPD site beyond 100 years, no health effects are expected.</p> <p>Off-Site: Once the disposal facilities at CRL are closed and capped, long-term care, maintenance, and monitoring activities at the CRL site are expected to continue into this phase. There will be very few workers present, and worker exposure will be minimal.</p>	As there are not expected to be workers present at the NPD site beyond 100 years, no health effects are expected.

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4.3.5.3 Non-Human Biota

Non-Human Biota	
Includes/Excludes	VCs
<p>Includes:</p> <ul style="list-style-type: none"> • Normal operational exposure of VCs to <ul style="list-style-type: none"> ○ Radiation ○ Chemical Contaminants ○ Noise • Safety <ul style="list-style-type: none"> ○ Malfunctions ○ Accidents ○ Disruptive Events <p>Excludes:</p> <ul style="list-style-type: none"> • Traffic Effects (see Environmental Component #2.1 (Section 4.3.2.1)) 	<p>Non-Human Biota (See Table 3-1)</p> <ul style="list-style-type: none"> • Terrestrial Vegetation • Soil Invertebrates • Birds • Mammals • Amphibians and Reptiles • Aquatic plants • Benthic invertebrates • Fish

Timeframe: Decommissioning Execution			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↑↑ Risk	↑↑ Risk	↑ Risk
<p>The risk of exposure for non-human biota is not expected to change in this timeframe under normal operation conditions, or under other events, for example:</p> <p><u>Earthquake:</u> a design-basis earthquake effect may occur due to the gradual aging of the facility since its construction. However, the likelihood of a beyond-design-basis earthquake occurring in the Decommissioning Execution phase is negligible, and as such the risk is also negligible.</p> <p><u>Severe Weather:</u> Extreme weather</p>	<p>The removal and preparation of the reactor system and components for transportation, and the grouting of the remaining material in-situ could lead to releases to the geosphere and biosphere, and exposure to non-human biota.</p> <p><u>Earthquake:</u> similar to “1. Continued SwS”.</p> <p><u>Severe Weather:</u> During the active decommissioning phase of the project, this alternative will behave very similarly to “4. In-Situ Disposal”.</p>	<p>The removal and preparation for transportation could lead to releases to the geosphere and biosphere, and exposure to non-human biota.</p> <p><u>Earthquake:</u> similar to “1. Continued SwS”.</p> <p><u>Severe Weather:</u> During the active decommissioning phase of the project, this alternative will behave very similarly to “4. In-Situ Disposal”.</p> <p>While the likelihood is small, there is the possibility that a tornado or similar event could affect the waste as it is being</p>	<p>As a result of the increase in activities taking place on site it is expected that there will be a higher risk of releases to the geosphere and biosphere, and exposure to non-human biota.</p> <p><u>Earthquake:</u> similar to “1. Continued SwS”.</p> <p><u>Severe Weather:</u> During the active decommissioning phase of the project the system could be more susceptible to severe weather, as there is a higher likelihood of the facility being exposed to the weather.</p>

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Timeframe: Decommissioning Execution			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↑↑ Risk	↑↑ Risk	↑ Risk
<p>conditions involve high or low temperatures, excessive humidity, heavy precipitation including rain, snow, ice or hail, strong winds, and severe tornadoes.</p> <p>Extreme temperatures and humidity have no impact on the facility. Extreme precipitation could lead to the potential for flooding or with sufficient snow accumulation, could lead to collapse of the building, however this is highly unlikely. Furthermore, flooding could lead to releases of contaminants and therefore exposure of the VCs to these contaminants.</p> <p>Extreme winds or tornadoes could impact the above ground structures, either directly from the wind, or as a result of projectiles. This is also not expected to be likely due to the reinforced concrete walls and the steel beams supporting the roof.</p>	<p>While the likelihood is small, there is the possibility that a tornado or similar event could affect the waste as it is being transported. Depending on the method of transport this effect could be large.</p> <p><u>Additional Risks:</u> the removal and breaching of the reactor vessel and other primary systems carries an increased risk of malfunctions and accidents, and could result in a higher exposure to Non-Human Biota.</p> <p>Overall, this option is higher risk than “1. Continued SwS”.</p>	<p>transported. Depending on the method of transport this effect could be large.</p> <p><u>Additional Risks:</u> the removal and breaching of the reactor vessel and other primary systems carries an increased risk of malfunctions and accidents, and could result in a higher exposure to Non-Human Biota.</p> <p>Overall, this option is higher risk than “1. Continued SwS”.</p>	<p>Specifically, if high winds or heavy precipitation were to occur while the above ground buildings were removed, but before final capping, this could result in increased releases.</p> <p>Overall, this option is slightly higher risk than “1. Continued SwS”.</p>

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Non-Human Biota			
Timeframe: Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↓ Risk	↓ Risk	↓↓ Risk
<p>As the facility begins to degrade with time there may be a need for more frequent maintenance, thereby resulting in potentially more releases. This could result in slightly higher exposure of the non-human biota.</p> <p><u>Earthquake</u>: as with the Decommissioning Execution timeframe, the potential effect from a DB earthquake is low, and the likelihood of a BDB earthquake occurring low, and as such the risk is negligible.</p> <p><u>Severe Weather</u>: the effects of severe weather are the same as in the Decommissioning Execution timeframe.</p>	<p>On-Site: Following the partial dismantling and removal of the facility, the in-situ site will behave similarly to “4. In-Situ Disposal”.</p> <p>Interim Storage at CRL: During interim storage, the CRL site will have lower risk than “1. Continued SwS” as the waste will be stored in the containers, thereby limiting releases to the environment.</p> <p>Disposal Activities at CRL: The handling, transportation, and emplacement of waste will increase the risk to non-human biota health slightly due to the potential releases to the biophysical environment.</p> <p>Interim Storage at CRL: Following emplacement and disposal of waste at the CRL site, the risk to non-human biota health will be similar to “4. In-Situ Disposal”.</p> <p>Overall: the risk will be slightly lower than “1. Continued SwS”</p>	<p>On-Site: Following the full dismantling and removal of the facility, there will no longer be any waste on-site. Thus, no impacts to the non-human biota are expected at the NPD site.</p> <p>Interim Storage at CRL: During interim storage, the CRL site will have lower risk than “1. Continued SwS” as the waste will be stored in containers, thereby limiting releases to the environment.</p> <p>Disposal Activities at CRL: The handling, transportation, and emplacement of waste, will increase the risk to non-human biota health slightly due to the potential releases to the biophysical environment.</p> <p>Final Disposal: Following emplacement and disposal of waste at the CRL site, the risk to public health will be similar to “4. In-Situ Disposal”.</p> <p>Overall: the risk will be slightly lower than “1. Continued SwS”.</p>	<p>Once the facility has been closed, the risk to non-human biota will be greatly reduced because the contaminant release will be delayed by the grouting.</p> <p><u>Earthquake</u>: If there is an earthquake of sufficient magnitude to damage the grout, there will be some contamination within the grout that will become exposed to groundwater. However, the surface area of these exposed fractures within the grout will be limited compared to an ungrouted source term. The risk, in case of an earthquake will therefore be much lower.</p> <p><u>Severe Weather</u>: with the entire facility being below ground and closed with the concrete cap, the effect of any severe weather will be mitigated to the point that the effects will be negligible.</p> <p>Overall the risk to non-human biota will be much lower than the baseline.</p>

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Non-Human Biota			
Timeframe: Post-Institutional Controls			
1. Continued SwS	2. Partial Dismantling and Removal	3. Full Dismantling and Removal	4. In-Situ Disposal
Baseline	↓↓ Risk	↓↓ Risk	↓↓ Risk
<p>Current baseline exposure (Radiation and chemical) is expected to increase with time due to gradual degradation of confinement systems (e.g., concrete walls), seepage of groundwater into the facility and gradual leaching of radionuclides and chemicals into the surrounding geosphere and biosphere. It is assumed that the potential loss of institutional controls in the long term will result in reduced maintenance and hence enhanced degradation with time.</p> <p><u>Earthquake:</u> With continued degradation of the facility with time, and the absence of maintenance activities in the time period beyond institutional controls, the risk will increase (compared to SwS under current conditions) because the facility will become more susceptible to</p>	<p>Although the waste will be apportioned to two disposal facilities (the NPD disposal facility and an ILW disposal facility), the total inventory is unchanged, and the overall risk of exposure for non-human biota is the same as “4. In-Situ Disposal”.</p>	<p>Although the waste will be apportioned to two disposal facilities (for both LLW and ILW), the total inventory is unchanged, and the overall risk of exposure for non-human biota is the same as “4. In-Situ Disposal”.</p>	<p>The long-term risk will be much lower, because the radionuclides and chemicals are grouted in place, thereby delaying their gradual release to the surrounding geosphere and biosphere. For the radioactive inventory, this additional barrier and associated delay will allow for continued decay within the system thereby reducing the risk of exposure.</p> <p><u>Earthquake:</u> If there is an earthquake of sufficient magnitude to damage the grout, there will be some contamination within the grout that will become exposed to groundwater. However, the surface area of these exposed fractures within the grout will be limited compared to an ungrouted source term. The risk, in case of an earthquake will therefore be much lower.</p>

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<p>structural damage as it degrades. The radioactive inventory however, will gradually decrease with time so that in the very long term, the risk will start to decrease.</p> <p><u>Severe Weather:</u> as the facility degrades it could also become more susceptible to severe weather impairment, and this could result in increased Non-Human Biota exposure.</p> <p><u>Glaciation:</u> Glaciation is not expected to occur within the next 100,000 years, however, regardless of when it occurs it is expected that the facility would be spread over a large area, thereby exposing any remaining contaminants to the environment. (Arcadis and Quintessa 2017).</p>			<p><u>Severe Weather:</u> as with the Institutional Controls phase, the risk of severe weather on the facility is extremely low due to the below ground emplacement and the concrete cap.</p> <p><u>Glaciation:</u> During glaciation, it is likely that even the grouted below grade facility would be distributed, however, the emplacement within the bedrock, and the grout fill may mitigate some damage.</p> <p>Overall the risk to Non-Human Biota is much lower than the base case.</p>
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4.3.6 Dose and Injury to Workers During Decommissioning

4.3.6.1 Radiological dose to workers

For the Decommissioning Execution phase, an estimate of the collective dose to perform the alternate of full dismantling and removal has been performed (McVeigh 2018). The dose estimates have been made using the same level of detail and similar assumptions as the Detailed Decommissioning Plan (Aikens 2019). The collective dose estimate for the “3. Full Dismantling and Removal” is 761 person•mSv, which is approximately 50 times greater than the Detailed Decommissioning Plan dose estimate of 14.7 person•mSv for “4. In-Situ Disposal”. The estimated collective dose for removal of the calandria alone is on the order of 300 person•mSv based on the breakdown of work packages that would need to be executed. The worker dose estimate for “3. Full Dismantling and Removal” is only for the Decommissioning Execution phase and does not include the Institutional Controls phase where workers would receive doses during re-handling and packaging of this waste during transition from storage to disposal.

Based on these scoping calculations, the dose benefits to workers in alternative “4. In-Situ Disposal” are more significant than the minimal dose benefit to the public in alternatives “2. Partial Dismantling and Removal” and “3. Full Dismantling and Removal”. Ultimately the assessment undertaken in this report remains unchanged with consideration of the potential availability of a deep geologic repository.

4.3.6.2 Injury to workers

Safety is a core value at CNL; a safety culture governs the actions of all activities undertaken. Despite this emphasis on safety, it is possible that some injuries will occur, and that some injuries may occur, resulting in lost-time, or even fatality, during the Decommissioning Execution phase. The statistics for construction, demolition, and trucking accidents indicate that injuries are a fairly common part of working in these industries, regardless of efforts to prevent and mitigate against injury.

CNL will minimize the quantity and magnitude of these incidents as much as possible using safe work practices. Procedures and programs will be in place to ensure safe working conditions and compliance with provincial health and safety regulations. CNL requires that contractors and their subcontractors maintain a level of safety equivalent to that of CNL employees while on-site to ensure that the site preparation and construction activities at NPD are carried out safely.

Work activities carried out within the province of Ontario are subject to the Occupational Health and Safety Act. The main purpose of the Act is to protect workers from health and safety hazards on the job. The Act imposes duties on employers and workers, and establishes and enforces rights for workers and procedures for dealing with workplace hazards.

The Infrastructure Health & Safety Association (IHSA) publishes injury rates associated with different sectors. Activities during the Decommissioning Execution phase were assigned to the relevant sector for which IHSA injury rates were available: demolition, industrial, commercial & institutional construction, and general trucking. Using the projected duration of Decommissioning Execution activities, and the sector-specific rates for lost-time and non-lost time injuries, and traumatic fatalities, the estimated number of injuries for each alternative was calculated (Table 4.3-1).

Table 4.3-1 Estimated Number of Injuries for each Alternative

Alternative Means	Estimated number of injuries			
	Lost-time injuries	Non-lost time injuries	Traumatic fatalities	Total
1. Continued SwS	0.00	0.00	0.00	0.00
2. Partial Dismantling	6.0E-01	2.3E+00	4.2E-03	2.88
3. Full Dismantling	1.2E+00	4.4E+00	8.3E-03	5.61
4. In-Situ Disposal	1.9E-01	7.8E-01	1.4E-03	0.97

The estimated number of injuries for the “3. Full Dismantling and Removal” is 5.61, which is over 5 times greater than the estimate of 0.97 for “4. In-Situ Disposal”, and approximately two-fold higher than “2. Partial Dismantling”. The estimated number of injuries is directly linked with the duration of activities (i.e., extent of effort) in the Decommissioning Execution phase.

It is expected that the rates of injury or fatality for employees working during the Decommissioning Execution phase will be similar to those at other construction sites for jobs of similar duration and complexity in Ontario. Therefore, if the workers were not employed at the NPD site, they would be exposed to similar risk at another construction site within the province.

4.4 Identification of Preferred Means

4.4.1 Relative Risk

A set of summary tables was prepared to more easily compare the relative risk and effects of the four alternatives for all of the environmental components and VCs. Table 4.4-1 to Table 4.4-3 below show the relative risk assessment from all of the analysis in three tables, one for each timeframe.

As for previous tables, the risk symbols have been colour-coded, see Table 4.2-1 above.

The differences between alternatives is seen in the Decommissioning Execution timeframe are pronounced. All of the alternatives carry increased risk relative to the baseline case, “1. Continued SwS”. This is due to the increase in activity associated with each of the options. It can also be seen that while “4. In-Situ Disposal” does have a higher risk than the baseline case, it is lower than the “2. Partial Dismantling and Removal” and “3. Full Dismantling & Removal” for almost all of the environmental components. This is due to the increased extent and effort associated with “2. Partial Dismantling and Removal” and “3. Full Dismantling & Removal”, and therefore increased emissions and risk to the atmospheric and surface water environments. Furthermore, the increased effort results in additional worker dose and exposure, and potential for accidents. Thus, “4. In-Situ Disposal” offers a lower risk to worker health and the environment.

The differences between the alternative means are still pronounced in the Institutional Controls phase. Overall, all alternatives now carry a reduced risk relative to the baseline case, “1. Continued SwS”. Mainly, this is because additional containment provided by these alternatives. This reduction is most pronounced

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for the “4. In-Situ Disposal” alternative because of the additional containment relative to the interim storage in alternatives “2. Partial Dismantling and Removal” and “3. Full Dismantling and Removal”. The dismantling and removal alternatives offer increased containment once the waste is permanently disposed, however in the Institutional Controls phase, this is offset by the increased activity associated with maintenance and disposal activities (e.g., transportation, multiple handling, emplacement).

Finally, in the Post- Institutional Controls timeframe, all alternatives have a reduced risk relative to the baseline case due to the containment provided as part of permanent disposal. In general, there is little difference between alternatives, as the final disposal options are all considered safe, and would have been subject to a robust regulatory regime to attain approval. The only difference between the alternatives is seen for worker health, as long-term care, maintenance, and monitoring activities are expected to continue into the Post-Institutional Controls timeframe at the off-site disposal locations. When looking at the probability of inadvertent human intrusion into the disposal sites, there is a slight difference between “4. In-Situ Disposal” and the dismantling alternatives “2. Partial Dismantling and Removal” and “3. Full Dismantling and Removal”. The probability of human intrusion is negligibly higher in the dismantling alternatives, due to the need for two disposal sites, instead of one disposal site in “4. In-Situ Disposal”. This difference is negligible because the additional site is a deep geological repository with a very low probability of inadvertent human intrusion.

Table 4.4-1 Summary of Relative Risk for Decommissioning Execution Timeframe

Alternative Means	Environmental Components														
	Environmental Effects						Miscellaneous Physical Effects			Socio-economic Effects	Effects on Indigenous People	Health Effects (Normal)			
	Atmospheric Environment	Surface Water Environment	Aquatic Environment	Terrestrial Environment	Geological and Hydrogeological Environment	Radiation and Radioactivity Environment	Land Use	Traffic and Transportation	Physical and Cultural Heritage Resources	Socioeconomic Effects	Effects on Indigenous Peoples' Rights and Interests	Public Health	Worker Health	Non-Human Biota	
1. Continued SWS	Baseline														
2. Partial Dismantling and Removal	↑↑	↑↑	≈	↑↑	↑	↑↑	≈	↑↑	≈	↑	↑	↑↑	↑↑	↑↑	
3. Full Dismantling and Removal	↑↑	↑↑	≈	↑↑	↑↑	↑↑	≈	↑↑	≈	↑	↑	↑↑	↑↑	↑↑	
4. In-Situ Disposal	↑	↑	≈	↑↑	↑	↑	≈	↑	≈	↑	↑	↑	↑	↑	

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Table 4.4-2 Summary of Relative Risk for Institutional Controls Phase

Alternative Means	Environmental Components													
	Environmental Effects						Miscellaneous Physical Effects			Socio-economic Effects	Effects on Indigenous People	Health Effects (Normal)		
	Atmospheric Environment	Surface Water Environment	Aquatic Environment	Terrestrial Environment	Geological and Hydrogeological Environment	Radiation and Radioactivity Environment	Land Use	Traffic and Transportation	Physical and Cultural Heritage Resources	Socioeconomic Effects	Effects on Indigenous Peoples' Rights and Interests	Public Health	Worker Health	Non-Human Biota
1. Continued SWS	Baseline													
2. Partial Dismantling and Removal	↓	↓	≈	↓	↓	↓	↓	↑	≈	↓	↓	↓	↓	↓
3. Full Dismantling and Removal	↓	↓	≈	↓	↓	↓	↓↓	↑	≈	↓	↓	↓	↓	↓
4. In-Situ Disposal	↓↓	↓↓	≈	↓↓	↓↓	↓↓	↓	≈	≈	↓	↓	↓↓	↓↓	↓↓

Table 4.4-3 Summary of Relative Risk for Post-Institutional Controls Timeframe

Alternative Means	Environmental Components													
	Environmental Effects						Miscellaneous Physical Effects			Socio-economic Effects	Effects on Indigenous People	Health Effects (Normal)		
	Atmospheric Environment	Surface Water Environment	Aquatic Environment	Terrestrial Environment	Geological and Hydrogeological Environment	Radiation and Radioactivity Environment	Land Use	Traffic and Transportation	Physical and Cultural Heritage Resources	Socioeconomic Effects	Effects on Indigenous Peoples' Rights and Interests	Public Health	Worker Health	Non-Human Biota
1. Continued SWS	Baseline													
2. Partial Dismantling and Removal	↓↓	↓↓	↓↓	↓↓	↓↓	↓↓	↓↓	≈	↓	↓↓	↓↓	↓↓	↑	↓↓
3. Full Dismantling and Removal	↓↓	↓↓	↓↓	↓↓	↓↓	↓↓	↓↓	≈	↓	↓↓	↓↓	↓↓	↑	↓↓
4. In-Situ Disposal	↓↓	↓↓	↓↓	↓↓	↓↓	↓↓	↓↓	≈	↓	↓↓	↓↓	↓↓	≈	↓↓

4.4.2 Additional Considerations

4.4.2.1 Absolute Risk

In addition to relative risk, the alternative means were also compared with respect to absolute risk. This is to ensure that if a negligible risk, of alternative means X, is deemed to be higher than an even smaller risk, of alternative means Y, that it does not give undue credibility to alternative means Y. Similarly, if alternative means X is deemed to have less risk than alternative means Y, but both alternative means carry a significant risk to the environment, alternative means X cannot be considered as a good option, as it will still have significant environmental effects, regardless of how it compares to alternative means Y.

The main differences between the alternative means are related to:

- 1) The increased effort (e.g., material handling, transportation), emissions, and releases associated with the “2. Partial Dismantling and Removal” and “3. Full Dismantling and Removal” alternatives
- 2) The immediate disposal in “4. In-Situ Disposal” which eliminates susceptibility to low probability malfunctions and accidents.

First, despite differences in effort, emissions, and releases, all alternatives would be fundamentally safe. This is because all alternatives would be subject to a robust regulatory regime and undertaken with measures to ensure safety. For example, by ensuring that work is undertaken in compliance with work control documents and radiation protection protocols, worker doses for all alternatives would be maintained well below relevant dose criteria. Similarly, the hypothetical disposal facilities (e.g., the ILW and LLW disposal facilities) can be assumed to be safe, because the approval of such facilities would be contingent on regulatory approval.

Second, although two alternatives require interim storage prior to the availability of the appropriate disposal facilities, this storage will be safe. During interim storage, it is expected that maintenance activities will ensure the integrity of the containment, and will ensure that releases carry no undue risk, under normal operating conditions.

4.4.2.2 Timely Reduction of Legacy Liability

In addition to the relative and absolute risk assessments discussed above, there is one final consideration in the selection of a preferred means. As stated in the problem statement, Section 1.2, one of the major concerns of this project is the timely reduction of Canada’s Nuclear Legacy Liability. Based on the assessments throughout this report it can be seen that “1. Continued SwS” does not provide any reduction to the legacy liability. “2. Partial Dismantling and Removal” provides a reduction in the legacy liability, as some of the waste has been packaged moved to CRL for storage and eventual disposal, and the remaining waste is grouted securely in place. Similarly, “3. Full Dismantling and Removal” provides will provide a reduction in the legacy liability, as the waste has been packaged moved to CRL for storage and eventual disposal. For both of these alternative means, the interim storage of waste and reliance on the eventual approval and construction of disposal facilities for LLW and ILW limit the timely reduction of legacy liability.

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“4. In-Situ Disposal” succeeds in providing timely reduction of the legacy liability by immediately securing the contamination within the grouted monolith. This alternative means is the only feasible alternative means identified that most significantly reduces the legacy liability in a timely manner.

4.4.3 Preferred Means

Based on the comparison of the relative risk to the environmental VCs, absolute risk to the environmental VCs, and additional consideration, “4. In-Situ Disposal” has been found to be the preferred means for completing this project. A quantitative assessment of environmental effects to the VCs is underway as part of a Decommissioning Safety Assessment (DecomSA) (Arcadis 2019a), Postclosure Safety Assessment (PostSA) (Arcadis and Quintessa 2019), and Ecological Risk Assessment (EcoRA) (Arcadis 2019b) for “4. In-Situ Disposal”.

5.0 SUMMARY

This section provides Step #4 of the CEAA Operational Policy Statement: Addressing “Purpose of” and “Alternative Means” under the Canadian Environmental Assessment Act, 2012 (CEAA 2015).

The decommissioning of the NPDWF has been proposed using the In-Situ Disposal approach as discussed in Section 2.2, triggering an EA. An alternative means assessment is a required input to the EIS as defined in the CEAA 2012, the CNSC “Generic Guidelines for the Preparation of an Environmental Statement”, REGDOC 2.9.1, and the CEAA Operational Policy Statement: Addressing “Purpose of” and “Alternative Means” under the *Canadian Environmental Assessment Act, 2012* (CEAA 2015). This report provides the alternative means assessment for the decommissioning of the NPDWF. The objective of this report is to provide a qualitative analysis of the environmental risks (including health) of alternative decommissioning techniques, as specified in the Project Description (Titterington 2016). The alternative means for decommissioning that are provided in the Project Description and have been considered for this project are (Titterington 2016):

1. Continued Storage with Surveillance (SwS)
2. Partial Dismantling and Removal
3. Full Dismantling and Removal
4. In-Situ Disposal

Each of these four alternative means are described in more detail below, along with a pictographic representation of the approach.

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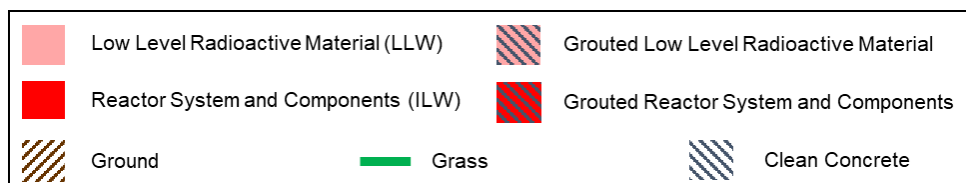
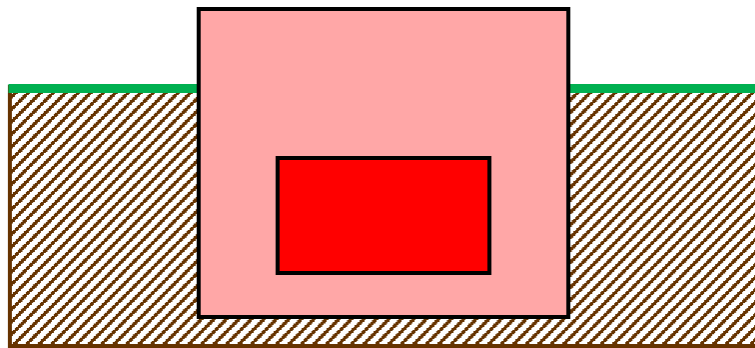
1. Continued Storage with Surveillance (SwS)

“Continue with a deferred decommissioning approach which includes maintaining the NPDWF in the Storage with Surveillance phase to allow for further radioactive decay.” (Titterington 2016)

For this analysis it has been assumed that this approach involves continuing to defer decommissioning by maintaining the NPDWF in the SwS phase, thereby allowing for further radioactive decay. This will involve continued maintenance, monitoring and yearly reporting in the form of annual compliance reports. Specific activities may change over time as the state of the facility changes.

Continued SwS serves as a baseline case against which the other alternative means are compared.

NPD Site



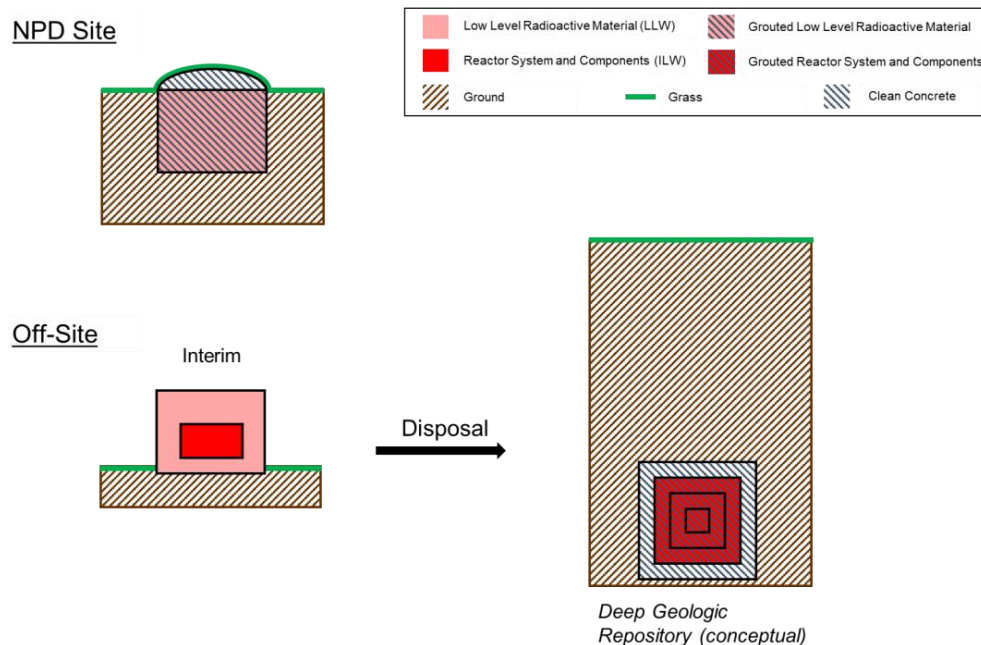
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2. Partial Dismantling and Removal

“Partial removal of the source term (i.e., reactor systems and components) for interim storage at the Chalk River Laboratories (CRL) site until the waste undergoes final disposal at the CRL site. The remaining facility systems, structures and components will remain in-situ.” (Titterington 2016)

This alternative means is a combination of the in-situ disposal and full removal alternatives, and involves removal of the reactor system and components. The feeders, pressure tubes, calandria tubes, calandria and associated bioshielding will be removed, and the fuel handling room will be decommissioned. This waste would be packaged in containers for transport and storage. Additionally, a few drums of waste from the spent fuel bay cleanup would likely also be removed. This waste would be temporarily stored at the CRL site, prior to final disposal. It is assumed that a disposal facility for ILW will become available at CRL at some point during the Institutional Controls phase. Activities associated with the construction of such a facility are not considered in this assessment; only disposal-related activities (e.g., transportation, handling, emplacement) are considered. The remaining facility systems, structures, and components will remain in-situ, and will be decommissioned in the same manner as for “4. In-Situ Disposal”. The above ground structures will be demolished and the rubble emplaced in the below grade structures prior to grouting. A concrete cap and engineered barriers would cover the facility and the surrounding area would be remediated. The stack would remain intact to continue serving as a habitat for chimney swifts.

During the Institutional Controls phase, surveillance, inspection, maintenance, and monitoring activities will be undertaken at the NPD site. These activities will include inspection of the integrity of the disposal facility, i.e., concrete cap and engineered barrier, and maintenance such as re-grading and removing trees and deep-rooted plants. The specific monitoring activities would be developed in compliance with applicable CSA N288 series documents for groundwater, effluent, and environmental monitoring.



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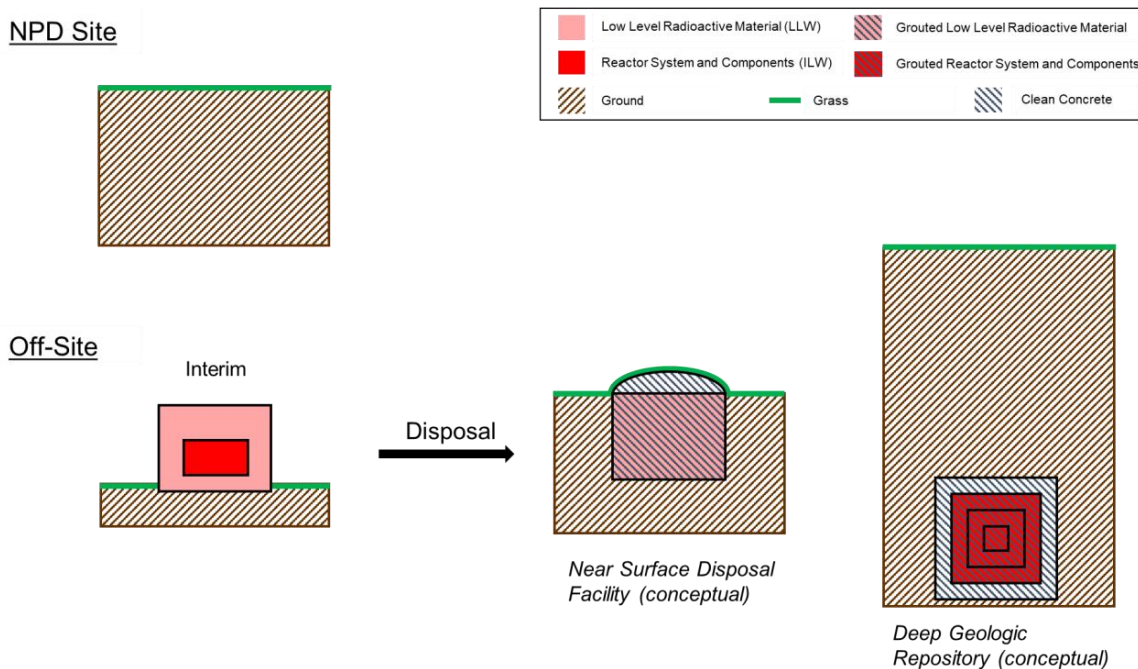
3. Full Dismantling and Removal

“Full dismantling and removal of all systems, structures and components for interim storage at the CRL site, until the waste undergoes final disposal at the CRL site.” (Titterington 2016)

For this analysis it has been assumed that this alternative means involves removing all radioactive material from the site and storing it temporarily at CRL, until a final disposal location is available. It is assumed that disposal facilities for both low-level waste (LLW) and intermediate-level waste (ILW) will become available at CRL during the Institutional Controls phase. The activities associated with the construction of these facilities are not in the scope of this assessment; only the disposal-related activities (e.g., transportation, handling, emplacement) are considered.

All structures on-site would be demolished and removed from the site, along with any nuclear or hazardous waste. This would include the removal of the reactor and the associated systems. It would also include removal of the stack and construction of a replacement roosting structure. The site would be remediated following the removal of all structures. It has also been assumed that the waste will be stored in containers within a building at the CRL Site due to the lack of a disposal facility at the time of waste removal.

During the Institutional Controls phase, it is assumed that minimal surveillance, inspection, and maintenance activities will be undertaken at the NPD site. It is expected that monitoring activities will continue to demonstrate the enhancement of the site following removal of the facility. Similarly, monitoring of the chimney swift population and use of the roosting structure will be required. General maintenance of the property will also be required (e.g., surface condition of roads and landfills).



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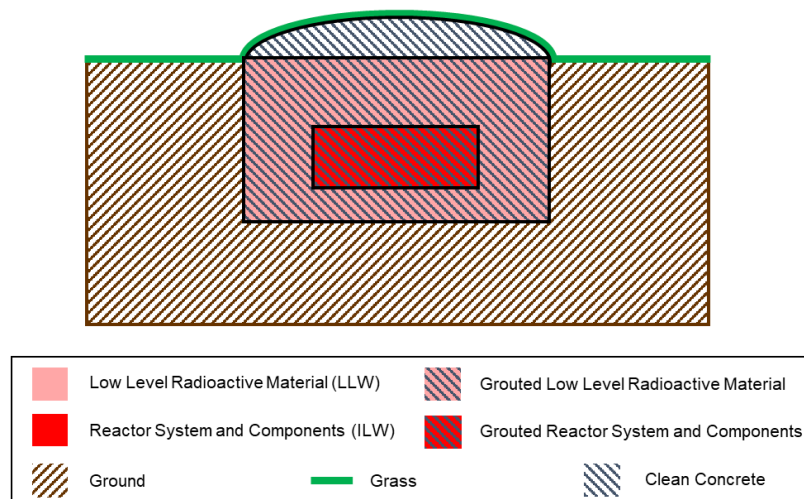
4. In-Situ Disposal

“In-Situ Disposal where the source term will be isolated inside the below grade structure and systems to allow for continued radioactive decay.” (Titterington 2016)

For this analysis it has been assumed that this alternative means involves grouting the reactor and associated systems in place within the building as a means of decommissioning. The above ground structures will be demolished, and the rubble will also be grouted within the below grade structures. The stack would not be demolished, as it will be left as a habitat for chimney swifts. Finally, a concrete cap and engineered barrier system would be placed over the facility to close it and the site will be remediated.

During the Institutional Controls phase, surveillance, inspection, maintenance, and monitoring activities will be undertaken at the NPD site. These activities will include inspection of the integrity of the disposal facility, i.e., concrete cap and engineered barrier, and maintenance such as re-grading and removing trees and deep-rooted plants. A draft follow-up program has been developed in compliance with applicable CSA N288 series documents for groundwater, effluent, and environmental monitoring to be undertaken during both the Decommissioning Execution and Institutional Controls phases.

NPD Site



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All four of these alternative means have been shown to be technically feasible based on the following criteria:

- Reliable Technology, i.e. does the alternative means use a previously demonstrated technology?
- Regulatory Compliance, i.e. does the alternative means meet regulatory requirements?

Additionally, all four of the alternative means have also been shown to be economically feasible, based on the following criterion:

- Cost, i.e. is the alternative within the financial guarantee limit from NRCan?

The environmental effects of each alternative means were assessed with respect to the key VCs identified for this study. These VCs are consistent with the comprehensive list of VCs selected for the EIS (see EIS Section 4). All of the potential interactions between the proposed decommissioning tasks and the VCs were considered during all three timeframes:

- Decommissioning Execution
- Institutional Controls
- Post-Institutional Controls

5.1 Relative Risk

Relative risk to the VCs for the four alternative means was assessed with respect to “1. Continued SwS” as the baseline. The results of this relative risk assessment are shown below in Table 5.1-1 through Table 5.1-3. The relative risk scale is defined in Table 4.2-1.

During the Decommissioning Execution timeframe, all of the alternatives carry increased risk relative to the baseline case “1. Continued SwS” (Table 5.1-1). This is due to the increase in decommissioning activities that are associated with each of the options. It can also be seen that while “4. In-Situ Disposal” does have a higher risk than the baseline case, it is lower than the “2. Partial Dismantling and Removal” and “3. Full Dismantling & Removal” on almost all of the environmental components. This is due to the increased extent and effort associated with “2. Partial Dismantling and Removal” and “3. Full Dismantling & Removal”, and therefore increased emissions and risk to the atmospheric and surface water environments. Furthermore, the increased effort results in additional worker dose and exposure, and potential for accidents. Thus, “4. In-Situ Disposal” offers a lower risk to worker health and the environment.

In the Institutional Control timeframe, the alternative means carry a reduced risk relative to the baseline case “1. Continued SwS” (Table 5.1-2). This is mainly due to the additional containment provided by these alternatives. This reduction in risk is most pronounced for “4. In-Situ Disposal” due to the permanent disposal achieved at the end of the Decommissioning Execution timeframe. Although the dismantling and removal alternatives have a reduced risk, this is lessened by the interim storage in containers, and undertaking of maintenance and disposal activities (multiple handling, transportation, emplacement).

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Finally, in the Post-Institutional Controls timeframe, all alternatives have a reduced risk relative to the baseline case due to the containment provided as part of permanent disposal (Table 5.1-3). In general, there is little difference between alternatives, as the final disposal options are all considered safe, and would have been subject to a robust regulatory regime to attain approval. The only difference between the alternatives is seen for worker health, as long-term care, maintenance, and monitoring activities are expected to continue into the Post-Institutional Controls timeframe at the off-site disposal locations. When looking at the probability of inadvertent human intrusion into the disposal sites, there is a slight difference between “4. In-Situ Disposal” and the dismantling alternatives “2. Partial Dismantling and Removal” and “3. Full Dismantling and Removal”. The probability of human intrusion is negligibly higher in the dismantling alternatives, due to the need for two disposal sites, instead of one disposal site in “4. In-Situ Disposal”. This difference is negligible because the additional site is a deep geological repository with a very low probability of inadvertent human intrusion.

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Table 5.1-1 Summary of Relative Risk for the Decommissioning Execution Phase

Alternative Means	Environmental Components														
	Environmental Effects						Miscellaneous Physical Effects			Socio-economic Effects	Effects on Indigenous People	Health Effects (Normal)			
	Atmospheric Environment	Surface Water Environment	Aquatic Environment	Terrestrial Environment	Geological and Hydrogeological Environment	Radiation and Radioactivity Environment	Land Use	Traffic and Transportation	Physical and Cultural Heritage Resources	Socioeconomic Effects	Effects on Indigenous Peoples' Rights and Interests	Public Health	Worker Health	Non-Human Biota	
1. Continued SWS	Baseline														
2. Partial Dismantling and Removal	↑↑	↑↑	≈	↑↑	↑	↑↑	≈	↑↑	≈	↑	↑	↑↑	↑↑	↑↑	
3. Full Dismantling and Removal	↑↑	↑↑	≈	↑↑	↑↑	↑↑	≈	↑↑	≈	↑	↑	↑↑	↑↑	↑↑	
4. In-Situ Disposal	↑	↑	≈	↑↑	↑	≈	≈	↑	≈	↑	↑	↑	↑	↑	

Table 5.1-2 Summary of Relative Risk for the Institutional Controls Phase

Alternative Means	Environmental Components													
	Environmental Effects						Miscellaneous Physical Effects			Socio-economic Effects	Effects on Indigenous People	Health Effects (Normal)		
	Atmospheric Environment	Surface Water Environment	Aquatic Environment	Terrestrial Environment	Geological and Hydrogeological Environment	Radiation and Radioactivity Environment	Land Use	Traffic and Transportation	Physical and Cultural Heritage Resources	Socioeconomic Effects	Effects on Indigenous Peoples' Rights and Interests	Public Health	Worker Health	Non-Human Biota
1. Continued SWS	Baseline													
2. Partial Dismantling and Removal	↓	↓	↓	↓	≈	↑	↓	≈	↓	↓	↓	↓	↑	↓
3. Full Dismantling and Removal	↓	≈	↓	↓↓	↑	↑	↓	≈	↓	↓	↓	↓	↑	↓
4. In-Situ Disposal	↓↓	↓↓	↓↓	↓	↓↓	↓↓	↓	≈	↓	↓	↓	↓↓	↓↓	↓↓

Table 5.1-3 Summary of Relative Risk for the Post-Institutional Controls Phase

Alternative Means	Environmental Components													
	Environmental Effects						Miscellaneous Physical Effects			Socio-economic Effects	Effects on Indigenous People	Health Effects (Normal)		
	Atmospheric Environment	Surface Water Environment	Aquatic Environment	Terrestrial Environment	Geological and Hydrogeological Environment	Radiation and Radioactivity Environment	Land Use	Traffic and Transportation	Physical and Cultural Heritage Resources	Socioeconomic Effects	Effects on Indigenous Peoples' Rights and Interests	Public Health	Worker Health	Non-Human Biota
1. Continued SWS	Baseline													
2. Partial Dismantling and Removal	≈	↓	↓	↓↓	↓	↑	↓↓	≈	≈	↓	↓	≈	≈	≈
3. Full Dismantling and Removal	≈	≈	≈	↓↓	≈	↑	↓↓	≈	≈	↓	↓	≈	≈	≈
4. In-Situ Disposal	↓	↓↓	↓↓	↓↓	↓↓	↓↓	↓↓	≈	↓	↓↓	↓↓	↓↓	≈	↓↓

5.2 Absolute Risk

Overall, despite differences in effort and activity, emissions, and releases, all alternatives are fundamentally safe. This is because all alternatives would be subject to a robust regulatory regime and undertaken with measures to ensure safety. The main differences between the alternative means are related to:

- 1) The increased effort (e.g., material handling, transportation), emissions, and releases associated with the “2. Partial Dismantling and Removal” and “3. Full Dismantling and Removal” alternatives
- 2) The immediate disposal in “4. In-Situ Disposal” which eliminates susceptibility to low probability malfunctions and accidents.

First, despite differences in effort, emissions, and releases, all alternatives would be fundamentally safe. This is because all alternatives would be subject to a robust regulatory regime and undertaken with measures to ensure safety. For example, by ensuring that work is undertaken in compliance with work control documents and radiation protection protocols, worker doses for all alternatives would be maintained well below relevant dose criteria. Similarly, the hypothetical disposal facilities (e.g., the ILW and LLW disposal facilities) can be assumed to be safe, because the approval of such facilities would be contingent on regulatory approval.

Second, although alternatives “2. Partial Dismantling & Removal” and “3. Full Dismantling & Removal” require interim storage prior to the availability of the appropriate disposal facilities, this storage will be undertaken safely. During interim storage, it is expected that maintenance activities will ensure the integrity of the containment, and will ensure that releases carry no undue risk, under normal operating conditions.

5.3 Timely Reduction of Legacy Liability

One of the major concerns of this project is the timely reduction of Canada’s Nuclear Legacy Liability. The baseline alternative “1. Continued SwS” does not provide any reduction to the legacy liability. “2. Partial Dismantling and Removal” provides some reduction in the legacy liability, as some of the waste has been grouted securely in place, while the remaining waste packaged moved to CRL for interim storage and eventual disposal. Similarly, “3. Full Dismantling and Removal” provides some reduction in the legacy liability, as the waste has been packaged moved to CRL for storage and eventual disposal. For both of these alternative means, the interim storage of waste and reliance on the eventual approval and construction of disposal facilities for LLW and ILW delay the reduction of legacy liability. “4. In-Situ Disposal” succeeds in providing timely reduction of the legacy liability by immediately securing the contamination in place.

5.4 Conclusions

Based on the comparison of the relative risk to the environmental VCs, absolute risk to the environmental VCs, and additional consideration, “4. In-Situ Disposal” has been found to be the preferred means for completing this project. More detailed quantitative assessments (the Decommissioning Safety Assessment, Post-Closure Safety Assessment, and Ecological Risk Assessment) of environmental effects to the VCs are underway for “4. In-Situ Disposal”.

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APPENDIX A: INTERNATIONAL SUPPORT FOR IN-SITU DISPOSAL AS A DECOMMISSIONING AND DECONTAMINATION OPTION



APPENDIX A: International Support for In-Situ Disposal as a Decommissioning and Decontamination Option

It is acknowledged that In-Situ Disposal, also referred to as Entombment, is supported by the IAEA only under exceptional circumstances (e.g. accidents such as the Chernobyl case) as stated in the IAEA Safety Requirements (IAEA 2014; Laraia 2014): “*Entombment, in which all or part of the facility is encased in a structurally long lived material, is not considered a decommissioning strategy and is not an option in the case of planned permanent shutdown. It may be considered a solution only under exceptional circumstances (e.g. following a severe accident)*”. However, given the significant potential for reduced dose, radioactive waste and cost with In-Situ Disposal, this method has been supported internationally on several projects in the U.S. and European Union, mainly on small reactors.

Three small nuclear power reactors were entombed in the United States in 1969-1970: Hallam Nuclear Power Facility in Nebraska (240 MW sodium cooled graphite-moderated reactor), Piqua Nuclear Power Facility in Ohio (45.5 MW organically cooled and moderated reactor), and Boiling Nuclear Superheating Power Station (BONUS) in Puerto Rico (50 MW boiling water research reactor). In all three cases the fuel was removed from the site prior to decommissioning, as is with the NPDWF. The entombment process at these sites was simple but continued monitoring since decommissioning has shown that the entombment has successfully contained the radioactive contamination of these three reactors (Birk *et al.* 2000).

Other examples where entombment has been applied within the last few years to nuclear reactors in the U.S. and European Union are provided below (Belencan *et al.* 2013; Laraia 2000):

- Heavy Water Components Test Reactor (HWCTR), Savannah River Site, USA: An experimental nuclear reactor used to test the concept of heavy water moderated and cooled reactor for civilian power from late 1962 to December 1964.
- Lucens Reactor, Switzerland: Thirty years after the accident that put an end to Lucens operation, the decision was made to fill and seal the caverns housing the reactor facility, and to release and terminate its nuclear licence.
- Boiling Water Reactor Experiment-1 Landfill, INEEL, USA: The BORAX-1 reactor was a small experimental reactor used in the summer months of 1953 and 1954 for testing boiling water reactor technology. In 1954, the design mission of BORAX-1 was completed and one final test was conducted that resulted in the intentional destruction of the reactor.
- Entombment of Super Kukla Facility, Nevada Test Site (NTS), USA: Lawrence Livermore’s National Laboratory’s Super Kukla prompt –burst reactor was installed at the Nevada Test Site in 1964. The reactor was used to evaluate the damage that radiation might cause to materials in the vicinity of a nuclear blast.
- Savannah River Site: the R- and P-Reactors, USA: During the early 1950s, five production reactor facilities were built at the Savannah River Site to produce materials to support building of the nation’s nuclear weapons stockpile in response to the Cold War. R-Reactor and P-Reactor were the first facilities completed in 1953 and 1954. The R-Reactor was removed from service in 1964 and the P- Reactor in 1988.

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- Decommissioning of Industrial Uranium-Fuelled Graphite Moderated Reactor at Krasnoyarsk Mining Chemical Plant, Russian Federation: The site is home to three industrial uranium-graphite reactors, namely AD, ADE-1 and ADE-2. The AD was a single purpose flow reactor that used thermal neutrons and operated from 1958 to 1992. The DE-1 was designed for power generation but in fact was only used as a single-purpose flow reactor that operated from 1961 to 2010.
- IRT-M Reactor, Tblisi, Georgia: The nuclear research reactor IRT-M belonged to the Institute of Physics in Tblisi and operated from 1960 to 1988.

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