UNDERTAKING J13.7

Undertaking

Reference : JT1.17

TO PROVIDE AN AVAILABLE ECONOMIC ANALYSIS OF THE IMPACT OF DECOMMISSIONING.

Response

Attachment 1 is OPG's assessment entitled, "A Preliminary Assessment to Determine the Financial Impact of Using a Prompt Decommissioning Approach for OPG's Nuclear Generating Stations." As shown on page 5 of the assessment, prompt decommissioning would increase the present value of the liability by approximately $500M for Pickering alone and by about $700M for all OPG nuclear stations, compared to OPG's planned deferred decommissioning strategy.

Prompt decommissioning (also known as immediate dismantling) is defined as the strategy in which the equipment, structures, components and parts of a facility containing radioactive material are removed or decontaminated to a level that permits the facility to be released for unrestricted use as soon as possible after permanent shutdown. The term "prompt" in the assessment refers to a safe storage duration of 11 years after station shut down. A period of 11 years for safe storage is required as used nuclear fuel removed from the core must cool in wet fuel bays for a minimum of 10 years in accordance with the licensed capability of OPG's dry storage containers established by the CNSC.

OPG's planned deferred decommissioning strategy is to shut down and store its nuclear generating stations in a safe state for nominally 30 years, followed by dismantlement, demolition, and site restoration.

Both the prompt decommissioning and deferred decommissioning scenarios are assumed to have the same staffing requirements. There is no ability to use operating staff to perform dismantlement work because different skill sets and unions are involved in these two activities.

OPG's assessment was based on costs reflected in a draft of the 2017 ONFA Reference Plan that were available at the time that the assessment was carried out in June, 2016. These costs may differ from those subsequently approved in the 2017 ONFA Reference Plan.

ONTARIO POWER GENERATION

Report

OPG Confidential	
Document Number: N-REP-00960-10006	Usage Classification: N/A
Sheet Number: N/A	Revision: R000

Title:

A PRELIMINARY ASSESSMENT TO DETERMINE THE FINANCIAL IMPACT OF USING A PROMPT DECOMMISSIONING APPROACH FOR OPG'S NUCLEAR GENERATING STATIONS

© Ontario Power Generation Inc., 2016. This document has been produced and distributed for Ontario Power Generation Inc. purposes only. No part of this document may be reproduced, published, converted, or stored in any data retrieval system, or transmitted in any form or by any means (electronic, mechanical, photocopying, recording, or otherwise) without the prior written permission of Ontario Power Generation Inc.

A Preliminary Assessment to Determine the Financial Impact of Using a Prompt Decommissioning Approach For OPG's Nuclear Generating Stations

2017 ONFA Based Update

N-REP-00960-10006-R000
2016-06-27

Order Number: N/A
Other Reference Number: N/A

OPG Confidential

Prepared by: J. Kennard, Section Manager, Cost Estimating, NWMO — Date: 29/6/2016

Reviewed by: V. Bostan, Section Manager, Nuclear Decommissioning Engineering, OPG — Date: 29-06-2016

Reviewed by: V. Seegobin, Manager, Decommissioning & Safstor Engineering, OPG — Date: 29-JUN-16

Approved by: J. Keto, Vice President, Nuclear Decommissioning, OPG — Date: 29 June 2016

Table of Contents

List of Tables and Figures

Page

Revision Summary

Revision Number	Date	Comments
R000	2016-06-27	Initial issue.

This report is an update of the original prompt decommissioning assessment report developed in 2013 following the 2012 ONFA update (N-REP-00960-10002-R000 December 2013). The baseline 30 year deferred decommissioning cost estimates used in this report are the draft April 2017 ONFA update station decommissioning cost estimates.

Executive Summary

Ontario Power Generation's (OPG's) planned deferred decommissioning strategy of its nuclear generating stations includes an assumed nominal 30 year safe storage period prior to the dismantling of station equipment and facilities. The Low and Intermediate Level Waste (L&ILW) produced during the safe storage and dismantling periods of the decommissioning is assumed to be emplaced in an appropriate long-term L&ILW Deep Geologic Repository (DGR).

Assessment Objective

In order to assess key decommissioning cost drivers a study was initiated by OPG's Nuclear Decommissioning group to determine the financial impact of varying safe storage periods.

All amounts quoted are in 2017$ unless otherwise indicated. The safe storage periods were varied and compared to the base 2017 ONFA reference case.

Impact of Prompt Scenario in Safe Storage Period

The study considered safe storage periods varying between 11[1] and 20 years to approximate *alternative* decommissioning scenarios. The term "prompt" in this report refers to a safe storage duration of 11 years.

When all OPG nuclear generating stations were considered, a reduction of the safe storage period from 30 to 11 years reduced the constant $ liability by 3.7% or $526M but increased the PV liability by 17% or $729M.

When only considering Pickering A&B stations, a reduction of the safe storage period from 30 to 11 years reduced the total constant $ liability by approximately 3% or $157M but increased the PV liability by 20% or $491M.

[1] A minimum ten year period is required to cool used fuel in the wet bays and one year will be required to transfer used fuel to dry storage.

NOTE

The objective of this study was to determine the financial impact of varying the decommissioning safe storage period on the total and Pickering only decommissioning liabilities. This study does not include impacts to the Used Fuel Storage, L&ILW Operations and L&ILW Long Term Disposal programs. As such the study makes no recommendation regarding an optimum decommissioning strategy or safe storage period.

The assumptions and dates used in this report are based on the draft April 2017 ONFA Reference Plan submitted to the Province in May, 2016 and may not reflect current planning assumptions and financial results.

1.0 STUDY OBJECTIVES

A major cost component of OPG's nuclear waste management and decommissioning liability is associated with the decommissioning of its nuclear generating stations. In order to evaluate OPG's deferred decommissioning strategy as compared to alternative prompt decommissioning strategies a decommissioning cost study was initiated by the Nuclear Decommissioning group at OPG.

The projected end of life of the Pickering nuclear generating stations in 2022/2024 identified the need to study the cost impact of accelerating the decommissioning of the Pickering generating stations; and the overall cost impact of a change in decommissioning strategy at all OPG nuclear generating stations.

The study was to address the effect of the reduction of the safe storage period and its associated change in constant $ and present value $. The reduction in the safe storage period was intended to approximate the impact of a prompt decommissioning approach.

TLG Services Inc, an external contractor who developed the 2017 ONFA Decommissioning cost estimates, was tasked with adjusting the cost estimates for different safe storage periods. TLG Services Inc, in conjunction with OPG, provided the high level technical assumptions necessary for the adjustment of the baseline cost estimates for these safe storage periods.

The NWMO was tasked with the integration and financial adjustment of the updated TLG cost estimates to complete the financial analysis.

This report summarizes the study findings, including the cost implications of the strategies considered to accelerate the decommissioning process to approximate an 11 year and 20 year safe storage period. The term "prompt" in this report refers to safe storage duration of 11 years.

2.0 BACKGROUND

Ontario Power Generation's (OPG) planned approach to the decommissioning of its nuclear generating stations is based on a nominal 30 year deferred decommissioning strategy. This multi-stage approach includes the disposition of L&ILW resulting from the decontamination and dismantling of the facilities in a L&ILW DGR [R-1]. The funding of the decommissioning of the nuclear generating stations is regulated by the Ontario Nuclear Funds Agreement (ONFA). Under the agreement, the decommissioning liability is updated on a five year cycle. The required funding to complete the decommissioning is accumulated within the operating lives of the nuclear generating stations. The recent 2017 ONFA Reference Plan update of the estimated decommissioning liability was based on the projected end of life dates shown in Table 1 using the nominal 30 year deferred decommissioning strategy [R-1].

Table 1: Station Planning Assumptions

Station/Unit	Unit In-Service Date	2017 ONFA (30 year deferred)		
		End of Life	Dismantling Date	Site Restoration Complete
Pickering A – Unit 1	Jul, 1971	2022	2051	2064
Pickering A – Unit 2/3	Dec, 1971 Jun, 1972	2005	2052/53	
Pickering A – Unit 4	Jun, 1973	2022	2054	
Pickering B – Unit 5	May, 1983	2024	2055	2065
Pickering B – Unit 6	Feb, 1984	2024	2056	
Pickering B – Unit 7	Jan, 1985	2024	2057	
Pickering B – Unit 8	Feb, 1986	2024	2058	
Darlington – Unit 1	Nov, 1992	2053	2084	2093
Darlington – Unit 2	Oct, 1990	2049	2085	
Darlington – Unit 3	Feb, 1993	2052	2086	
Darlington – Unit 4	Jun, 1993	2055	2087	
Bruce A – Unit 1	Sep, 1977	2043	2086	2095
Bruce A – Unit 2	Sep, 1977	2043	2087	
Bruce A – Unit 3	Feb, 1978	2061	2088	
Bruce A – Unit 4	Jan, 1979	2062	2089	
Bruce B – Unit 5	Mar, 1985	2061	2090	2099
Bruce B – Unit 6	Sep, 1984	2057	2091	
Bruce B – Unit 7	Apr, 1986	2063	2092	
Bruce B – Unit 8	May, 1987	2063	2093	

The 2017 ONFA update included cost estimates for all OPG owned nuclear generating stations and waste management facilities which form the most significant portion of the decommissioning liability. The decommissioning cost estimates were prepared by TLG Services Inc. The basis of the cost estimates, including comparisons to the previous cost estimates, is detailed in the station decommissioning cost study reports and comparison reports prepared by TLG [R-3 to R-10].

The cost estimates include updates to both economic and technical assumptions. The economic update reflects current conditions and costs in 2015 dollars (i.e. disposal, labor, insurance, regulatory agency fees, property taxes, and energy costs). The technical update reflects current industry practice and experience in the United States. Decommissioning cost estimate summary details can be found in the “2017 ONFA Reference Plan Update Decommissioning Summary Cost Estimate Report” [R-11].

Table 2 details the estimated costs to decommission the OPG nuclear generating stations stated in 2015 constant M$.

Table 2: 2017 ONFA Station Decommissioning Liabilities – Detail (2015 Constant k$)

Work Breakdown Structure	Bruce A	Bruce B	Pickering A	Pickering B	Darlington	Total	% of CTD*
DGR EXPENSES	**$ 108,160**	**$ 113,217**	**$ 126,239**	**$ 108,855**	**$ 175,673**	$ 632,144	**4.8%**
DGR Excavation (Years 2039 thru 2043)	$ 79,196	$ 82,899	$ 92,434	$ 79,705	$ 128,630	$ 462,864	3.6%
DGR Decommissioning (2100 thru 2104)	$ 28,964	$ 30,318	$ 33,805	$ 29,150	$ 47,043	$ 169,281	1.3%
MANAGEMENT OF HEAVY WATER	**$ 34,067**	**$ 34,067**	**$ 9,280**	**$ 9,280**	**$ 38,766**	**$ 125,460**	**1.0%**
PREPARATION FOR SAFE STORAGE	**$ 348,060**	**$ 353,078**	**$ 392,040**	**$ 517,300**	**$ 586,575**	**$ 2,197,053**	**16.9%**
Defueling	$ -	$ -	$ 4,571	$ 9,149	$ 10,257	$ 23,977	0.2%
Preparation and Implementation	$ 72,919	$ 76,262	$ 16,172	$ 90,423	$ 95,735	$ 351,510	2.7%
Engineering and Planning	$ 2,500	$ 2,500	$ -	$ 2,500	$ 2,500	$ 10,000	0.1%
Decontamination of Systems/Structures	$ -	$ -	$ -	$ -	$ -	$ -	0.0%
Decontamination Equipment and Supplies	$ 121	$ 121	$ 601	$ 198	$ 120	$ 1,161	0.0%
Health Physics Equipment and Supplies	$ 4,179	$ 4,179	$ 7,683	$ 7,962	$ 4,891	$ 28,895	0.2%
Dismantling Equipment and Tooling	$ 15	$ 15	$ 11	$ 18	$ 17	$ 75	0.0%
Waste Processing	$ 24,697	$ 24,697	$ 2,061	$ 5,564	$ 17,477	$ 74,496	0.6%
Energy	$ 17,665	$ 18,310	$ 59,418	$ 48,896	$ 24,401	$ 168,690	1.3%
Insurance, Fees and Taxes	$ 12,541	$ 13,570	$ 29,387	$ 47,850	$ 41,244	$ 144,592	1.1%
Staffing	$ 183,173	$ 183,173	$ 222,625	$ 242,800	$ 308,439	$ 1,140,210	8.7%
Overhead Costs	$ 30,251	$ 30,251	$ 49,511	$ 61,941	$ 81,492	$ 253,446	1.9%
SAFE STORAGE	**$ 312,071**	**$ 391,061**	**$ 474,341**	**$ 437,863**	**$ 554,834**	**$ 2,170,169**	**16.6%**
Facility Maintenance	$ 31,093	$ 36,501	$ 37,056	$ 36,553	$ 46,271	$ 187,474	1.4%
Health Physics Supplies	$ 11,288	$ 13,444	$ 14,027	$ 14,874	$ 17,285	$ 70,918	0.5%
Waste Processing	$ 5,892	$ 6,152	$ 1,110	$ 5,498	$ 8,679	$ 27,331	0.2%
Energy	$ 45,737	$ 54,689	$ 88,073	$ 79,110	$ 65,837	$ 333,447	2.6%
Insurance, Fees and Taxes	$ 98,109	$ 137,825	$ 164,088	$ 146,175	$ 247,010	$ 793,208	6.1%
Staffing	$ 79,133	$ 94,356	$ 122,648	$ 74,932	$ 112,246	$ 483,316	3.7%
Overhead Costs	$ 40,817	$ 48,094	$ 47,338	$ 50,225	$ 57,505	$ 243,980	1.9%
Heavy Water Storage (Pickering Only)	$ -	$ -	$ -	$ 30,496	$ -	$ 30,496	0.2%
PREPARATIONS FOR DISMANTLING	**$ 189,526**	**$ 171,786**	**$ 163,103**	**$ 172,417**	**$ 192,102**	**$ 888,933**	**6.8%**
Preparations	$ 65,353	$ 56,642	$ 58,041	$ 59,614	$ 65,448	$ 305,098	2.3%
Engineering and Planning	$ 28,721	$ 18,813	$ 25,493	$ 28,297	$ 28,721	$ 130,044	1.0%
Health Physics Supplies	$ 2,402	$ 2,402	$ 2,049	$ 2,350	$ 2,401	$ 11,603	0.1%
Dismantling Equipment and Tooling	$ 3,059	$ 3,059	$ 2,890	$ 3,398	$ 3,398	$ 15,806	0.1%
Waste Processing	$ 305	$ 305	$ 185	$ 210	$ 331	$ 1,336	0.0%
Energy	$ 12,457	$ 12,457	$ 7,949	$ 9,346	$ 11,967	$ 54,177	0.4%
Insurance, Fees and Taxes	$ 4,592	$ 5,473	$ 4,563	$ 5,169	$ 7,324	$ 27,121	0.2%
Staffing	$ 65,495	$ 65,495	$ 56,883	$ 57,392	$ 65,463	$ 310,728	2.4%
Overhead Costs	$ 7,142	$ 7,139	$ 5,049	$ 6,641	$ 7,048	$ 33,020	0.3%
DISMANTLING	**$ 1,136,936**	**$1,150,607**	**$ 1,153,211**	**$ 1,043,867**	**$1,415,009**	**$ 5,899,630**	**45.3%**
Preparations	$ 62,232	$ 60,118	$ 92,190	$ 44,503	$ 90,078	$ 349,121	2.7%
PHT and Moderator System Removal	$ 365,286	$ 368,754	$ 334,444	$ 308,980	$ 458,670	$ 1,836,134	14.1%
Disposal of Plant Systems	$ 111,792	$ 111,792	$ 107,047	$ 131,484	$ 298,947	$ 761,063	5.8%
Decontamination of Site Buildings	$ 50,455	$ 56,546	$ 69,089	$ 30,395	$ 59,065	$ 265,550	2.0%
Final Survey	$ 61,568	$ 61,009	$ 47,825	$ 47,450	$ 61,644	$ 279,496	2.1%
Decontamination Equipment and Supplies	$ 13,130	$ 12,861	$ 13,278	$ 14,658	$ 18,371	$ 72,298	0.6%

Health Physics Supplies	$ 35,695	$ 35,575	$ 31,221	$ 30,637	$ 42,899	$ 176,026	1.4%
Dismantling Equipment and Tooling	$ 42,191	$ 42,382	$ 45,996	$ 47,165	$ 39,878	$ 217,612	1.7%
Waste Processing	$ 16,360	$ 16,268	$ 12,139	$ 12,503	$ 18,752	$ 76,023	0.6%
Energy	$ 32,546	$ 32,682	$ 25,467	$ 24,468	$ 25,007	$ 140,171	1.1%
Insurance, Fees and Taxes	$ 22,078	$ 27,731	$ 38,023	$ 21,902	$ 23,294	$ 133,028	1.0%
Staffing	$ 274,849	$ 276,176	$ 281,418	$ 283,604	$ 226,172	$ 1,342,219	10.3%
Overhead Costs	$ 48,755	$ 48,712	$ 55,075	$ 46,117	$ 52,231	$ 250,890	1.9%
SITE RESTORATION	**$ 248,850**	**$ 257,599**	**$ 170,438**	**$ 137,621**	**$ 306,223**	**$ 1,120,731**	**8.6%**
Demolition of Remaining Site Buildings	$ 87,179	$ 91,213	$ 64,519	$ 88,164	$ 181,813	$ 512,888	3.9%
Site Closeout	$ 60,685	$ 60,665	$ 1,926	$ 1,303	$ 2,583	$ 127,162	1.0%
Dismantling Equipment and Tooling	$ 33,786	$ 33,850	$ 37,584	$ 1,005	$ 36,123	$ 142,348	1.1%
Energy	$ 2,919	$ 3,020	$ 2,212	$ 2,567	$ 3,602	$ 14,319	0.1%
Insurance, Fees and Taxes	$ 11,588	$ 15,181	$ 12,224	$ 14,187	$ 18,765	$ 71,944	0.6%
Staffing	$ 38,322	$ 38,806	$ 39,548	$ 16,644	$ 40,625	$ 173,945	1.3%
Overhead Costs	$ 14,372	$ 14,865	$ 12,426	$ 13,750	$ 22,711	$ 78,124	0.6%
Total Cost To Decommission (CTD*)	**$ 2,377,670**	**$2,471,415**	**$ 2,488,651**	**$ 2,427,204**	**$3,269,180**	**$ 13,034,121**	**100.0%**
Risk Contingency (4%)	**$ 95,107**	**$ 98,857**	**$ 99,546**	**$ 97,088**	**$ 130,767**	**$ 521,365**	
Total Cost With Risk Contingency	**$ 2,472,777**	**$2,570,272**	**$ 2,588,197**	**$ 2,524,292**	**$3,399,947**	**$ 13,555,485**	

Table 3 provides the total estimated cost to decommission the generating stations in 2015 constant M$, and for the 2017 ONFA reference plan update period from 2017 forward in 2017 constant M$.

Table 3: 2017 ONFA Station Decommissioning Liabilities – Total

Generating Station	TLG 2015 / 2016 Estimates 2015 constant M$ (2015 forward)	2017 ONFA Reference Plan Update 2017 constant M$ (2017 forward)
Pickering A	2,588	2,660
Pickering B	2,524	2,604
Bruce A	2,473	2,573
Bruce B	2,570	2,674
Darlington	3,400	3,535
Total	13,555	14,045

For 2017 ONFA, oversight costs specific to the OPG decommissioning program were not included in the TLG Services cost estimates but rather estimated separately by OPG. These costs include oversight by the OPG Nuclear Decommissioning Division and the NWMO. Details regarding the oversight costs are found in “2017 ONFA Reference Plan Update Operational Oversight Cost Estimate Report” [R-13]. For 2017 ONFA a heavy water management cost was included for each station within the station cost estimates prepared by TLG Services.

The total decommissioning cost for all OPG nuclear generating stations including Decommissioning Oversight for all OPG stations is shown in Table 4.

Table 4: 2017 ONFA Station Decommissioning Liability Including Oversight and Heavy Water Management

Activity	2017 ONFA Reference Plan Update 2017 constant M$ (2017 forward)
Station Decommissioning	14,045
Decommissioning Oversight*	110
Total Decommissioning Cost	14,155
Total (2017 PV M$)	4,140

* Cost allocated equally to all OPG nuclear station units.

3.0 DECOMMISSIONING STRATEGY SELECTION

The approaches available for the decommissioning of nuclear generating stations are well documented in the nuclear industry. A detailed description of common decommissioning approaches is beyond the intended scope of this study; however a brief overview of the approaches will provide some context to OPG's currently selected strategy.

3.1 Decommissioning Approaches

There are four principle approaches to the decommissioning of nuclear generating stations and additional variations which combine features of the three.

The four principle approaches are [R-15]:

(1) Prompt Decommissioning – Also known as Immediate Dismantling
(2) Deferred Dismantling – Also known as Deferred Decommissioning
(3) Entombment
(4) Hybrid

3.1.1 Prompt Decommissioning

Prompt decommissioning is the strategy in which the equipment, structures, components and parts of a facility containing radioactive material are removed or decontaminated to a level that permits the facility to be released for unrestricted use as soon as possible after permanent shutdown. In this study this approach will be compared to the deferred decommissioning approach.

3.1.2 Deferred Decommissioning

Deferred decommissioning is the strategy in which the final dismantling of the facility is delayed and the facility is placed into long-term storage where it is maintained in a safe condition. This strategy may involve some initial decontamination or dismantling, but a major part of the facility will remain for a certain time period. This time period might range from a few years to 50 years, after which time the decommissioning process will be completed and the facility released from regulatory control.

The deferred approach is the currently selected OPG decommissioning strategy.

3.1.3 Entombment

Entombment is the strategy in which the radioactive contaminants are encased in a structurally long lasting material until the radioactivity decays to a level that permits release of the facility from regulatory control. While the entombment option is a recognized option by the CNSC, and is in use in some parts of the world, it is not an approach which OPG considers appropriate for use at its sites to date and will thus not be discussed further within this report.

3.1.4 Hybrid

Hybrid decommissioning is the strategy in which decommissioning proceeds according to a sequence of dismantling activities and periods of safe storage or entombment according to prevailing conditions e.g. resource availability, safety, environmental and stakeholder conditions. An assessment of hybrid options could be undertaken at a future date. Such an assessment would be complex and involve a significant technical component in assessing hybrid scenarios.

3.2 Factors Affecting Strategy Selection

The selection of a decommissioning strategy is dependent on a number of factors which a utility must consider. The Table 5 lists typical key factors which may be considered in the selection.

Table 5: Typical Factors Affecting Decommissioning Strategy Selection

Factor	Description
1	Health and safety
2	Regulatory
3	Funding approach
4	Adequacy of funding
5	Availability of interim waste storage facilities (L&ILW)
6	Availability of long-term waste management facilities (L&ILW and used fuel)
7	Cost of decommissioning L&ILW waste management
8	Expected end use/condition of site
9	Availability of technology
10	Availability of trained personnel
11	Used fuel options/implications
12	Economies of scale for multi-unit installations
13	Operating station staff transition plan
14	Multi-unit station operational implications

The key factors are typically re-classified as “pros” or “cons” when making the decommissioning strategy decision as shown in Table 6 for Prompt versus Deferred decommissioning.

Table 6: Pros and Cons of Prompt Versus Deferred Decommissioning

Strategy	Pro	Con
Prompt Decommissioning	• Land is available earlier for redevelopment • More knowledge retention during decommissioning • Lower constant dollar due to shorter safe storage period (less upkeep) • Socially most acceptable	• More dose exposure to workers • Higher PV costs • Unavailability of a L&ILW disposal facility (PNG only) • More intermediate level waste and less free release waste due to decay • Unavailability of a used fuel disposal facility (PNG only)
Deferred Decommissioning	• Allows for continued growth of decommissioning fund • Less dose exposure to workers • Less intermediate level waste and more free release waste due to decay • Potential for reduced dismantling costs due to advances in technology • A L&ILW DGR to accept decommissioning waste would be available • Lower PV costs	• Less knowledge retention during decommissioning • Higher constant dollar cost due to a longer safe storage period (more upkeep)

4.0 DECOMMISSIONING AT OPG

4.1 Rationale for Deferred Decommissioning Strategy

OPG is obligated to meet the requirements of the Canadian Nuclear Safety and Control Act with regard to the operation and decommissioning of its nuclear generating stations. Under the Act, OPG must provide a financial guarantee (CNSC Financial Guarantee) for the eventual decommissioning of its nuclear generating stations and other Class I facilities. (e.g. waste management facilities)

The CNSC Financial Guarantee needs to meet the requirements of Regulatory Guides G-206 and G-219 published by the CNSC ([R-16] to [R-17]) and CSA N294-09 [R-18].

G-219, titled “Decommissioning Planning for Licensed Facilities”, requires that Preliminary Decommissioning Plans (PDPs) be prepared in support of station licenses and financial guarantees. The PDPs submitted to the CNSC identify the overall approach to the decommissioning of the facilities including the planned decommissioning strategy.

OPG’s current strategy for decommissioning is to shut down and store its nuclear generating stations in a safe state for nominally 30 years (referred to as “Deferred Decommissioning”), followed by dismantlement, demolition, and site restoration. The duration of the Safe Storage period was determined by balancing the reduced decommissioning cost and occupational dose against the increased social and economic costs of a longer storage period.

OPG has chosen a *30 year deferred decommissioning strategy* decommissioning strategy that is considered to minimize both the occupational radiation dose to staff and the potential exposure to the public and the environment. OPG has identified this approach within the PDPs as its planned approach since the inception of its nuclear program.

The “Deferred Dismantling” strategy for decommissioning of OPG’s nuclear plants was chosen based on detailed consideration of the following:

Radiation Protection

- Avoids dose/radiation exposure – Dismantling the radioactive parts of the nuclear stations are considered to be the most challenging, and labour and cost intensive activities involved in decommissioning. Hence, reducing the amount of radiation exposure to workers, public and the environment was one of the most important factors considered when OPG was developing the strategy for decommissioning. The 30 year deferral approach reduces the potential dosage through the natural decay of radionuclides and is consistent with the As Low As Reasonably Achievable (ALARA) principle.

Waste Management

- Deferred decommissioning allows time to implement the long-term L&ILW strategy – OPG plans to place L&ILW generated during decommissioning (for Pickering or other facilities) in the L&ILW DGR located in Kincardine.

- Deferred decommissioning allows time to implement the Used Fuel disposal repository – OPG currently assumes that a long-term used fuel management facility will be in-service in 2043. While OPG's current approach for selected generating stations is to accelerate the transfer of used fuel from wet-bays to dry storage, it is assumed that the remaining stations will move fuel directly from the wet-bays to the facility starting in 2043. This will impact the ability of some stations to decommission promptly if required.

- Wet-bay limit on fuel movement – When used fuel is removed from OPG reactors, it must remain in the station wet-bays for a period of approximately 10 years to cool before transfer to dry storage. This limits all stations to a minimum 11 year deferral period on decommissioning. (1 additional year for emptying the wet bays.)

- Reduced disposal cost for waste – In addition to the dismantling and radioactive exposure reasons cited in item 1, the deferred approach will reduce the volume of ILW produced since it would decay to LLW and hence the associated cost of disposal. Also some LLW (such as contaminated soil) would decay to a point which it could be free released.

- Multi-Unit station advantage – The deferred dismantling approach is often used at multi-unit stations when one or more of the units are shutdown while others continue to operate (e.g. Pickering). This is especially true of stations which share some common systems (all OPG stations).

Financial

- Funding – The funding required for the decommissioning of nuclear generating stations is accumulated over the operating lives of the stations. Funding levels are based on the present value of future costs.

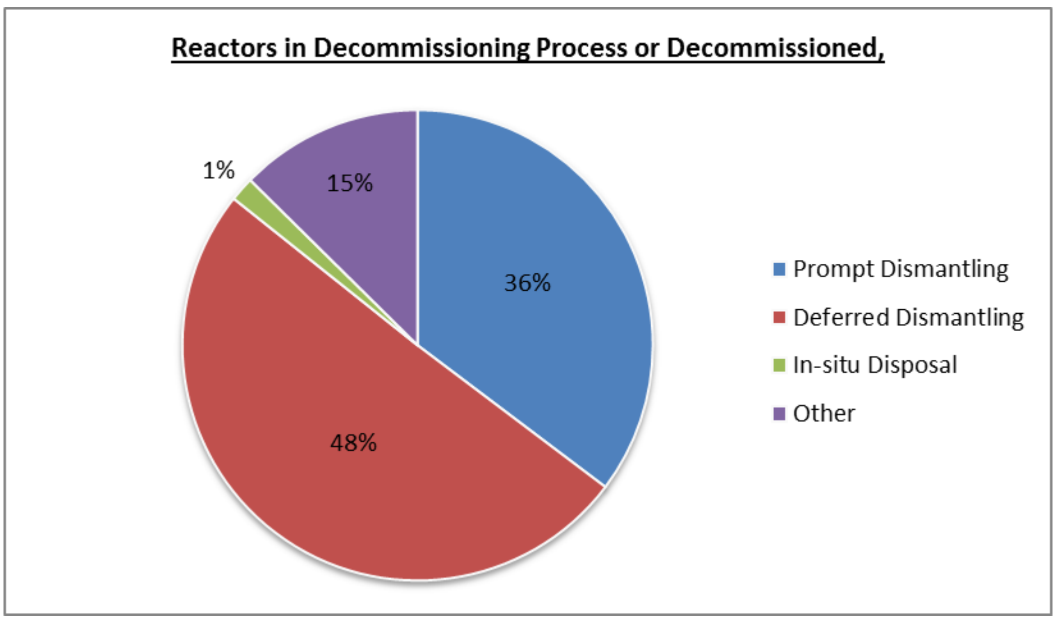
- Potential for reduced costs – Dismantling costs may decline in the future with the advent of new technologies and use of industry operating experience.

International Experience

- As of December 2015, 157 power reactors worldwide had been permanently shut down. Of these, 34 power reactors had been fully decommissioned and licences terminated. Of the remaining 123 power reactors:

  - ➢ 59 opted for deferred dismantling
  - ➢ 44 opted for prompt dismantling
  - ➢ 2 opted for in-situ disposal
  - ➢ 18 had not commenced decommissioning and/or did not have a specified strategy

Figure 1: International Decommissioning Experience



4.2 Periodic Review of OPG Decommissioning Strategy

OPG's decommissioning strategy has historically been reviewed on a five year cycle; typically aligned with ONFA reference plan update [R-19]. OPG reviews the decommissioning strategy internally during the regular review process of planning assumptions for the ONFA Reference plan update. The most recent internal review was completed in 2016 at the time of the 2017 ONFA reference plan update. OPG also reviews all decommissioning assumptions on a yearly basis to determine if any changes are required. Specific to Pickering, a report was completed in 2015 to present the rationale for selecting OPG's 30 year deferred decommissioning strategy [R-21].

4.3 Benchmarking of OPG Decommissioning Cost Estimates

OPG's decommissioning strategy and costs are often benchmarked against industry practice. In 2012 OPG contracted with an external consultant to benchmark its current (2011) decommissioning cost estimates against industry practice and results [R-20]. The benchmarking study concluded that OPG's cost estimates are of a similar order of magnitude with other facilities similar in nature, location and size. The study also concluded that OPG's decommissioning cost projections are in line with industry practice The methodology used to benchmark OPG's cost estimates was based on converting all available data into the IAEA's International Structure for Decommissioning Costs (ISDC) structure so to allow for direct comparison and analysis.

4.4 OPG Decommissioning Process

The current OPG deferred decommissioning process is detailed in Appendix H. The process, including the staged activities, is used to form the basis of the OPG station decommissioning cost estimates.

In industry practice, *Safe Storage* is generally defined as "the strategy in which the nuclear facility is placed and maintained in a condition that allows the nuclear facility to be safely stored and subsequently decontaminated (deferred decontamination) to levels that permit release for unrestricted use."

The staged activities meet or exceed the requirements of G-206, G-219, and CSA N294-09 regarding nuclear generating station decommissioning.

The decommissioning stages included within each nuclear generating station cost estimate include:

- Stage 1 - Preparation for Safe Storage
- Stage 2 - Safe Storage
- Stage 3A - Preparation for Dismantling
- Stage 3B - Dismantling
- Stage 3C - Site Restoration

5.0 ASSUMPTIONS

The sections below describe the assumptions used to develop the various scenarios and to perform the analysis.

5.1 Safe Storage Scenarios and Assumptions

A principle objective of the cost study was to address the effect of the reduction of the safe storage period and its associated change in the constant $ and PV $ projected for the decommissioning of the nuclear generating stations. The reduction in the safe storage period is intended to approximate the impact of a prompt decommissioning approach.

The OPG reference case scenario includes a nominal 30 year safe storage period following the shutdown of the last unit in a given four unit station. To achieve reductions in the 30 year safe storage period, the baseline 2017 ONFA cost estimates were adjusted by TLG Services for the changes in safe storage periods at a macro level. For each scenario the specific changes to the cost estimate assumptions are provided in the appendices.

Appendices B to G of this document provide details for two additional scenarios intended to address a range of reasonable deferral periods. The scenarios include 11 year and 20 year safe storage periods.

For each scenario the appendices detail:

(1) The deferral dates for the start of dismantling and the completion of site restoration for the specific scenario. (All scenarios use the same shutdown dates as in the case of the 2017 ONFA reference plan.)
(2) The assumptions applied to the 2017 ONFA decommissioning cost estimates to adjust the safe storage period.
(3) The constant dollar and present value dollar liabilityfor the specific scenario.

Table 7 shows the high level assumptions applied to the decommissioning cost estimate scenarios in the form of adjustments to approximate the impact of the adjusted safe storage periods.

The scenario results are summarized in Section 6.0 of this document.

5.2 Unquantified Factors

In developing the adjustments to the 30 year deferred baseline cost estimates for the 11 and 20 year scenario cases a number of factors were identified which could not be cost quantified without a more detailed analysis. These included the following:

(1) More decontamination required during Dismantling (less decay) as compared to 30 year scenario.
(2) An increase in Work Difficult Factors during Dismantling due to less decay as compared to 30 year scenario.
(3) The impact of having Used Fuel on site post site-restoration for PNGS. (applicable for 11-year scenario)
(4) Reduce staff turnover thereby reducing hiring and training (applicable for 11-year scenario)
(5) Safe-Storage project and plant experience maintained reducing the amount of knowledge transfer required (applicable for 11-year scenario)
(6) Mitigation of the risk of records/documents being lost of unavailable during dismantling (applicable for 11-year scenario)
(7) Activities required to revise the DGR Operational Licence for emplacement of decommissioning waste as well as the risk of not getting the necessary approvals from the CNSC.

Table 7: Deferral Scenario Assumptions

Item	11-Year Scenario	20-Year Scenario
1	Shut down dates remain unchanged as compared to 30 year scenario.	Shut down dates remain unchanged as compared to 30 year scenario.
2	The safe-storage dormancy durations were reduced such that “Preparations for Dismantling” start immediately after all spent fuel has been removed from the spent fuel storage bays 11 years after station shutdown. (10 years cooling of fuel in wet bays and 1 year for fuel removal from wet bays.) Durations for Dismantling and Site Restoration remains unchanged as compared to 30 year scenario.	The safe-storage dormancy durations were reduced such that “Preparations for Dismantling” start 20 years after station shutdown. Durations for Dismantling and Site Restoration remains unchanged as compared to 30 year scenario.
3	Sequence of “unit” dismantling remains unchanged as compared to 30 year scenario.	Sequence of “unit” dismantling remains unchanged as compared to 30 year scenario.
4	The “starting” cash flows utilized for the Bruce Stations reflect the OPG Post Turnover Station Responsibility costs.	The “starting” cash flows utilized for the Bruce Stations reflect the OPG Post Turnover Station Responsibility costs.
5	Include cost of PHT flush in Prep for Safe-Storage. Note: TLG to use escalated costs from the 2012 Cost Estimate.	Include cost of PHT flush in Prep for Safe-Storage. Note: TLG to use escalated costs from the 2012 Cost Estimate.
6	Increase ILW containers by 25% as compared to 30 year scenario.	Increase ILW containers by 10% as compared to 30 year scenario.
7	Increase volume of Calandria Vault concrete in Pickering A by 10% as compared to 30 year scenario.	Increase volume of Calandria Vault concrete in Pickering A by 5% as compared to 30 year scenario.
8	Include $200M (includes contingency) for an additional Interim Storage facility required to store Pickering Heavy Water. Note 1: The cost will incur during the 2 years prior to Preparation for Dismantling. Note 2: The cost for transportation is assumed to be included in the $200M.	Include $200M (includes contingency) for an additional Interim Storage facility required to store Pickering Heavy Water. Note: The cost will incur during the 2 years prior to Preparation for Dismantling. Note 2: The cost for transportation is assumed to be included in the $200M.
9	Interim Heavy Water Storage yearly energy cost and operational and maintenance cost remains unchanged as compared to the 30 year scenario (i.e. $50K/year for heating for 5 years <u>per station</u> and $1.1M/year for operations and maintenance from <u>2023-2050 for PNGS</u>)	Interim Heavy Water Storage yearly energy cost and operational and maintenance cost remains unchanged as compared to the 30 year scenario (i.e. $50K/year for heating for 5 years and $1.1M/year for operations and maintenance <u>from 2023-2050 for PNGS</u>)

10	DGR Decommissioning timeline stays the same as compared to 30 year scenario. (2100-2105)	DGR Decommissioning timeline stays the same as compared to 30 year scenario. (2100-2105)
11	Stage 3 (Prep for Dismantling) Assumptions 1. Site Characterization – No change as compared to 30 year scenario. 2. Review and Revise Plant Dwgs & Specs – 50% reduction as compared to 30 year scenario. 3. Define Major Work Sequence – No change as compared to 30 year scenario. 4. Perform Site-specific Cost Analysis – No change as compared to 30 year scenario. 5. Prepare and Submit License Termination Plan – No change as compared to 30 year scenario.	Stage 3 (Prep for Dismantling) Assumptions 1. Site Characterization – No change as compared to 30 year scenario. 2. Review and Revise Plant Dwgs & Specs – No change as compared to 30 year scenario. 3. Define Major Work Sequence – No change as compared to 30 year scenario. 4. Perform Site-specific Cost Analysis – No change as compared to 30 year scenario. 5. Prepare and Submit License Termination Plan – No change as compared to 30 year scenario.
12	No impact to Preparation for Safe-Storage activities as compared to 30 year scenario. (e.g., heating, staffing, plant modifications, etc.)	No impact to Preparation for Safe-Storage activities as compared to 30 year scenario. (e.g., heating, staffing, plant modifications, etc.)
13	No change to Environmental Assessment costs during Stage 3 as compared to 30 year scenario.	No change to Environmental Assessment costs during Stage 3 as compared to 30 year scenario.
14	Pickering A – Units 2 and 3 have already completed Stage 1 resulting in a 20+ years difference between Stage 1 and Stage 3. No adjustments were made to the two units as compared to 30 year scenario (except for the revised safe-storage duration).	Pickering A – Units 2 and 3 have already completed Stage 1 resulting in a 20+ years difference between Stage 1 and Stage 3. No adjustments were made to the two units as compared to 30 year scenario (except for the revised safe-storage duration).

6.0 STUDY RESULTS

6.1 Safe Storage Period Impact (Deferred vs. Prompt Decommissioning)

OPG's deferred decommissioning strategy is sub-divided into a number of phases. These include Preparation for Safe Storage, Safe Storage, Preparation for Dismantling, Dismantling, and Site Restoration. The *safe storage* period extends for a nominal 30 years following the shutdown of the final unit of an OPG multi-unit station. A minimum safe storage period of 11 years is required to allow used fuel to cool sufficiently for 10 years before being transferred to dry storage containers for interim storage on-site which takes approximately 1 year.

The cost study considered safe storage periods varying between 11 and 20 years to approximate *alternative* decommissioning scenarios.

Table 8 illustrates the high level impact of varying the safe storage period from the OPG planned 30 year period. Results for safe storage periods of 11 years and 20 years are detailed in the table.

In total, for all OPG nuclear generating stations, a reduction of the safe storage period from 30 to 11 years reduces the constant $ liability by 3.7% or $526M but increases the PV by 17% or $729M.

To achieve the reduction to 11 years, the reference base cost estimate was adjusted such that "preparation for dismantling" activities were accelerated. Refer to Appendix B for details.

In the case of Pickering A and B, a reduction of the safe storage period from 30 to 11 years reduces the total constant $ liability by approximately 3% or $157M but increases the PV liability by 20% or $491M.

For comparative purposes the base case 2017 ONFA decommissioning costs were compared to the adjusted costs for each safe storage period. Under ONFA, OPG assumes that the Bruce A and B station decommissioning costs are offset by the conditions of the Bruce Lease between OPG and Bruce Power. Under the lease, both Bruce A and Bruce B will be returned (turned-over) to OPG at the same time to continue safe storage and for decommissioning in 2065. Using 2017 ONFA planning assumptions, prior to the turn-over date, safe storage costs for Bruce A and Bruce B units which shut down prior to this date will be incurred by Bruce Power.

Table 8: Impact of Variation in Deferred Decommissioning Periods

2017 Constant K$ (2017 Forward)

Station	Shutdown*	2017 ONFA** Cost	11 Yr Deferred Cost	11 Yr Deferred % Change	20 Yr Deferred Cost	20 Yr Deferred % Change
Pickering A	2022	$ 2,692,724	$ 2,479,530	-7.92%	$ 2,495,405	-7.3%
Pickering B	2024	$ 2,626,841	$ 2,683,006	2.14%	$ 2,690,427	2.4%
Bruce A	2062	$ 2,572,689	$ 2,446,526	-4.90%	$ 2,570,918	-0.1%
Bruce B	2063	$ 2,673,876	$ 2,600,301	-2.75%	$ 2,687,295	0.5%
Darlington	2055	$ 3,534,936	$ 3,366,178	-4.77%	$ 3,477,976	-1.6%
Total		$ 14,101,067	$ 13,575,541	-3.73%	$ 13,922,023	-1.3%

2017 PV K$ (2017 Forward)

Station	Shutdown*	2017 ONFA** Cost	11 Yr Deferred Cost	11 Yr Deferred % Change	20 Yr Deferred Cost	20 Yr Deferred % Change
Pickering A	2022	$ 1,255,877	$ 1,438,172	14.5%	$ 1,289,030	2.6%
Pickering B	2024	$ 1,213,645	$ 1,522,543	25.5%	$ 1,387,863	14.4%
Bruce A	2062	$ 514,458	$ 568,750	10.6%	$ 527,062	2.5%
Bruce B	2063	$ 507,882	$ 565,635	11.4%	$ 521,485	2.7%
Darlington	2055	$ 807,641	$ 933,280	15.6%	$ 821,567	1.7%
Total		$ 4,299,502	$ 5,028,379	16.95%	$ 4,547,007	5.8%

* last station unit per 2017 ONFA

** 30 year deferred 2017 forward before OPG oversight

Figures 2 to 4 illustrate the impact of the variation in the safe storage (deferral) period for OPG nuclear generating stations individually and in total.

Figure 2: Station Decommissioning Cost (Constant$)

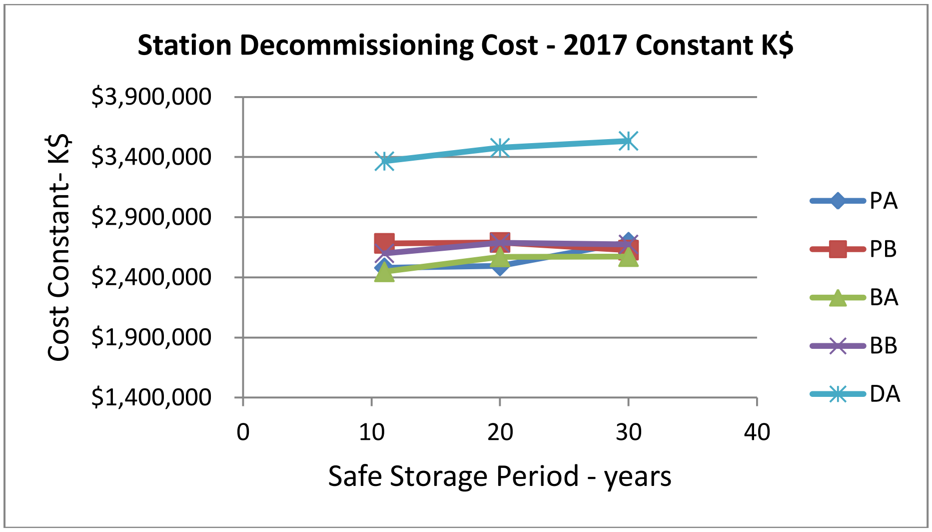


Figure 3: Station Decommissioning Cost (PV$)

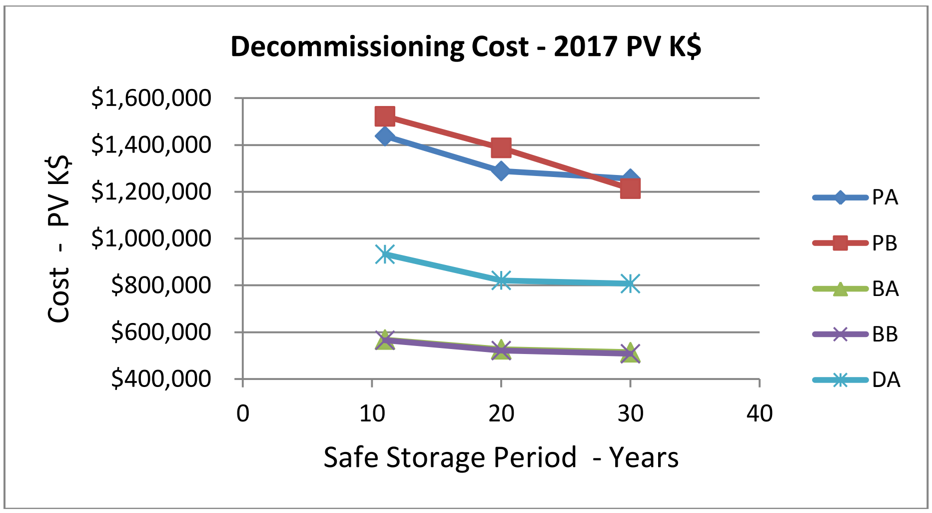
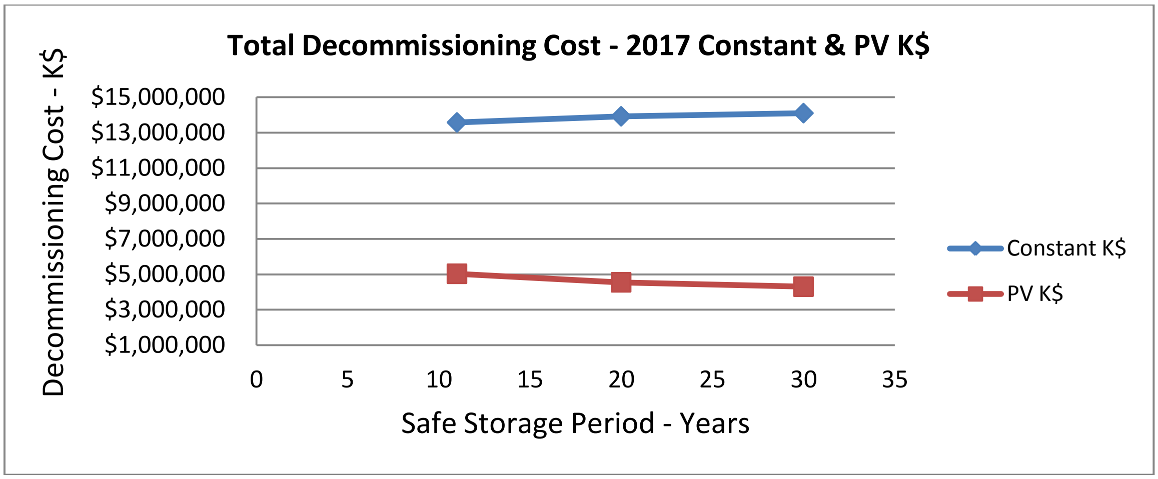


Figure 4: Total Decommissioning Cost All Stations



Refer to Appendices D and G for further details.

7.0 REFERENCES

[R-1] Nuclear Waste Forecasts for 2017 Ontario Nuclear Funds Agreement Update, W-REP-03460-10001, Published by OPG, 2016

[R-2] 2017 ONFA Reference Plan Update Program Summary Cost Estimate Report, W-REP-00400-00004, 2011

[R-3] Decommissioning Cost Study for the Darlington Nuclear Generating Station, NK38-REP-00962.2-10003, Rev. A. Published by TLG Services Inc., March 2016.

[R-4] Decommissioning Cost Study for the Pickering Nuclear Generating Station, P-REP-00962.2-00001, Rev. A. Published by TLG Services Inc., March 2016.

[R-5] Decommissioning Cost Study for the Bruce A Nuclear Generating Station, 06819-REP-00962.1-00001, Rev. A. Published by TLG Services Inc., March 2016.

[R-6] Decommissioning Cost Study for the Bruce B Nuclear Generating Station, 06819—REP-00962.2-00002, Rev. A. Published by TLG Services Inc., March 2016.

[R-7] Comparison of Pickering NGS A 2010 to 2015 (Rev A), P-REP-00962.2-00002, Published by TLG Services Inc. , March 2016.

[R-8] Comparison of Bruce NGS A 2010 to 2015 (Rev A), 06819-REP-00962.2-00003, Published by TLG Services Inc. , March 2016.

[R-9] Comparison of Bruce NGS B 2010 to 2015 (Rev A), 06819-REP-00962.2-00004, Published by TLG Services Inc., March 2016.

[R-10] Comparison of Darlington NGS 2010 to 2015 (Rev A), NK38-REP-00962.2-10004, Published by TLG Services Inc., March 2016.

[R-11] 2017 ONFA Reference Plan Update Decommissioning Summary Cost Estimate Report, W-REP-00960-00017-R00, 2016

[R-12] 2017 ONFA Reference Plan Update – Summary Report, W-REP-08620.05-00005, Published by OPG, April 2016

[R-13] 2017 ONFA Reference Plan Update Operational Oversight Cost Estimate Report, 00216-REP-03900-00012, 2016

[R-14] 2017 ONFA Reference Plan Update Segregated Fund Contribution, W-REP-03462-10038, Published by OPG, April 2016

[R-15] Decommissioning Strategies for Facilities Using Radioactive Material, IAEA Safety Report Series No 50, IBSN 92-0-113206-9, 2007

[R-16] Regulatory Document G-206 Financial Guarantees for the Decommissioning of Licensed Activities, Canadian Nuclear Safety Commission, June 2000

[R-17] Regulatory Document G-219 Decommissioning Planning for Licensed Activities, Canadian Nuclear Safety Commission, June 2000

[R-18] Canadian Standards Association, N294-09 (R2014), Decommissioning of Facilities Containing Nuclear Substances

[R-19] Review of OPG's Deferred Dismantling Strategy (2006 ONFA Update), W-REP-03462-10026-R00, August 2006

[R-20] OPG Report, "Benchmarking of Nuclear Power Plant Decommissioning Cost Estimates", N-REP-00960-0451799, Dec. 2012

[R-21] OPG Report, "Decommissioning Strategy for Pickering Nuclear Generating Station", P-PLAN-00960-00005-R000, October 2015

Appendix A: 2017 Decommissioning Waste Volumes

2017 Decommissioning Waste Volumes (M3)			
Facility	**LLW**	**ILW**	**LLW+ILW**
Darlington	47,042	3,572	50,614
Pickering A	33,509	2,864	36,373
Pickering B	28,483	2,890	31,373
Bruce A	27,692	3,479	31,171
Bruce B	29,057	3,566	32,623
Total Stations	**165,783**	**16,371**	**182,154**
Pickering WMF	191		
Darlington WMF	123		
WWMF	4,947		
RWOS1 & CMLF	1,199		
Total WMFs	**6,460**		
Grand Total	**172,243**	**16,371**	**188,614**

Appendix B: 11 Year Prompt Decommissioning Dates

Station/Unit	Unit In-Service Date	2017 ONFA (30 year deferred)			2017 Prompt (11yr deferred)	
		End of Life	Dism.	Site Rest. Complete	Dism.	Site Rest. Complete
Pickering A – Unit 1	Jul, 1971	2022	2051	2064	2035	2048
Pickering A – Unit 2/3	Dec, 1971 Jun, 1972	2005	2052/53		2036/2037	
Pickering A – Unit 4	Jun, 1973	2022	2054		2038	
Pickering B – Unit 5	May, 1983	2024	2055	2065	2039	2050
Pickering B – Unit 6	Feb, 1984	2024	2056		2040	
Pickering B – Unit 7	Jan, 1985	2024	2057		2041	
Pickering B – Unit 8	Feb, 1986	2024	2058		2042	
Darlington – Unit 1	Nov, 1992	2053	2084	2093	2068	2077
Darlington – Unit 2	Oct, 1990	2049	2085		2069	
Darlington – Unit 3	Feb, 1993	2052	2086		2070	
Darlington – Unit 4	Jun, 1993	2055	2087		2071	
Bruce A – Unit 1	Sep, 1977	2043	2086	2095	2075	2084
Bruce A – Unit 2	Sep, 1977	2043	2087		2076	
Bruce A – Unit 3	Feb, 1978	2061	2088		2077	
Bruce A – Unit 4	Jan, 1979	2062	2089		2078	
Bruce B – Unit 5	Mar, 1985	2061	2090	2099	2079	2088
Bruce B – Unit 6	Sep, 1984	2057	2091		2080	
Bruce B – Unit 7	Apr, 1986	2063	2092		2081	
Bruce B – Unit 8	May, 1987	2063	2093		2082	

Appendix C: 11 Year Prompt Assumptions

Note: Cash flows were developed from the baseline Safe-Storage scenarios (The four decommissioning cost studies [R 3 to 6]) using the following basic assumptions for the 11 yr deferred case:

General Cost adjustments made to achieve “11 Yr Deferred”.

1. The pre-shutdown and transition annual costs from the 30 year scenario were used directly for the annual costs through the end of wet fuel storage (11 years post shutdown). Subsequent Safe-storage years from the 30 year scenario were removed to achieve the shortened storage period.
2. Decon flush costs were added to the transition period costs for each unit. Costs were estimated by taking the costs from the previous estimate and escalating by the blended escalation rate provided by OPG.
3. Pre-dismantling Environmental Assessment costs and Pre-dismantling CNSC Fees are assumed to start at specific times in regard to the start of dismantling. Due to the removal of the “Pre-Dismantling” Safe-storage years to achieve the shortened duration, it was necessary to “overlay” these costs into their specific years. These costs were “overlayed” into the cash flow at the specified times (6 years and 3 years prior to dismantling start respectively). These are “common” costs applied to Unit 0.
4. Due to the shortened timeframe between shutdown and the start of Stage 3, the preparation for dismantling cost for “Review and Revise Plant Dwgs & Specs costs were adjusted down by 50%.
5. Calandria ILW containers and costs were adjusted by artificially increasing the number of ILW containers (25% for 11 yr scenario) in TLG’s calandria workbooks for each station. The increase in cost generated by the increase in containers was applied to each of the generating units.
6. The annual costs for the DGR Excavation (2039-2043) and DGR Decommissioning (2100-2105) remain in the currently assumed years.

Pickering Only (11 Year Scenario):

1. Pickering A, Units 2 & 3, due to early shutdown, no adjustments were made.
2. Activated concrete volume was adjusted for a 10% increase in Calandria Activated concrete for Units 1 & 4. This applies to Pickering A only.
3. A CAPEX cost of $200 million was added for the storage of heavy water off-site due to shortened Safe storage period. It is assumed that this OPG provided cost includes a 15% allowance and transportation. This cost is assumed to start 2 years prior to preparation for dismantling start of Pickering A and to be incurred for 2 years. These costs were applied to Pickering B.
4. Interim Heavy Water Storage yearly expenses are assumed to be unchanged as compared to the 30 year.

Bruce A Only (11 Year Scenario):

1. Bruce A, Units 1 & 2, due to earlier shutdown than Units 3 & 4, no adjustments were made.

Appendix D: 11 Year Scenario Results

Decommissioning Liability - ONFA 2017 30 Year Deferred vs 11 Year Prompt										
Case	Scenario	Pickering A	Pickering B	Bruce A	Bruce B	Darlington	Total	Incr to ONFA Case (All Prompt)	Incr to ONFA Case (PK Only)	Cost
ONFA 2017	30 Year Deferred	$ 2,692,724	$ 2,626,841	$ 2,572,689	$ 2,673,876	$ 3,534,936	$ 14,101,067			2017k$
		$ 1,255,877	$ 1,213,645	$ 514,458	$ 507,882	$ 807,641	$ 4,299,502			PV 2017 k$
Case 0.0	11 Year Prompt	$ 2,479,530	$ 2,683,006	$ 2,446,526	$ 2,600,301	$ 3,366,178	$ 13,575,541			2017k$
		$ 1,438,172	$ 1,522,543	$ 568,750	$ 565,635	$ 933,280	$ 5,028,379	**$ 728,877**	**$ 491,193**	PV 2017 k$
	Delta from ONFA (Constant$)	-$ 213,194	$ 56,165	-$ 126,164	-$ 73,576	-$ 168,758	-$ 525,526			2017k$
	Delta from ONFA (pv$)	$ 182,295	$ 308,898	$ 54,292	$ 57,753	$ 125,639	$ 728,877			PV 2017 k$

Fund Contributions Impact in K$			
Incr to ONFA Case (All Prompt)	Comments	Incr to ONFA Case (PK Only)	Comments
$ -	No Funding Impact	$ -	No Funding Impact

Title:

A PRELIMINARY ASSESSMENT TO DETERMINE THE FINANCIAL IMPACT OF USING A PROMPT DECOMMISSIONING APPROACH FOR OPG'S NUCLEAR GENERATING STATIONS

Appendix E: 20 Year Deferred Decommissioning Dates

Station/Unit	Unit In-Service Date	2017 ONFA (30 year deferred)			2017 Prompt (20yr deferred)	
		End of Life	Dism.	Site Rest. Complete	Dism.	Site Rest. Complete
Pickering A – Unit 1	Jul, 1971	2022	2051	2064	2044	2056
Pickering A – Unit 2/3	Dec, 1971 Jun, 1972	2005	2052/53		2045/2046	
Pickering A – Unit 4	Jun, 1973	2022	2054		2047	
Pickering B – Unit 5	May, 1983	2024	2055	2065	2046	2056
Pickering B – Unit 6	Feb, 1984	2024	2056		2047	
Pickering B – Unit 7	Jan, 1985	2024	2057		2048	
Pickering B – Unit 8	Feb, 1986	2024	2058		2049	
Darlington – Unit 1	Nov, 1992	2053	2084	2093	2077	2086
Darlington – Unit 2	Oct, 1990	2049	2085		2078	
Darlington – Unit 3	Feb, 1993	2052	2086		2079	
Darlington – Unit 4	Jun, 1993	2055	2087		2080	
Bruce A – Unit 1	Sep, 1977	2043	2086	2095	2084	2093
Bruce A – Unit 2	Sep, 1977	2043	2087		2085	
Bruce A – Unit 3	Feb, 1978	2061	2088		2086	
Bruce A – Unit 4	Jan, 1979	2062	2089		2087	
Bruce B – Unit 5	Mar, 1985	2061	2090	2099	2088	2097
Bruce B – Unit 6	Sep, 1984	2057	2091		2089	
Bruce B – Unit 7	Apr, 1986	2063	2092		2090	
Bruce B – Unit 8	May, 1987	2063	2093		2091	

Appendix F: 20 Year Deferred Assumptions

Note: Cash flows were developed from the baseline Safe-Storage scenarios (The four decommissioning cost studies (R 3 to 6]) using the following basic assumptions for the 20 yr deferred case:

General Cost adjustments made to achieve "20 Yr Deferred".

1. Decon flush costs were added to the transition period costs for each unit. Costs were estimated by taking the costs from the previous estimate and escalating by the blended escalation rate provided by OPG.
2. The shortened Safe-storage duration was achieved by removing the appropriate number of "typical" Safe-storage years from the middle of the 30 year scenario Safe-storage period.
3. Pre-dismantling Environmental Assessment costs and Pre-dismantling CNSC Fees are included in the annual "pre-dismantling" Safe-storage costs linked into the cash flow. Therefore, these costs do not need to be "overlayed" into the 20 year scenarios. These are "common" costs applied to Unit 0.
4. Calandria ILW containers and costs were adjusted by artificially increasing the number of ILW containers (10% for 20 yr scenario) in TLG's Calandria workbooks for each station. The increase in cost generated by the increase in containers was applied to each of the generating units.
5. The annual costs for the DGR Excavation (2039-2043) and DGR Decommissioning (2100-2105) remain in the currently assumed years.

Pickering Only (20 Year Scenario):

1. Pickering A, Units 2 & 3, due to early shutdown no adjustments were made.
2. Activated concrete volume was adjusted for a 5% increase in Calandria Activated concrete for Units 1 & 4. Pickering A only.
3. A CAPEX cost of $200 million was added for the storage of heavy water off-site due to shortened storage period. It is assumed that this OPG provided cost includes a 15% allowance and transportation. This cost is assumed to start 2 years prior to preparation for dismantling start of Pickering A and to be incurred for 2 years. These costs were applied to Pickering B.
4. Interim Heavy Water Storage yearly expenses are assumed to be unchanged as compared to the 30 year scenario.

Bruce A Only (20 Year Scenario):

1. Bruce A, Units 1 & 2, due to earlier shutdown than Units 3 & 4, no adjustments were made.

A PRELIMINARY ASSESSMENT TO DETERMINE THE FINANCIAL IMPACT OF USING A PROMPT DECOMMISSIONING APPROACH FOR OPG'S NUCLEAR GENERATING STATIONS

Appendix G: 20 Year Scenario Results

Decommissioning Liability - ONFA 2017 30 Year Deferred vs 20 Year Prompt											Fund Contributions Impact in K$			
Case	Scenario	Pickering A	Pickering B	Bruce A	Bruce B	Darlington	Total	Incr to ONFA Case (All Prompt)	Incr to ONFA Case (PK Only)	Cost	Incr to ONFA Case (All Prompt)	Comments	Incr to ONFA Case (PK Only)	Comments
ONFA 2017	30 Year Deferred	$ 2,692,724	$ 2,626,841	$ 2,572,689	$ 2,673,876	$ 3,534,936	$ 14,101,067			2017k$				
		$ 1,255,877	$ 1,213,645	$ 514,458	$ 507,882	$ 807,641	$ 4,299,502			PV 2017 k$				
Case 0.0	20 Year Prompt	$ 2,495,405	$ 2,690,427	$ 2,570,918	$ 2,687,295	$ 3,477,976	$ 13,922,023			2017k$				
		$ 1,289,030	$ 1,387,863	$ 527,062	$ 521,485	$ 821,567	$ 4,547,007	**$ 247,505**	**$ 207,371**	PV 2017 k$	$ -	No Funding Impact	$ -	No Funding Impact
	Delta from ONFA (Constant$)	-$ 197,319	$ 63,587	-$ 1,771	$ 13,419	-$ 56,959	-$ 179,044			2017k$				
	Delta from ONFA (pv$)	$ 33,153	$ 174,218	$ 12,605	$ 13,603	$ 13,926	$ 247,505			PV 2017 k$				

Appendix H: OPG Deferred Decommissioning Stage Detail

The following sub-sections describe the activities associated with the current OPG deferred decommissioning approach. The stage descriptions have been extracted from the Darlington GS Decommissioning Cost Study but are common to all OPG nuclear generating stations. [R-3]

STAGE 1 – Preparation for Safe Storage

In anticipation of the cessation of station operations, detailed preparations are undertaken to provide a smooth transition from plant operations to site decommissioning. The organization required to manage the intended decommissioning program is assembled from available plant staff and outside resources, as required. Preparations include the planning for permanent defueling of the reactors, revision of technical specifications appropriate to the operating conditions and requirements, a characterization of the facility and major components, and the development of the safe storage plan.

At least four or five years prior to the scheduled shutdown, OPG would start conceptual engineering and planning of the decommissioning. Preliminary site radiological characterization would also be initiated at this time, with subsequent (more detailed) characterization performed as needed. OPG will submit a detailed decommissioning plan towards the end of the safe storage period consistent with the timing of an application for a decommissioning license to the CNSC. This submittal would include a description of the planned safe storage activities, a corresponding schedule, and an estimate of expected costs. It would also address any un-reviewed environmental impacts associated with the proposed decommissioning scenario. Existing operational technical specifications will require review and modification to reflect plant conditions and the safety concerns consistent with permanent cessation of operations.
The process of placing a unit in safe storage includes, but is not limited to, the following activities, which are expected to occur after unit shutdown:

- Defuel the reactor, transferring the used fuel to the intermediate storage pool. This activity will be carried out by plant personnel in accordance with existing operating technical specifications. The existing used fuel storage facilities will continue to operate until the used fuel is either transferred to the fuel repository or to dry storage.
- Drain the heavy water from the moderator and primary heat transport systems.
- Drain/de-energize/secure all non-contaminated systems not required to support dormancy operations.
- Dispose of contaminated filter elements and resin beds not required for processing wastes from decontamination activities.
- Drain/de-energize/secure all contaminated systems. Decontaminate systems as required for future maintenance and inspection.
- Prepare lighting and alarm systems whose continued use is required. Consistent with any code requirements de-energize and/or secure portions of fire protection, electric

power, and heating, ventilation and air-conditioning (HVAC) systems whose continued use is not required.

- Clean loose surface contamination from building access pathways.
- Perform a site characterization of the plant and the licensed site.
- Perform an interim radiation survey of plant; post warning signs as appropriate.
- Erect physical barriers and/or secure all access to radioactive or contaminated areas, except as required for controlled access, i.e., inspection and maintenance.
- Install security and surveillance monitoring equipment and relocate security fence around secured structures, as required.

The cost estimates assume that demolition would be delayed for those structures located outside the secured area (licensed area) until after all radioactive material in excess of release levels has been removed.

STAGE 2 – Safe Storage

Activities required during the planned dormancy period for the Safe Storage strategy include 24-hour security, preventive and corrective maintenance on security systems, area lighting, general building maintenance, fire protection, heating and ventilation of buildings, routine radiological inspections of contaminated structures, maintenance of structural integrity, and a site environmental and radiation monitoring program. The duration of the dormancy period was selected such that the dismantling operations are initiated after a nominal period of 30 years.

Equipment maintenance, inspection activities, and routine service are performed by resident maintenance personnel. This work force will maintain the structures in a safe condition, provide adequate lighting, heating, and ventilation, and perform periodic preventive maintenance on essential site equipment.

An environmental surveillance program is carried out during the dormancy period to ensure that potential adverse releases of radioactive material to the environment are controlled and prevented. Appropriate emergency procedures are established and initiated for releases that could exceed prescribed limits. The environmental surveillance program constitutes an abbreviated version of the program in effect during normal plant operations. A small plant staff is maintained during this period to support the maintenance, inspection, and surveillance programs.

Security during the dormancy period is conducted primarily to prevent unauthorized entry and to protect the public from the consequences of its own actions. Security will be provided by the security fence, sensors, alarms, surveillance equipment, etc., that must be maintained in good condition for the duration of this period. Fire and radiation alarms are also to be monitored and maintained.

STAGE 3A – Preparations for Dismantling

After a nominal 30 year safe storage period and in anticipation of dismantling, detailed preparations are undertaken to provide a smooth transition from safe storage to site dismantling. The organization required to manage the intended dismantling activities is assembled from available plant staff at Darlington and other OPG stations, and from outside resources as required. Preparations include a detailed physical and radiological characterization of the facility and major components, and the development of the dismantling or license termination plan.

Planning would include a site characterization, description of the dismantling activities, plans for site remediation, detailed plans for the final radiation survey, designation of the end-use of the site, an updated cost estimate to complete the dismantling, and any associated plans for environmental remediation.

Although the initial radiation levels due to 60Co will decrease significantly during the safe storage period, the internal components of the calandria will still exhibit sufficiently high radiation dose rates to require remote sectioning due to the presence of long-lived radionuclides. Portions of the biological shield will still be radioactive due to the presence of activated trace elements with long half-lives (152Eu and 154Eu).

Decontamination will require controlled removal and disposal. It is assumed that radioactive corrosion products on inner surfaces of piping and components will not have decayed to levels that will permit unrestricted use or allow conventional removal. These systems and components are surveyed as they are removed and disposed of in accordance with the prevailing radiological release criteria.

Prior to the commencement of dismantling operations, preparations are undertaken to reactivate site services and prepare for dismantling. Activity specifications and detailed procedures are also developed at this time.

Engineering and Planning

The dismantling operations will be designed to accomplish the required tasks within the ALARA guidelines for protection of personnel from exposure to radiation hazards. It will also address the continued protection of the health and safety of the public and the environment during the dismantling activity.

Much of the work in preparing the plan is also relevant to the development of the detailed engineering plans and procedures. This work includes, but is not limited to:

- Site preparation plans for the proposed dismantling activities.
- Detailed procedures and sequences for removal of systems and components.
- Evaluation of the disposition and selection of the most suitable option for the calandria and its internals.

- Plans for decontamination of structures and systems.
- Design/procurement and testing of tooling and equipment.
- Identification/selection of specialty contractors.
- Procedures for removal and disposal of radioactive materials.
- Sequential planning of activities to minimize conflicts with simultaneous tasks.

Site Preparations

In preparation for dismantling, the following activities are initiated.

- Prepare site support and storage facilities, as required.
- Perform site characterization study to determine extent of site contamination.
- Clean all plant areas of loose contamination and process all liquid and solid wastes.
- Conduct radiation surveys of work areas, major components (including the calandria and internals), sampling of internal piping contamination levels, and primary shield cores.
- Correlate survey data and normalize for development of packaging and transportation procedures.
- Determine transport and disposal container requirements for activated materials and/or hazardous materials, including shielding and stabilization. Fabricate or procure such containers.
- Develop procedures for occupational exposure control, control and release of liquid and gaseous effluent, processing of radwaste including; resins, filter media, metallic and non-metallic components generated in dismantling, site security and emergency programs, and industrial safety.

STAGE 3B - Dismantling

Significant dismantling activities involve the following steps:

- Construct temporary facilities and modify existing storage facilities to support the dismantling activities. These may include a cutting station (for boilers and other large components), additional changing rooms and contaminated laundry facilities for increased work force, establishment of laydown areas to facilitate equipment removal, upgrading roads to facilitate hauling and transportation, and modifications to the reactor building to facilitate access of large/heavy equipment.
- Design and fabricate shielding and contamination control envelopes to support removal and transportation activities. Specify and/or procure specialty tooling and remotely operated equipment. Modify containment to support segmentation activities and prepare rigging for segmentation and extraction of heavy components, including the steam generators.
- Procure required shipping canisters, cask liners, and Industrial Packages (IPs) from suppliers.

- Conduct decontamination of components and piping systems as required to control (minimize) worker exposure. Remove, package, and dispose of all piping and components that are no longer essential to support dismantling operations.
- Remove steam generators for shipment and controlled disposal. The steam generators will be segmented prior to disposal. They are considered large objects which exceed the waste disposal facility size/weight guidelines. After segmentation, decontaminate exterior surfaces, as required, and seal-weld openings (nozzles, inspection hatches, and other penetrations). The segmented sections can serve as their own disposal containers provided that all penetrations are properly sealed and the internal contaminants are stabilized.
- At each calandria face, remove the fuelling machine bridge structure and insulated feeder cabinet which encloses the PHT headers and feeder tubes.
- Remove the PHT and moderator piping and pumps. Package the piping in IPs; the pumps are sealed with steel plate so as to serve as their own containers. Segment those components that are considered large object waste that exceed the waste disposal facility size guidelines. Ship piping and pumps for disposal.
- Install calandria segmentation system in reactor vault and test.
- Modify existing used fuel handling system in fuelling duct and Unit 0 to handle segmented portions of the calandria.
- Segment the calandria/shield tank structure, removing the ILW first. Major activities will include the following:
    - Install temporary shielding as necessary.
    - Remove all horizontal and vertical control elements and their associated drive mechanisms.
    - Cut welds and remove end fittings and pressure tubes from calandria; cut into lengths to fit shielded cask liners for disposal.
    - Cut welds and remove calandria tubes from calandria structure; cut into lengths to fit shielded cask liners for disposal.
    - In parallel with the pressure tube and calandria tube removal, begin removal of the steel shot in the calandria faces. Shot removal must be coordinated with pressure tube and calandria tube removal to minimize area doses to segmentation crew.
    - Transport all waste to Unit 0 for packaging via modified used fuel handling system.
    - Segment the balance of the calandria structure.
- Remove the balance of the systems and equipment from the reactor vault, including the pressurizer and bleed cooler. These components will be segmented prior to disposal. They are considered large object waste that exceeds the waste disposal facility size guidelines. Decontaminate exterior surfaces, as required, and seal-weld openings (nozzles, inspection hatches, and other penetrations). The segmented sections can serve as their own disposal containers provided that all penetrations are properly sealed and the internal contaminants are stabilized.
- Remove systems and associated components as they become non-essential to the vessel removal operation, related decommissioning activities, or worker health and

safety (e.g., waste collection and processing systems, electrical and ventilation systems, etc.).

- Remove activated concrete biological shield and accessible contaminated concrete. Remove those portions of the associated enclosures necessary for access and component extraction.
- Remove contaminated equipment and material from the Central Service Area, Fuelling Facilities Auxiliary Areas, D2O and TRF facilities, and Vacuum Structure. Remediate until radiation surveys indicate that the structure can be released for unrestricted access.
- Remove all remaining LLW and ILW along with any remaining hazardous and toxic materials. Material removed in the decontamination and dismantling of the nuclear units will be routed to an on-site central processing area. Material that meets clearance criteria will be released for unrestricted disposition, e.g., as scrap, recycle or general disposal. Contaminated material will be characterized and packaged for controlled disposal at a licensed regional facility located in Ontario.
- Remove remaining components, equipment, and plant services in support of the area release survey(s).
- Conduct final radiation survey to ensure that all radioactive materials in excess of permissible residual levels have been remediated. This survey may coincide with the regulator's site inspection. A termination survey can be developed using a guidance document such as the "Multi-Agency Radiation and Site Investigation Manual," issued by the U.S. NRC. This manual delineates the statistical approaches to survey design and data interpretation. It also identifies state-of-the-art, commercially available, instrumentation and procedures for conducting radiological surveys. Use of guidance such as this ensures that survey design and implementation are conducted in a manner that provides a high degree of confidence that applicable criteria are satisfied. Once the survey is complete, the results are provided to the regulator(s) in a format that can be verified. The regulator can then review and evaluate the information, perform an independent confirmation of radiological site conditions, and make a determination on final abandonment of the decommissioning license.

STAGE 3C – Site Restoration

Site restoration activities may begin following the completion of dismantling operations. Efficient removal of the contaminated materials and verification that residual radionuclide concentrations are below regulatory limits will result in substantial damage to many of the structures. Blasting, coring, drilling, scarification (surface removal), and the other decontamination activities will substantially damage power block structures including the reactor vault, reactor auxiliary bay, fuelling facilities auxiliary areas and central service area. Verifying that subsurface radionuclide concentrations meet site release requirements may require removal of grade slabs and lower floors, potentially weakening footings and structural supports. This removal activity will be necessary for those facilities and plant areas where historical records, when available, indicate the potential for radionuclides having been present in the soil, where system failures have been recorded, or where it is required to confirm that subsurface process and drain lines were not breached over the operating life of the station.

It is assumed that non-essential structures and site facilities will be dismantled as a continuation of the decommissioning activity. Foundations and exterior walls are assumed to be removed to a nominal depth of one meter below grade whenever possible. Foundation grade slabs greater than one meter in thickness are abandoned in place and covered over with a one meter layer of fill. The one meter depth allows for the placement of both gravel for drainage and topsoil for erosion control through vegetation. Site areas affected by the dismantling activities are cleaned and the plant area graded as required to prevent ponding and inhibit the resurfacing of subsurface materials. Activities include:

- Perform demolition of the remaining portions of the reactor auxiliary bays, reactor vaults, fuelling facilities auxiliary areas, and central service area. Internal floors and walls are removed from the lower levels upward, using controlled blasting techniques. Concrete rubble and clean fill produced by demolition activities are used on-site to backfill voids. Suitable materials can be used on site for fill; otherwise the rubble is trucked off site for disposal as construction debris.
- Remove remaining buildings using conventional demolition techniques for above ground structures, including the turbine halls, vacuum building, and other site structures.
- Prepare the final decommissioning program report.
- Apply for a License to Abandon from the CNSC.