THE D2O STORAGE PROJECT

1.0 OVERVIEW

This Exhibit supports OPG's request to incorporate the remaining $494.7M[1] of capital cost for the Heavy Water Storage and Drum Handling Facility ("D2O Storage Project" or "project)[2] at the Darlington Nuclear Generating Station ("Darlington") into its rate base. The D2O Storage Project is a Facilities and Infrastructure Project within the scope of the Darlington Refurbishment Program ("DRP") because it is necessary to enable execution of the unit refurbishments, in addition to supporting ongoing station and Tritium Removal Facility ("TRF") operations. The cost of the D2O Storage Project is included within the $12.8B estimate to complete the DRP.

The D2O Storage Project was undertaken: (1) to provide storage of tritiated heavy water[3] and processing capability for the removal of heavy water from Darlington units undergoing refurbishment; (2) to assist with the management of heavy water at Darlington during normal operations; and (3) to provide additional storage capacity necessary to improve the functionality of OPG's TRF and support the outages necessary to extend its operating life. CANDU reactors cannot operate without heavy water, which is necessary for both their moderator and primary heat transport ("PHT") systems. See Attachment 1 for an Introduction to Heavy Water and its use in CANDU Reactors.

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[1] The total cost of the project is $510M, consisting of $509.3M in capital and $0.7 in OM&A for removal costs incurred in 2013. Of the $509.3M in capital cost, the $14.6M placed in service in 2014 has already been approved for inclusion in rate base and is reflected in the rate base approved in EB-2016-0152. In the EB-2013-0321 Decision with Reasons (pp. 58-59), the OEB originally approved a forecast in-service amount greater than $14.6M over 2014-2015 and subsequently approved the Capacity Refurbishment Variance Account ("CRVA") balances at December 31, 2014 (EB-2014-0370) and December 31, 2015 (EB-2016-0152) that trued up the revenue requirement impacts to the $14.6M actual in-service amount (e.g. see EB-2016-0152: Ex. L-2.2-1 Staff-008 and Ex. L-9.1-1 Staff-210).

[2] The D2O Storage Project building is sometimes referred to in project documentation as the Heavy Water Management Building West Annex or Heavy Water Storage Facility, but for simplicity and consistency with past filings, this evidence uses the terms "D2O Storage Project" or "project" throughout.

[3] The terms "heavy water" and the simplified chemical symbol "D2O" are used interchangeably in this document to refer to Deuterium oxide. For a discussion of D2O, how it is used in CANDU reactors and the function of the TRF, see Attachment 1.

The project scope was to build a facility to store 2.1 million litres (or 2,100 m^3) of heavy water in tanks that meet the nuclear safety requirements necessary to address the radiological hazard posed by tritium in the heavy water.

This Exhibit describes the construction of the D2O Storage Project and how OPG was able to successfully complete the project. Because the project was inherently complex and difficult to design, engineer and construct, the evidence that follows is necessarily detailed to provide an understanding of the challenges that OPG encountered and overcame. The sections that follow present the D2O Storage Project's history from its pre-Darlington refurbishment origins in 2005 through to its completion in 2020, when the facility supported the refurbishment of Unit 3 by storing the heavy water drained from its PHT system.

This evidence explains the construction of this first of a kind, multifaceted facility within the protected area of Darlington,[4] while the station was undergoing refurbishment and the resulting costs. The evidence details the many systems that must work together to safely provide the functionality that the facility delivers. These systems are necessitated by the properties of heavy water and the requirement that OPG, at all times, safeguard the health of its employees and the public, and protect the environment and its assets. Despite the many issues discussed below, OPG was able to complete this complex project safely and with quality, thereby delivering benefits to Ontarians during the DRP and throughout Darlington's post-refurbishment life.

The evidence also addresses the costs of the project. It explains why the initial cost estimates were unrealistically low and did not reflect the full scope and cost of the project, as they were completed before project design was finished and before engineering began. The evidence also explains how the risks and complexity of the project were underestimated by two experienced nuclear industry contractors retained to engineer, procure materials for and construct the project. Both contractors significantly under-forecast the project's duration and

[4] The protected area of the Darlington Station houses the generating units and the facilities necessary to support their operation. Identification checks, physical barriers, armed security personnel, x-ray machines, and metal detectors are used to control access to the protected area and all entrants require radiation monitoring.

cost. The first of the two contractors was terminated by OPG based on performance. The second contractor ultimately agreed to complete the project for a maximum price that was tens of millions of dollars lower than the contractor's final cost to complete the project.

As shown in the independent expert report prepared by Bates White (see Ex. D2-2-11, Attachment 3), the $510M that OPG expended on the project is consistent with the cost to construct a facility with the functionality of the D2O Storage Project at the project's location inside the protected area of a nuclear generating station.

The evidence provides detailed information on the following:

- Section 2 – Introduction: Provides a high-level description of the D2O Storage Project and an explanation of why the project is needed. The section also provides OPG's capital in-service request for the project as well as the requested ratemaking treatment.
- Section 3 – Description of the D2O Storage Facility: Describes in detail the D2O storage facility including the building, its systems, components and functional capabilities.
- Section 4 – Origins of the D2O Storage Project and Section 5 – Merging the Refurbishment Heavy Water Storage and Operational Improvement Projects to Form the D2O Storage Project: Describe the origins of the project and why OPG ultimately chose to execute the D2O Storage Project among the alternatives assessed to meet station needs.
- Section 6 – Development of the D2O Storage Project: Discusses the preliminary work undertaken by OPG to better define the project including investigations into location, design, configuration and cost.
- Section 7 – Contracting for the D2O Storage Project: Details OPG's development of contracting options for the project and eventual decision to award the project to Black & McDonald ("B&M") as prime-contractor under an Extended Services Master Service Agreement ("ESMSA").
- Section 8 – Designing and Constructing the D2O Storage Project: Chronologically details the execution of the project by B&M from 2012 through to 2014, when OPG elected to terminate B&M based on performance.

- Section 9 – Project Execution by OPG and the Second Project Procurement: Continues the chronological detail of project execution during the period when OPG assumed the role of general contractor subsequent to B&M's termination (fall 2014 through 2015).
- Section 10 – Project Execution by the SNC-Lavalin/AECON Joint Venture ("CanAtom")[5] and Section 11 – Project Completion: Continue the chronological detail of project execution during the period when CanAtom was awarded the remainder of the project under an ESMSA, from spring 2015 to 2020 when the D2O Storage Project was completed. Also described is how OPG managed the storage of the heavy water from Unit 2 during its refurbishment.
- Section 12 – Commissioning and Related Activities: Describes the pre-commissioning and commissioning of the D2O storage facility.
- Section 13 – Business Case Summaries for the D2O Storage Project: Describes the evolution of the project's Business Case Summaries ("BCS") from the 2006 Developmental Release BCS for the Operational Improvement Project through to the 2018 Superseding Release Execution BCS.
- Section 14 – Conclusion: Concludes the Exhibit with a summary description of the challenges overcome by OPG in completing the project and the value it provides during the DRP and beyond.

Below are the Attachments to this Exhibit:

- Attachment 1 - Introduction to Heavy Water and its Use in CANDU Reactors
- Attachment 2 - D2O Storage Project Key Documents
  - 2a - Project Charter: Adding Heavy Water Storage/Drum Handling Facilities dated October 13, 2005
  - 2b - Project Charter: Refurbishment, Operational Improvement and Long Term D2O Storage dated August 18, 2010
  - 2c - Project Charter: Refurbishment, Operational Improvement and Long Term D2O Storage dated June 20, 2011

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[5] On February 7, 2018, the joint venture was rebranded and launched as CanAtom Power Group to reflect the collaborative efforts of each company in providing EPC services to OPG. For consistency, This Exhibit uses CanAtom throughout.

  - 2d - B&M ESMSA dated February 15, 2012
  - 2e - B&M ESMSA Amendment #1 dated June 28, 2013
  - 2f - B&M Purchase Order #217807 Rev. 11 – Final Revision (includes all previous revisions)
  - 2g - CanAtom ESMSA dated December 19, 2014
  - 2h - CanAtom ESMSA Amendment #1 dated July 7, 2015
  - 2i - CanAtom ESMSA Amendment #2 dated January 1, 2017
  - 2j - CanAtom Purchase Order #251088 Rev. 15 – Final Revision (includes all previous revisions)
  - 2k - 2006 Developmental Release BCS
  - 2l - 2011 Draft Developmental BCS
  - 2m - 2012 Full Release Definition BCS
  - 2n - 2012 Partial Release Execution BCS
  - 2o - 2013 Full Release Execution BCS
  - 2p - 2015 Superseding Release Execution BCS
  - 2q - 2018 Superseding Release Execution BCS
- Attachment 3 - List of Acronyms Associated with the Project
- Attachment 4 - Timeline of the Major Project Milestones
- Attachment 5 - Temporary Storage of Unit 2 Heavy Water

2.0 INTRODUCTION

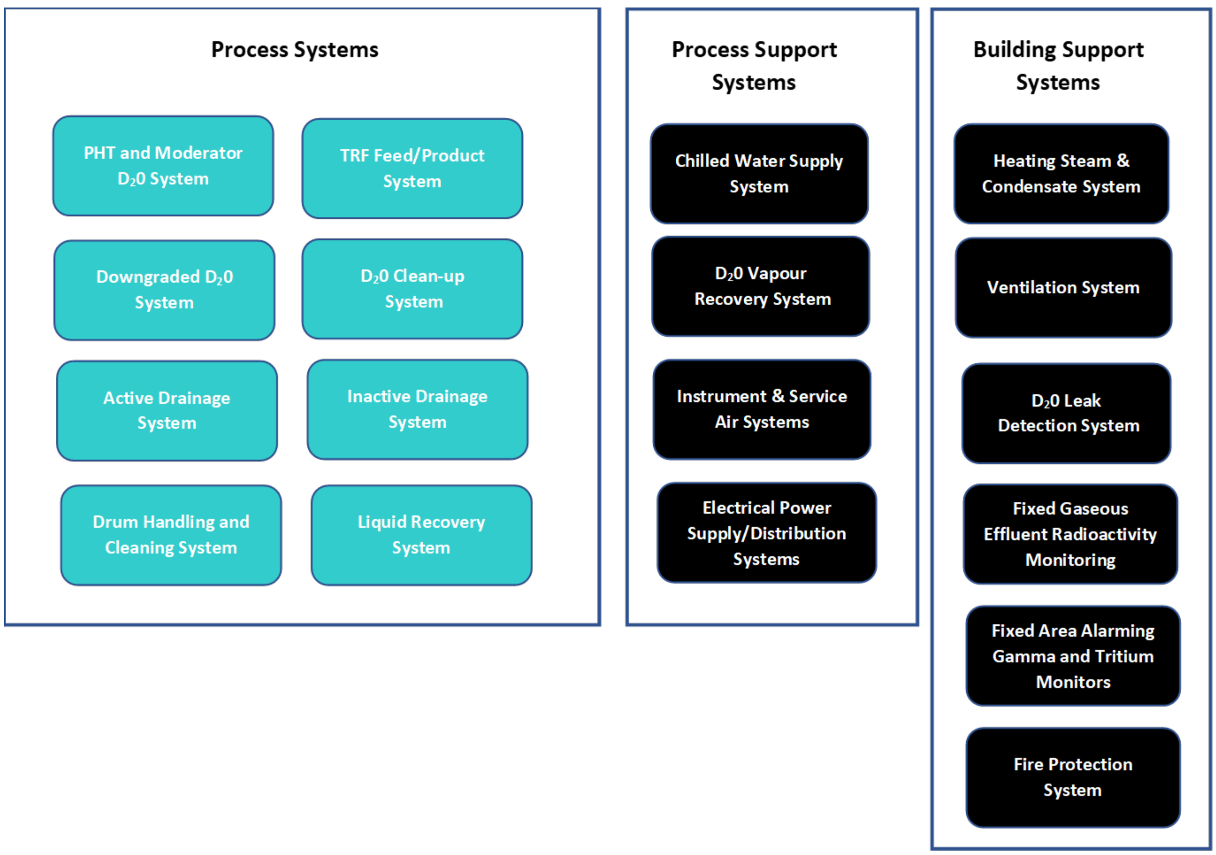
The sections that follow discuss the functionality and purpose of the D2O Storage Project and demonstrate that the $510M project cost accurately represents the cost of constructing this complex facility within the protected area of Darlington and under the conditions encountered.

2.1 What is the D2O Storage Project

The D2O Storage Project is a first-of-a-kind facility to store tritiated heavy water from Darlington units undergoing refurbishment and to support the operations of the TRF to remove tritium from heavy water, which is necessary to operate Ontario's nuclear fleet. To safely store various streams of heavy water, transport it to Ontario's operating nuclear facilities (directly to

Darlington via pipes and to the Pickering Nuclear Generating Station ("Pickering") and Bruce Nuclear Generating Stations ("Bruce") via OPG's radioactive material transportation program) and limit emissions, the project requires the systems shown in Figure 1. Each of these systems is fully explained in Section 3.

Figure 1 - D2O Storage Project Systems



Major elements of the project's construction involved:

- Relocating numerous pipes, cable lines and trailers that occupied the project site;
- Removing water during buried services removal and underground construction because the water table is approximately 2 to 2.5 m below the surface at the project site;
- Installation of a caisson wall (a concrete and steel shoring wall to support excavation) with tie backs into the surrounding soil and bedrock;
- Excavation 15 m below the surface to solid bedrock;

- Construction of a seismically qualified reinforced concrete dike that is 13 m deep and anchored to bedrock using 221 rock anchors;
- Placement of 25 large stainless steel nuclear grade[6] tanks within the seismic dike to store various streams of heavy water;
- Installation of three smaller nuclear grade stainless steel tanks required for the operation of the D2O Storage Project;
- Fabrication and installation of the nuclear grade stainless steel piping, valves, pumps and controls required to move heavy water among the tanks, to and from the adjacent Heavy Water Management Building ("HWMB"), and to the drum handling facility;
- Installation of active and inactive drainage systems;
- Connection of the piping in the D2O Storage Project facility to the HWMB via a seismically qualified tunnel that runs between the two facilities;
- Construction of a 16.5 m tall steel frame and concrete building above the dike;
- Erection of a 15.5 m monitored emission stack on the roof of the building;
- Installation of drum handling, testing and cleaning equipment on the ground floor of the facility;
- Installation of the electrical (including a 1,000 kW standby generator and battery backup), mechanical, alarm, heating and cooling, compressed air, vapour recovery for emission control and emission monitoring systems;
- Installation of instrument controls to integrate the D2O Storage Project facility's monitoring, operating and alarm systems with those of the HWMB to allow the facility to be operated remotely by personnel located in the control room of the HWMB; and
- Testing and commissioning all systems and ensuring that the tanks, valves and piping operate as designed, are clean and free of any foreign materials and do not leak.

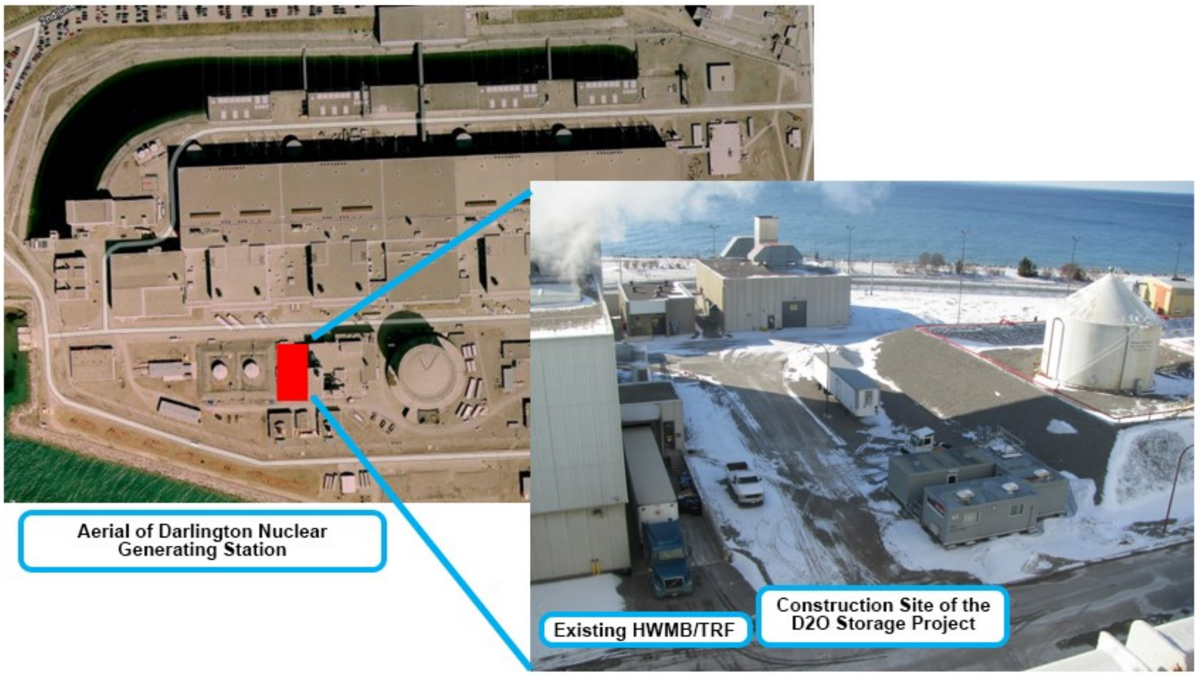
A timeline of the project's major milestones is included as Attachment 4.

[6] Nuclear grade materials are constructed to rigorous standards, including traceability of the materials used and requirements for testing, before they can be accepted for service.

The D2O Storage Project provides 1,500 m^3 of storage to accommodate the heavy water from the moderator and PHT systems of two Darlington units undergoing refurbishment simultaneously and 200 m^3 of storage to facilitate flushing and other support operations associated with refurbishment. The project also provides 400 m^3 of storage to improve ongoing heavy water operations at Darlington and at the TRF. The TRF provides detritiation services (i.e., the process of removing excess tritium from moderator and PHT systems in CANDU reactors to stay within operating and regulatory limits) to all the operating nuclear generating stations in Ontario. The drum handling, storage, testing and cleaning facility supports the regular transportation of heavy water to and from the Pickering and Bruce stations for Detritiation, and supports occasional heavy water transactions with other parties.

Figure 2 below contains a red box that situates the project site within the protected area of Darlington and a picture of the project site before construction began. As illustrated, the project site is adjacent to the HWMB/TRF (located to the east) because of the necessary integration with the tanks and piping in the HWMB and the operation of the TRF; the discharge building is to the north; Standby Generation Fuel Management Building No.1 is to the south; and the berm surrounding Standby Generator Fuel Oil Tank 2 is to the west. Prior to construction, the site housed temporary office trailers as shown below.

Figure 2 – Project Site Photographs Pre-Construction



2.2 The Purpose of the D2O Storage Project

The primary purpose of the D2O Storage Project is to support heavy water management for the DRP and, for the management of heavy water over the life of the Ontario nuclear fleet. Until the last Darlington unit is refurbished, 1,700 m^3 of the 2,100 m^3 of heavy water storage contained in the project will be used to support DRP; once DRP is complete, this storage capacity will support the Ontario nuclear fleet including the possible storage of heavy water upon completion of the planned Pickering shutdown. The remaining heavy water storage capacity, 400 m^3, supports ongoing operations at Darlington and the TRF. The drum cleaning, testing and storage facilities support the TRF and help meet the heavy water operational needs of Pickering and Bruce. The remainder of this section explains why the D2O Storage Project was required for these purposes.

2.2.1 <u>Supporting DRP</u>

The requirement for heavy water storage during refurbishment derives from the removal and replacement of all pressure and calandria tubes in the reactor core during Retube and Feeder

Replacement ("RFR"). Replacing these tubes requires draining and storing the heavy water from the PHT and moderator systems.

The refurbishment storage for two units undergoing refurbishment comprises: (1) 800 m^3 to store the heavy water from the PHT system (including auxiliaries), (2) 700 m^3 to store heavy water from the moderator system, and (3) 200 m^3 to store downgraded heavy water[7] produced during the drying and decontamination of the PHT system. The downgraded D2O storage used for decontamination is expected to be periodically available to station operations during the DRP, when not required for refurbishment.

The requirement to store two units' worth of heavy water is based on the DRP schedule. While early iterations of the DRP schedule contemplated a sufficiently long gap between each unit's refurbishment, such that only one unit at a time would have been drained,[8] OPG ultimately determined that, following Unit 2, aligning the refurbishment schedule with the units' remaining operating lives necessitated overlapping unit refurbishments. With the overlap, the D2O Storage Project must be able to store two unit's worth of heavy water. As discussed below in Section 5.2, OPG analyzed alternatives for storing two unit's worth of heavy water and concluded that the D2O Storage Project was the optimal solution to meet the need.

2.2.2 Addressing Ongoing Darlington Operational Needs and the TRF

As discussed below, prior to committing to the DRP, OPG had identified the need to increase heavy water storage at Darlington. Inadequate heavy water storage space at Darlington constrained OPG's ability to address competing demands for storage for outages and process needs. Increased storage was necessary to improve the management of heavy water during outages and the efficiency of detritiation.

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[7] Downgraded heavy water is heavy water that contains excess light water and may also contain impurities such as organic solvents. In order to be suitable for reactor use it must be upgraded to meet the requisite percentage of heavy water for reactor use and may also need to be cleaned to remove any impurities.
[8] The schedule without overlap assumed that there would be a minimum gap of 10 weeks between the refilling of one unit and the dewatering of the next unit, which was viewed as a sufficient gap to require only one unit's worth of heavy water storage.

More efficient detritiation capabilities also are necessary for OPG to meet the heavy water requirements of the entire Ontario nuclear fleet, including Pickering and Bruce. Detritiation is essential for health and safety reasons because it maintains tritium levels below the levels mandated by the Canadian Nuclear Safety Commission (“CNSC”) and OPG’s internal operating limits. In addition, detritiation is essential because heavy water is no longer produced on a commercial scale. Thus, the existing heavy water inventory must be managed for use throughout the operating lives of Ontario’s CANDU facilities and remain available to support their decommissioning.

With regard to TRF operations, the additional capacity created by the D2O Storage Project will: (1) allow greater storage of TRF feed and product to address any gaps between TRF availability and the demand for tritium removal, (2) enable the storage of additional heavy water to address periods when the TRF is undergoing an outage, (3) facilitate a more flexible schedule for heavy water shipments to and from Pickering and Bruce, and (4) potentially assist with heavy water management once Pickering operations end.

OPG also requires additional heavy water storage to execute its long-term plan to extend the life of the TRF. The TRF came into operation in 1989 and major components will reach end of life in 2025 absent life extension. Through a series of outages, OPG will be repairing and replacing equipment at the TRF to improve its operation and extend its life to match the lives of the refurbished Darlington units. The additional storage provided by the project will enable the storage of TRF feed and product during these life extension outages.

2.3 OPG’s Request and Ratemaking Treatment

OPG currently estimates that the total capital cost of the D2O Storage Project will be $509.3M. Chart 1 presents a breakdown of this figure into the major cost categories for the project’s expenditures.

Chart 1 - D2O Storage Project Capital Costs by Category

Cost Category	$M
OPG Project Management	$ 21.9
OPG Engineering	$ 13.3
OPG Procured Materials	$ 20.4
B&M and Sub-Contractors	$ 83.8
CanAtom and Sub-Contractors	$ 252.3
Other Contractors	$ 72.1
Interest	$ 45.5
Total	**509.3**

Elements of the D2O Storage Project were placed into service at various times as shown in Chart 2. In 2014, $14.6M was placed into service pursuant to the OEB's determination in EB-2013-0321.[9] The inclusion of the remaining $494.7M in OPG's rate base is requested in this application.

Chart 2 - Total D2O Storage Project Capital Additions by Year ($M)

2014	14.6
2016	160.0
2019	320.9
2020	13.8*
Total	**509.3**
Less amount previously placed in service	(14.6)
Total Requested Rate Base Addition	**494.7**

*The 2020 figure is the amount included in the 2020-2026 Business Plan, which forms the basis of OPG's application. A small portion of this amount (less than $0.1M) is expected to come into service in 2021. The actual in-service additions for 2020 and 2021 will be reconciled via entries in the CRVA.

[9] See Footnote 1

See Ex. D2-2-9, Table 5 for the D2O Storage Project capital project listing including in-service additions for the years 2016-2020.

The $160M placed in service in 2016 represents the costs of the seismic dike, five PHT storage tanks and the piping and equipment necessary to allow them to receive heavy water if required. These were declared useful once the seismic dike was complete, piping was installed to create a flow path to fill the PHT tanks with Unit 2 PHT heavy water, and the tanks were capable of storing heavy water. The $320.9M placed in service in 2019 represents the cost of the major process systems, process support systems and building support systems shown in Figure 1, above. The $13.8M being placed in service in 2020 represents the cost of the remaining equipment installed to complete the project, including radiation and tritium monitors, and system controls, and commissioning costs.

OPG requests that the remaining $494.7M be approved for inclusion in rate base based on the dates the various components were placed in service as discussed above. The revenue requirement impacts of these investments once in service have been recorded in the CRVA established under section 6(2) 4 of O. Reg. 53/05 and will continue to be recorded in the CRVA until the effective date for the payment amounts that include this project in the rate base.[10] OPG has proposed that deferral and variance account balances up to year-end 2019 be dispositioned as part of this application, which includes all unrecovered revenue requirement amounts from 2019 and earlier related to the D2O Storage Project, as discussed in Ex. H1-1-1.[11]

2.4 D2O Storage Project Business Case Summaries

The BCS for the project are discussed in Section 13 below and included as Attachments 2k – 2q. The D2O Storage Project was a first-of-a-kind project and the first major DRP project to be

[10] The revenue requirement approved in EB-2016-0152 included the tax impact of capital cost allowance ("CCA") deductions for forecasted capital expenditures on the D2O Storage Project as part of the CCA for the overall DRP expenditures, as set out in EB-2016-0152, Ex. F4-2-1, Table 3b, Note 3. The impact of the CCA for the D2O Storage Project expenditures was not removed from OPG's proposed revenue requirement in EB-2016-0152 Ex. N2-1-1.
[11] OPG has not sought recovery of any DRP-related CRVA balances, including those related to the D2O Storage Project, since the December 31, 2015 balances were last dispositioned in the EB-2016-0152 proceeding.

executed under the ESMSA using an Engineer, Procure and Construct ("EPC") contracting model. The initial estimates of the project's cost in the early BCS were prepared prior to the completion of the design, and before engineering. These estimates also did not reflect the full scope of the project, the functionality it ultimately provides and its complexity. As a result, they were unrealistically low. Moreover, the estimated cost did not fully reflect the conditions encountered during construction. For these reasons, the initial estimates should not be used in assessing the prudence of OPG's capital expenditures on the D2O Storage Project. Instead, the OEB should rely on the final BCS for the project, which was completed following the completion of all design work, with an approved maximum cost of $510M.[12]

2.5 Expert Report

OPG's counsel, Torys LLP, retained Bates White as an expert to provide an independent estimate of the cost to design, engineer, procure materials for, construct, and commission the as-built D2O Storage Project. Based on their review of the completed design and construction parameters, the Bates White team of experienced nuclear project personnel prepared an independent expert report entitled "Construction Cost Estimate for the Darlington Nuclear Generating Station D2O Storage Project," which is filed as Attachment 3 to Ex. D2-2-11.

Bates White concluded that the mean estimate of the total cost to complete the D2O Storage Project is $517.7M and the P90 estimate is $576.5M. This independent estimate validates that the $509.3M capital amount, which OPG is seeking to recover for the project, is representative of the expected cost to complete the D2O Storage Project.

3.0 DESCRIPTION OF THE D2O STORAGE FACILITY

3.1 Overview

The D2O Storage Project involved construction of a seismic dike and a concrete and steel building approximately 50.4 m long, 19 m wide and 16.5 m tall to house the tanks and

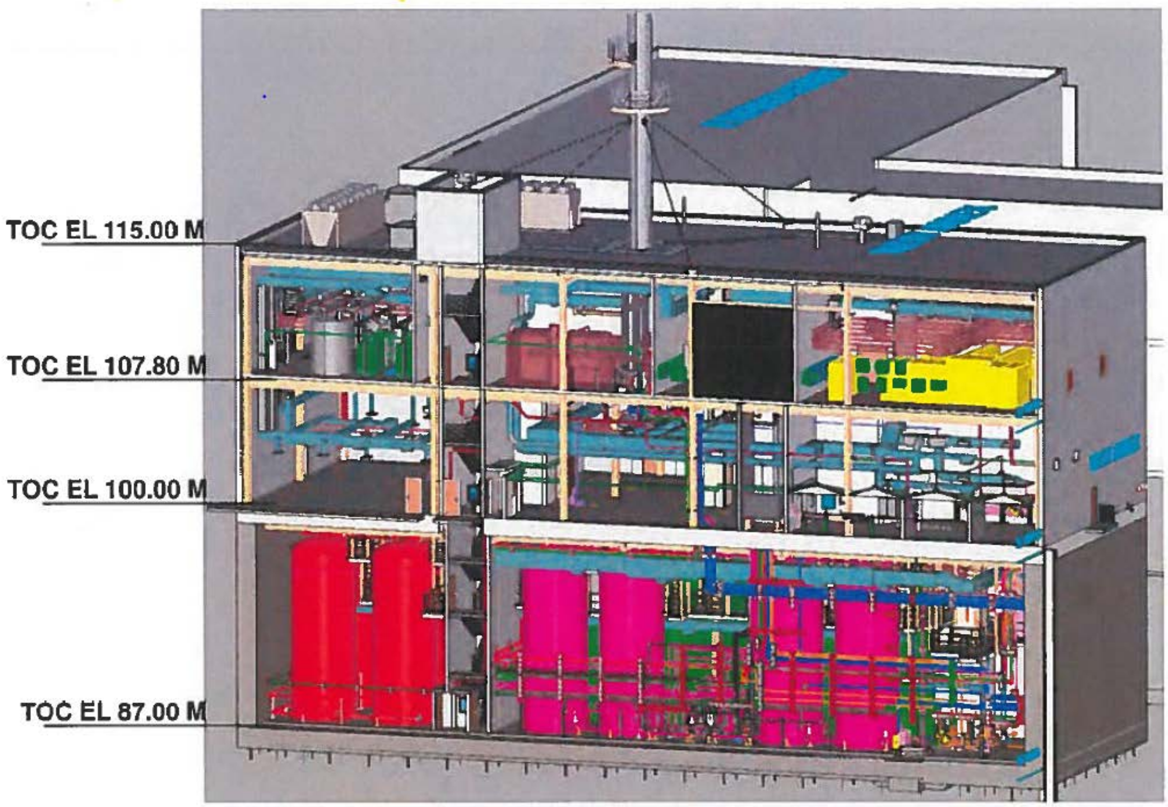
[12] See Attachment 2q, 2018 Superseding Release Execution BCS.

equipment necessary to store various streams of heavy water[13] and handle, clean, test and store the drums used to transport heavy water. Almost half of the facility is located underground with the floor of the seismic dike located 13 m below ground level.

The D2O Storage Project facility has three functional levels: (1) the seismically qualified dike, located at the basement level (elevation 87 m); (2) the drum handling and storage area, located on the first floor (elevation 100 m – at ground level); and (3) the electrical and mechanical systems and other equipment necessary to safely operate the building, located on the second floor (elevation 107.8 m). The first two levels of the building are aligned with the levels in the HWMB to facilitate movement of heavy water and equipment between the two structures. The purpose of each level and the equipment it contains are explained below.

[13] As discussed in Attachment 1, heavy water is used for both the moderator and PHT systems in CANDU reactors. The heavy water used in these two systems is kept separately because of the differences in the allowable concentration of tritium in each system. In addition, heavy water may become downgraded through the introduction of light water, requiring upgrading to increase the isotopic concentration of deuterium. Heavy water may also require cleaning if contaminants, such as organic carbon compounds, are introduced. All these streams of heavy water must be stored separately.

Figure 3 – Isometric View of the D2O Storage Project



In addition to the three main levels, there are also walkways, a service platform and a small concrete tunnel (“pipe chase”) at elevation 94 m, which contains the piping connecting the D2O Storage Project to the HWMB. At elevation 100 m there is a causeway connecting to the HWMB for the movement of D2O drums, people and equipment. An additional condensate platform housing a heat exchanger is located at elevation 104.3 m. A 15.5 m tall emissions stack is located on the roof (elevation 115 m).

The exterior building walls are composed of 0.3 m thick precast concrete panels. They extend from ground level (elevation 100 m) to the roof parapet at elevation 116.5 m. All exterior walls are fire-rated for two hours and provide fire separation between the new D2O Storage Project facility and the existing HWMB.

3.2 The Seismic Dike (Elevation 87 m)

As required by the National Building Code of Canada, the seismic dike is designed and engineered to safely contain the entire 2,100 m^3 volume of heavy water stored in the facility in the event an earthquake damages the tanks or piping causing a spill. By containing any heavy water released during an earthquake, the seismic dike is intended to ensure that tritium does not leak into the environment. The building code analysis and seismic requirements[14] cover Safety-Related Structures for CANDU nuclear plants, and set out the standards that the seismic dike must meet.

The project initially required that the Design Basis Earthquake ("DBE"),[15] which was used in the original analysis for design and construction of safety related systems at Darlington, be used in analyzing the seismic dike. Following OPG and CNSC review of the events at the Fukushima Daiichi Nuclear Power Plant, however, the Margin Design Earthquake ("MDE") replaced the DBE in the analysis for design and construction of the seismic dike. The MDE has an acceleration one and a half times stronger than that of the DBE; thus its use resulted in greater earthquake resistance for the facility. Because the entire dike is designed to withstand the ground movement associated with seismic activity, the individual tanks and piping contained within it were not required to be seismically qualified.

The floor and walls of the dike are reinforced concrete. Including the topping slab discussed below, the basement concrete floor is approximately 1.2 m thick. It is supported by a non-structural concrete sub-slab that is approximately 0.3 m thick, which was placed on the surface of the underlying bedrock as a level working surface from which to construct the building. The walls are 1.2 m thick. The concrete for the floor and walls was poured over a waterproof membrane. On the inside, the floor is fully coated by epoxy with a small strip of epoxy on the walls. The basement has concrete partition walls to separate areas holding different streams of heavy water and isolate the stairways.

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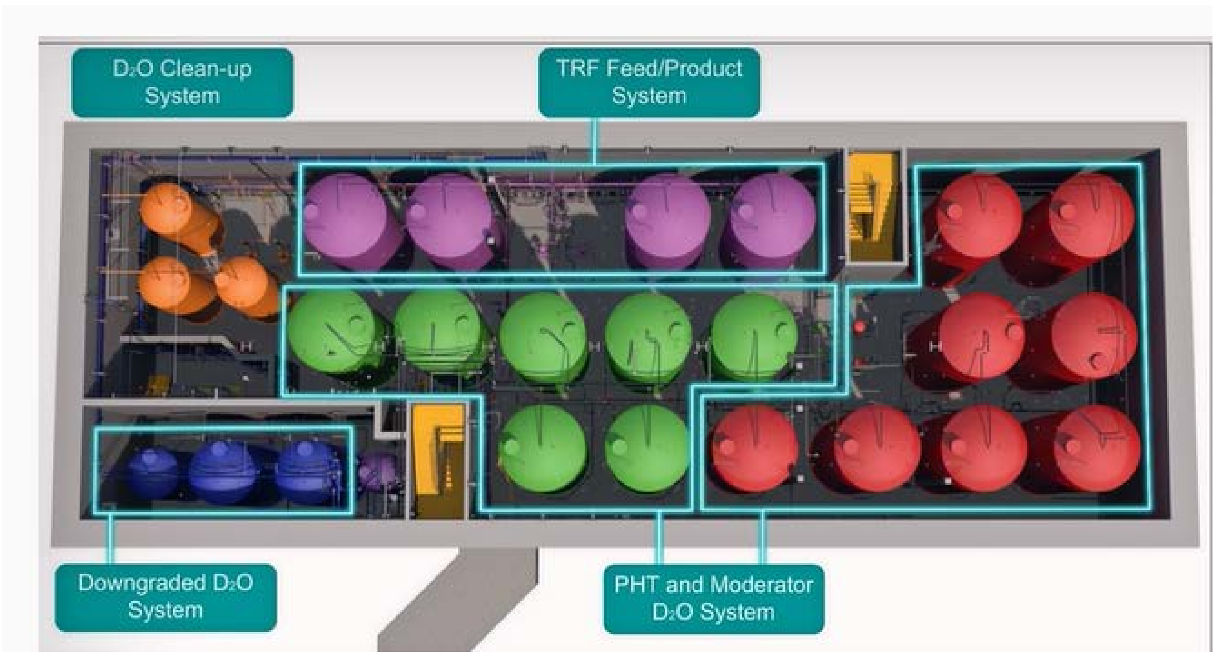
[14] Found in Canadian Standards Association 291-08 and the N289 series, respectively.
[15] The Design Basis Earthquake is defined as: an artificial representation of the combined effects, at the site, of a set of possible earthquakes having a very small probability of being exceeded during the life of the plant.

Figure 4 – Tank configuration within the Seismic Dike



The seismic dike holds 25 storage tanks (shown in Figure 4 above), grouped into four sub-systems: (1) D2O Supply System, which includes PHT tanks (eight red tanks) and Moderator (seven green tanks); (2) TRF Feed & Product System (four violet tanks); (3) Downgraded D2O System (three blue tanks); and (4) D2O Cleanup System (three orange tanks). These sub-systems contain various streams and volumes of heavy water as follows:

- 8 x 100 m^3 tanks store PHT D2O Supply;
- 7 x 100 m^3 tanks store Moderator D2O Supply;
- 4 x 100 m^3 tanks store TRF product (2 tanks) and feedstock (2 tanks);[16]
- 3 tanks (two 50 m^3 tanks and one 25 m^3 tank) store Downgraded D2O; and
- 3 x 25 m^3 tanks store D2O Cleanup.

[16] The TRF “product” is detritiated heavy water and the TRF “feedstock” is tritiated heavy water.

The total available capacity[17] of these 25 tanks is 2,100 m^3. For more information on the various uses of heavy water, please see Attachment 1.

The project also includes three smaller tanks that are not routinely used to store heavy water. The relief valve discharge tank is a 22 m^3 stainless steel tank intended to hold any excess heavy water discharged from the relief valves of the storage tanks described above in the event of an over-pressure incident. It is located within the seismic dike at elevation 87 m (the smaller purple tank located adjacent to the Downgraded D2O tanks in Figure 4, above). The inactive and active drainage tanks are two stainless steel tanks, each with a capacity of 3.8 m^3. They are located within the seismic dike at elevation 94 m above the downgraded heavy water pump room. The inactive tank collects water from drains on elevations 104 and 107.8 m. The active tank collects any heavy water and water that enters the active drainage system. This system routes the water collected for cleanup and upgrading.

[17] The Heavy Water storage tanks were designed with a safety margin of 10% (i.e., each tank is sized 10% greater than its rated capacity). As a result the D2O project actually includes 2,310 m^3 of total storage space, but only 2,100 m^3 is used to store heavy water.

Figure 5 – Active and Inactive Drainage Tanks at Elevation 94 m

The D2O storage tanks and associated piping and valves are constructed of stainless steel. Maintaining the chemical parameters of the heavy water is critical because the D2O system cannot accept corrosion or its by-products. The tanks and the associated piping and valves are all nuclear grade. The tanks generally are Class 6 nuclear grade, except for those storing moderator heavy water, which were constructed to the more stringent Class 3 nuclear grade because the moderator heavy water is more radioactive.

The D2O storage tanks were constructed in Cambridge, Ontario. They were shipped to the project individually via specialized low level float trailers resting in wooden bunks. Once all the tanks were received, they were lifted into the basement using cranes. Because of their size (each of the nineteen 100 m^3 tanks has a diameter of about 3.8 m and a height of approximately 11 m, which is taller than a typical three-story building), it was necessary to place the tanks in the seismic dike prior to completing the ground level floor slab. The floor slab forms the roof of the seismic dike and the base for the remaining floors of the D2O Storage Project building.

The storage tanks are connected to the D2O Supply System, Downgraded D2O System and D2O Cleanup System in the HWMB. This allows the facility to receive, store and send heavy water to the following systems and locations:

- Station Upgrader,
- Moderator System,
- PHT D2O Transfer,
- D2O Supply,
- Downgraded D2O Transfer,
- D2O Cleanup,
- TRF product/feed, and
- D2O drums.

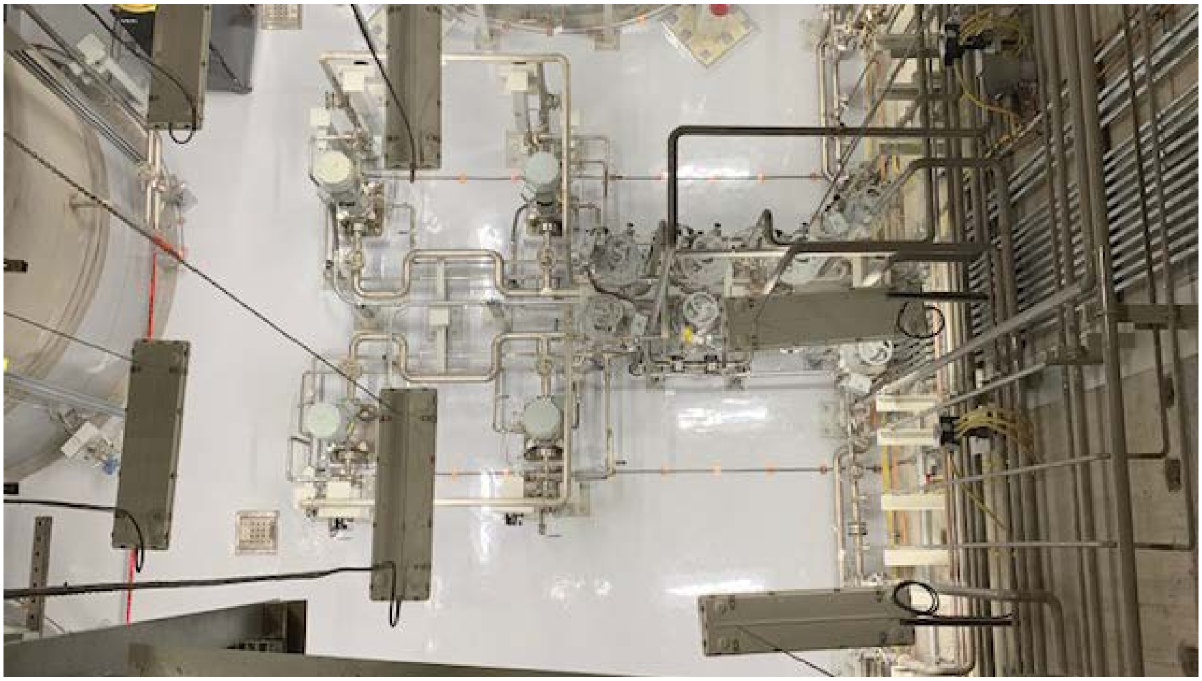
The listed sources address D2O steams used for different purposes within heavy water reactors and that contain different tritium[18] concentrations. OPG sets the standard for tritium concentration in the Darlington moderator system at less than or equal to 30.0 curies/kilogram (“Ci/kg”), and in the Darlington PHT system at less than or equal to 1.2 Ci/kg. The maximum tritium concentration for feed water at the inlet of the TRF feed treatment process is 34 Ci/kg. Both the downgraded heavy water transfer and D2O cleanup systems contain heavy water with a maximum tritium concentration of 10.0 Ci/kg.

[18] Tritium is the only radioactive isotope of hydrogen. The nucleus of a tritium atom consists of a proton and two neutrons. This contrasts with the nucleus of an ordinary hydrogen atom (which consists solely of a proton) and a deuterium atom (which consists of one proton and one neutron. See Attachment 1 for more information on heavy water and tritium.

The heavy water tanks are connected to the HWMB, and each other, through a complex array of pipes, valves and pumps. Each tank has a header which allows for multiple connections. For example, the tanks holding moderator heavy water are all interconnected to allow transfers among them and they are connected to the Darlington units' moderator systems (through the HWMB). The piping configuration allows rapid transfer to and from each unit's moderator system and independent filling and emptying of each tank. Connections between the tanks and the drum handling system allow for the filling and emptying of drums. Each tank can be isolated and drained if necessary.

Figure 6 – Piping Connections for the Moderator Tanks

Figure 7 – Overhead View of Piping and Vales for the TRF Feed/Product Heavy Water Stream



The heavy water in the tanks is covered by dry air to reduce potential contamination and limit emissions. The air is dried because moisture in the air can contaminate the heavy water by introducing conventional water (i.e., H_2O). The dry air is supplied by the instrument/service air system discussed in Section 3.4.2. The tanks include vent lines with pressure monitors to avoid over-pressurization.

If any heavy water were to escape during operations, an active drainage tank and liquid recovery sump are in place to capture any spilled heavy water and divert it to the downgraded heavy water system for processing.

The D2O Storage Project includes the design and installation of a new control panel located in the HWMB in close proximity to the existing control panel. The new control panel can monitor the D2O Storage Project tank volumes and vent line pressures and indicate alarms when levels or pressures reach high or low set points. Through the control panel, the operator can control and monitor each pump and each pneumatic valve. The project also includes local instrument panels beside the tanks.

A two-stage vapour recovery system was installed to capture and recycle tritium released during tank operations to minimize any emissions. OPG required a two-stage vapour recovery system for the D2O Storage Project to limit its tritium emissions to no more than 50 Ci/year (about 1 Ci/week). This requirement was made pursuant to OPG's tritium reduction initiatives. Under the DRP Environmental Assessment ("EA"), OPG committed that the DRP would not increase net tritium emissions and the two-stage vapour recovery system was employed as one of OPG's actions to meet this commitment.

The cover gas from the tanks is vented through vapour condensers to reduce the amount of D2O in the vapour entering the vapour recovery system. The two-stage vapour recovery system includes a first stage dryer, an evaporative cooler, and a second stage dryer. The first stage dryer removes D2O by drying it, condensing out the D2O in a chiller and routing the condensate to downgraded D2O storage tanks. The evaporative cooler uses demineralized water to cool and moisturize the dried air from the first stage dryer. The resulting vapour is then routed to the second stage dryer where it is again dried, and any remaining D2O is condensed out and routed to the downgraded D2O storage tanks. The exhaust from the second stage dryer is sent to the exhaust system stack filters. It is assessed by the stack monitor and then exhausted through the roof top emissions stack unless it exceeds emission standards. In this way, the vapour recovery system helps protect workers from exposure and prevents tritium releases to the environment.

The tank storage level includes monitoring and alarms for heavy water spills, airborne tritium emissions and smoke. Alarms are triggered onsite and in the HWMB control room if any of these conditions occur.

Smoke detectors are used to detect fire in the building. Laser beam detectors warn of fire risk due to smoke from equipment failure (e.g., if the motors used to move heavy water were to ignite). If the smoke breaks one of the multiple laser beams above the equipment, an alarm is triggered in the HWMB control room. Controllers respond by making a fire announcement over the public address system in the facility. The D2O Storage Project was able to forego installation of a sprinkler system for fire suppression because there is very little combustible material in the building.

Walkways and platforms at elevation 94 m provide access to the tops of the D2O storage tanks for maintenance and inspection work. Access to elevation 87 m and the platforms at 94 m occurs via two stairwells, stairwell #1 on the west side of the building and stairwell #2 on the east side.

As the D2O Storage Project is fully integrated with the operation of the HWMB/TRF, piping connects the storage tanks in both facilities. At elevation 94 m there is a small seismically qualified tunnel (interior dimensions of about 1.75 m high and 2.25 m wide), known as the pipe chase, that runs between the D2O Storage Project and the HWMB. The pipe chase also includes piping to connect the D2O Storage Project's drainage (active and inactive) to the HWMB drainage.

The pipe chase covers a distance of about 10.5 m. It comprises three angled sections to connect into the HWMB at a location south of where it exits the D2O Storage Project building. All sides of the pipe chase are constructed of 0.6 m thick concrete reinforced with rebar. It has a slightly sloping floor so that in the unlikely event of a heavy water spill, the spill would drain back into the D2O Storage Project facility's seismic dike. Piles driven into bedrock support the pipe chase, which was constructed as a seismically qualified structure because it conveys heavy water. Connecting the piping necessitated breaching the seismic dike in the HWMB, which required OPG to demonstrate that the connection between the pipe chase and the HWMB did not adversely impact the HWMB's seismic qualification.

Figure 8 – Pipe Chase

3.3 The Drum Processing Area (Elevation 100 m)

Historically, OPG has relied on drums to collect and store significant quantities of heavy water. An accumulation of drums increases radiological and conventional safety concerns. In addition, drums present an increased risk of environmental spills. The D2O Storage Project includes a drum handling area to avoid a backlog of heavy water drums waiting to be processed. The drum storage area provides centralized drum storage for Pickering and Darlington, improves the efficiency of processing drums going forward, and enhances protection of worker safety and the environment.

Figure 9 – Drum Handling, Cleaning and Testing Room

The drum handling and storage area is located on the ground floor of the D2O Storage Project building. Drums are unloaded and loaded at the loading dock at the HWMB and transported via the causeway connecting the HWMB and the D2O Storage Project facility using an electric cart. A hoist is provided for the removal of drums from the shipping overpack. Drums are dried, filled and labeled in this area. In the event of a spill or drum leakage, floor drains capture D2O and route it to the downgraded heavy water stream.

The drum handling operations comprise the:

- Emptying of drums into Downgraded Transfer Tanks;
- Cleaning of drums using heated demineralized water;
- Drying of drums using dry air;
- Pressure testing drums to ensure their integrity; and

- Filling of drums from any of the following sources: PHT D2O Supply Tanks, Moderator D2O Supply Tanks, Downgraded D2O Transfer Tanks, Cleanup D2O Supply Tanks, and the TRF.

The drum handling area includes:

- A header connected to the D2O storage tanks, with hoses and quick connects for draining and filling of drums;
- A demineralized water supply and hose for drum washing and cleaning;
- An instrument air supply for pressure testing of drums;
- Five vapour hoods connected to a dryer and condenser to remove tritium prior to the vapours being exhausted to emissions stack;
- Power supplies to drum cleaning equipment; and
- Instrumentation and controls equipment for monitoring tritium and pressure testing.

The drum storage area can hold 375 D2O drums, each with a capacity of approximately 209 L (46 imperial gallons). Included within this total is shielded storage for 75 drums that contain fission products emitting higher levels of gamma/beta radiation than the remaining drums. The drum handling system has the capacity to, at a minimum, empty six D2O drums or fill ten D2O drums per hour. It can clean up to six drums per hour. There are three drum dryers and four scales to weigh drums. The working area is designed to accommodate shipments and receipts of up to 40 drums at a time.

An emergency eyewash station and shower facilities are located near the drum handling area. If either is used, an audible alarm sounds in the D2O Storage Project building and an alarm is indicated in the HWMB control room.

A hatchway and hoisting device is provided at ground level to facilitate maintenance of the pumps, valves, and other small equipment in the seismic dike below. A condensate platform at elevation 104 m houses the heat exchanger and a drain. The heat exchanger takes steam from the Darlington powerhouse and uses it to heat a closed loop of water at the heat exchanger. The hot water is then pumped to elevation 107 m to heat up the building air exchanger, which, as discussed below, heats the D2O Storage Project building.

3.4 Process and Building Support Systems (Elevation 107.8 m)

The second floor (elevation 107.8 m) contains the electrical and mechanical systems necessary for building operation. These include the cables bringing electricity into the building, the building's internal electrical system, back up power supplies, chillers, air compressors, ventilation, vapour recovery, and emissions, fire and drainage monitoring equipment. A hatchway and hoisting device are provided at this elevation to facilitate regular maintenance of the equipment. As discussed in the following paragraphs, each of these complex systems is essential for the D2O Storage Project's safe and continuous operation.

3.4.1 Electrical System

The D2O Storage Project electrical distribution system is independent of Darlington's power system. In total, some 75 km of electrical cables situated in over 1,000 m of cable trays as well as grounding, junction boxes, and supports are required to meet the building's electricity needs. Each cable had to be safely pulled through the intricate array of trays, and thousands of connections had to be verified to ensure they were correct and then tested to ensure that they operated as designed.

Continuous power is necessary to maintain the environmental, nuclear and personnel safety of the D2O Storage Project facility. For example, the ventilation system must be available at all times to maintain negative pressure in the building to control potential emissions as discussed in the next section. The tritium monitoring and testing systems and emissions stack discussed below must also be continuously available to limit emissions. The building's heating system must be available whenever low temperatures are predicted because heavy water freezes at 4°C. Alarms, emergency lighting and breathing air are continuously required for the safety of personnel in the building.

Electricity to the project is provided at distribution voltage (13.8 kV), which is supplied by Elexicon Energy (formerly known as Veridian Connections) at a connection point outside the Darlington perimeter. An underground distribution cable transports electricity to the D2O building where an outdoor cable tray bridge brings it into the building. Once in the building, the cable is connected to a transformer and switchgear located in the second floor electrical room, which steps down this voltage to 600 V. Larger electrical loads, such as motors, compressors, chillers and larger pumps, are supplied at this voltage. The voltage is further reduced to 120 V to supply smaller loads including lighting, smaller pumps, motorized valves, receptacles, relays, controllers, alarms, annunciating devices, fire and smoke detection and control systems.

Two systems ensure continuous backup power to the building in the event that grid-provided power becomes unavailable. An uninterruptible power supply ("UPS") system can provide 40 minutes of uninterruptable 600 V and 120 V power for key emergency systems including radioactivity monitoring, leak detection, fire and smoke alarms and emergency lighting.[19] These loads cannot sustain interruptions of longer than three to six milliseconds. The UPS is fed by two motor control centers ("MCCs"). These two MCCs have selectable dual supplies from the 13.8 kV grid-supplied system and from the back-up diesel generator. The UPS allows critical loads to remain in operation while the standby diesel generator is started and loads are switched from grid-supplied to back-up power.

A standby diesel generator is located in a self-contained structure south of the D2O Storage Project. The structure contains a 600 V diesel generator, fuel storage as well as exhaust and fire detection and suppression systems. The generator can provide electricity to the building and has the fuel capacity to run for 36 hours on full load until grid-supplied power is restored. If required, the generator can be re-fuelled to extend its operation. The standby generator is linked to the main HWMB control room as well as to the motor control centre in the D2O Storage Project building.

[19] The fire alarm and public address systems also contain 24-hour dedicated batteries.

A new grounding system was installed to ensure protection of personnel, equipment and the electrical power system from the effects of lightning discharge, static voltage build-up and ground potential rise during power system faults. The new grounding system is interconnected with the existing system for the HWMB to achieve electrical continuity.

3.4.2 Mechanical Systems

The mechanical systems are required to provide cooling, heating, instrument and breathing air, emission monitoring, vapour recovery, leak detection, and fire and radiation alarms. The major systems include redundancy to allow continued safe operation during maintenance and repair.

The D2O Storage Project requires cooling for the vapour recovery system used to limit emissions, and to provide cooling for electrical equipment such as MCCs and UPS, which generate significant amounts of heat.

The cooling system comprises two independent 100 ton chillers to allow the D2O Storage Project facility to continue operating in the event that one of the chillers fails and to enable normal operations during chiller maintenance outages. The largest cooling load in the building is the electrical room, which alone requires 23 tons of cooling. Other significant cooling loads are the maintenance of building ambient temperature and the large motors in the ventilation and compressed air systems.

The chilled water system supplies heat exchangers local to the heat sources. The heat that is captured is transferred to the closed loop condenser water circuit through heat exchangers. This water is a mixture of glycol and demineralized water to prevent freezing since the condenser water goes to the rooftop fluid cooling units. The system is built out of stainless steel to withstand the chemistry of the demineralized water and glycol mixture.

Two large motors deliver the air flow for the HVAC system, which enables six air exchanges per hour. Each inlet fan has a capacity to move 60,000 cubic feet per minute of air while the exhaust fans have the capacity to move 70,000 cubic feet per minute each. This difference maintains slightly negative pressure in the building to help prevent any airborne contaminants from entering the environment. The HVAC system has duplicate filtration systems to allow uninterrupted service during filter changes and maintenance. A snow stop heater system is provided in the air intake plenum to melt the snow during the winter season to allow unimpeded airflow. In case of a fire alarm in the building, both the supply and exhaust fans are shut down.

Under normal operations, effluents from all potentially contaminated areas pass through pre-filter and HEPA filters to screen out particulates and ensure that any airborne radioactive particles present are removed prior to release into the atmosphere. There are also charcoal filters for radioactive emission removal that are normally kept in bypass, but are activated if radioactive particles are detected by the stack monitor located in the rooftop emission stack (discussed in the next section).

The HVAC system for the entire building is centrally controlled via a Supervisory Control and Monitoring System. The control panel is located in the main control room of the HWMB and provides separate controls for adjusting the temperatures in each major area of the facility as well as providing relevant displays and indications.

The instrument/service air system provides dry instrument compressed air, which is used for:

- Vapour recovery system,
- Drum handling and cleaning system,
- D2O tanks cover gas,
- Pneumatic air operated valves,
- Stack monitor analyzer, and
- Ventilation system filtration units' pneumatic dampers.

The instrument/service air system includes two independent compressors to enable continual operation in the event of a compressor outage or scheduled maintenance. The compressors are driven by 55 kW (73.8 HP) high-efficiency electric motors. The system also includes dryers and filters to dry and clean the compressed air. The controllers that automatically operate the system are linked to the main HWMB control room.

The D2O Storage Project facility uses pneumatically controlled valves so that in the event of loss of power and the resulting loss of compressed air, the valves would close to stop any movement of heavy water as a fail safe measure. Pneumatically controlled valves also allow the movement of heavy water to be controlled remotely from the HWMB facility. There are 1,040 valves in the D2O Storage Project building, including diaphragm, check, gate, and vacuum relief valves. Each valve was fully inspected and verified as leak-tight after installation.

3.4.3 Monitoring and Alarm Systems

The D2O Storage Project building is protected by a fire detection system, which operates on a continuous basis to monitor for smoke and fire, and alerts the operator in the event that smoke or fire are detected. This system includes heat detectors, smoke detectors, manual pull stations and remote indicators.

The fire protection system is monitored and controlled by the Main Fire Detection Panel located within the D2O Storage Project building on the ground level. It is connected to the fire and smoke detectors and monitors the duct sensors and HVAC system. In the event of a fire, the Main Fire Detection Panel sends an alarm signal to the General Ventilation System Control Panel which shuts down the ventilation system (i.e., the supply and exhaust fans) as required by the Fire Code.

The Fire Annunciation Panel is located in the HWMB control room. It duplicates the information displayed on the Main Fire Detection Panel, allowing for the integrated operation of the two heavy water storage buildings from the HWMB.

For fire fighting, the D2O storage facility includes 39 portable dry chemical fire extinguishers distributed on the elevations and platforms throughout the building. Eight hose cabinets supply fire water to the building’s various levels and a connector outside the building allows for external water supply to the system.

Elements of the D2O Leak Detection System are located throughout the D2O Storage Project. The D2O Leak Detection System comprises 33 moisture detection elements, also known as "beetles," located throughout the building in areas of potential D2O leakage.

If a leak is detected by a beetle in one of the floor drains, a beetle alarm is displayed on the local panel, and a general annunciation is displayed in the HWMB control room. The D2O Leak Detection System provides the operator with an indication of the leakage/spill location.

Fixed Area Alarming Tritium Monitors have been installed to continuously measure for the presence of tritium in the D2O Storage Project facility. OPG installs these monitors in any structure where tritium releases can occur. The monitor displays the tritium level and provides an audible and visible alarm should there be a tritium release. The readings from the monitors and alarms are replicated in the HWMB control room. The alarms warn personnel to evacuate the affected area and thereby minimize potential occupational exposure to tritium.

Similarly, OPG installed Fixed Area Alarming Gamma Monitors to detect potential radiological hazards in the D2O storage facility. These devices continuously monitor the concentration of gamma radiation in the surrounding areas. The readings and any alarms are displayed locally and in the HWMB control room.

3.5 The Roof (Elevation 115 m)

The roof contains a 15.5 m steel emission/ventilating stack and stack monitor. The stack has an outside diameter of 1.45 m. The stack is supported by an elevated platform anchored to the roof structural steel. One set of guy wires, designed to provide lateral support for the stack, is connected to the building columns.

The stack monitor is a lead-shielded sampling device attached to the emissions stack and connected to a computer, which tests for the presence of tritium, radiocarbon (C-14), radioiodine, and radon. If levels above the set points for any of these are detected, an alarm is issued to the HWMB control room. In that case, an operator is alerted and will take appropriate action to limit emissions including activating charcoal filters to absorb the radioactive particles.

All vapours from all sources within the building are passed through the stack after recovery to allow monitoring of compliance with release targets.

4.0 ORIGINS OF THE D2O STORAGE PROJECT

4.1 Operational Improvements to Heavy Water Storage and Drum Handling

The early origins of the D2O Storage Project date back to 2005 when OPG developed a Project Charter[20] to address needed operational improvements in its capacity to store heavy water and to clean, test and store the drums used to transport heavy water between the HWMB and Pickering (see Attachment 2a – Project Charter: Adding Heavy Water Storage/Drum Handling Facilities dated October 13, 2005). This planned operational improvement project was necessary to allow OPG to increase the amount of detritiated water available to address increasing concentrations of tritium observed at both Pickering and Darlington and to better manage the heavy water streams at Pickering and Darlington. OPG also required additional storage to undertake outages to repair and replace equipment at the TRF to improve its operation.

Throughout 2006, OPG continued working to develop the preferred alternative and estimate the cost of the operational improvement project. Through this process, OPG reduced its estimate of the storage needed for operational improvement, ultimately concluding that it required 400 m^3 of additional D2O storage and a facility to handle, store and pressure-test drums at Darlington. This reduction reflected a reduced scope and a refocusing of this project on Darlington; a separate project was also envisioned, which included constructing a drum cleaning facility at Pickering (the "Pickering Project"). A developmental BCS (see Attachment 2k – 2006 Developmental Release BCS) was issued for the project at Darlington in November 2006 for work to begin developing the project's design and gathering information on the cost of equipment. The Pickering Project was managed separately and ultimately deferred in March 2008.

[20] A Project Charter is a foundational document that establishes the need for a project, its objectives, scope, priority, timing, funding, resourcing, accountabilities and safety targets.

4.2 Advancing the Operational Improvement Project

Throughout 2007, OPG worked on defining the operational improvement project and determining how best to construct it at Darlington. OPG also began to engage the contractor community to better understand their abilities to design, construct and commission the operational improvement project.

During this time, OPG conducted detailed investigation of the site west of and adjacent to the HWMB (the eventual site of the D2O Storage Project). OPG engaged Trow Associates ("Trow") to perform a geotechnical assessment of the site. The purpose of the report was to assess subsoil and groundwater conditions by drilling three boreholes ranging in depth from about 13 to 19.5 m and sampling the cores. Based on an assessment of the borehole data, Trow provided an engineering report with geotechnical recommendations on the design and construction of the proposed structures. The report indicated several foundation types could be used for construction, including a caisson foundation down to bedrock at an approximate depth of between 13.5 and 14 m. The report also noted the presence of groundwater in the boreholes at depths of between 2 and 2.5 m and indicated the need for dewatering efforts for excavation below this level.

While OPG was in the process of developing the cost and design requirements for the operational improvement project, it also commenced the initiation phase of the DRP in late 2007. Therefore, a decision was made in 2008 to defer the operational improvement project, pending a decision on Darlington refurbishment. The deferral decision was taken for two reasons: (1) the potential to integrate refurbishment and operational improvement storage needs into a single project if Darlington refurbishment went forward; and (2) recognition that without the extended Darlington station life from the refurbishment, the operational improvement project would no longer be justified.

At the time that the operational improvement project was formally deferred in June 2008, approximately $1.9M of the released funds had been spent. Of this amount, approximately $1.3M had produced information that was deemed useful for the D2O Storage Project and was included in the project's costs. The remaining $0.6M was written off in 2010. The portion that was written off represented spending on preliminary engineering that was no longer useful, given the additional size and scope of the project.

5.0 MERGING THE REFURBISHMENT HEAVY WATER STORAGE AND OPERATIONAL IMPROVEMENT PROJECTS TO FORM THE D2O STORAGE PROJECT

5.1 Initial Assessment of Refurbishment Storage

In 2009, OPG began evaluating the heavy water storage needed to execute Darlington refurbishment. OPG's initial evaluation assessed options for a facility capable of meeting the storage needs of a single unit undergoing refurbishment because the preliminary refurbishment schedule assumed a 10-week gap between units. This resulted in an identified combined storage need of about 1245 m^3, comprising 845 m^3 for refurbishment and 400 m^3 for the TRF and ongoing operations.

OPG considered potential options for locating the new tanks and concluded that they were best housed in a new building located adjacent to the HWMB due to the cost and operational advantages of proximity. A conceptual cost estimate for a project to store 1,245 m^3 of heavy water was $138.5M in 2008 dollars (excluding interest). This figure reflected an estimated cost savings of 10-15% from undertaking the merged project compared to the projected cost for separate refurbishment and operational improvement projects. As Darlington refurbishment planning progressed and the expected duration of each unit's refurbishment was better understood, OPG concluded that it would need to refurbish two units in parallel. OPG determined that 1,700 m^3 of refurbishment storage would be necessary to store the heavy water from two reactors undergoing simultaneous refurbishment.

In 2010, OPG approved a revised project charter for the merged project (see Attachment 2b – Project Charter: Refurbishment, Operational Improvement and Long Term D2O Storage dated August 18, 2010). The revised charter merged Darlington's heavy water storage needs for operational improvement and refurbishment into a single D2O Storage Project with 2,100 m^3

of storage. The Pickering Project was cancelled.[21] As a result, the revised project charter included a drum handling and testing facility at Darlington to replace the facility previously planned for Pickering. The revised project charter included a conceptual estimate to complete the project of $210M.

5.2 Alternatives Evaluated

When OPG determined to proceed with planning for DRP it investigated alternative solutions for addressing heavy water storage. Two approaches were considered: construction of a new building at a different location at or around Darlington, and adding storage to an existing Darlington building. During development of the 2012 Full Release Definition BCS (discussed below in Section 13.3) (see Attachment 2m), two additional alternatives were considered: limiting the project to the 1,700 m^3 required to support refurbishment and construction of a drum warehouse to hold the approximately 7,200 drums that would be required to store the heavy water drained from two units undergoing overlapping refurbishment. Ultimately, each alternative was rejected for reasons set out below.

5.2.1 Stand Alone Building

OPG initially considered several locations for a new storage building including sites south (closer to Lake Ontario) of the HWMB/TRF. These sites were rejected because of their proximity to the lake shore and their potential use as future replacement sites for the TRF. The site adjacent to the HWMB/TRF was chosen because of the integration between the additional storage in the D2O Storage Project and the HWMB/TRF. The piping in these two facilities is connected to allow the transfer of various heavy water streams (e.g., PHT, Moderator and TRF Feed/Product) between them. OPG again reviewed the location of the D2O Storage Project as part of the value engineering exercise that OPG conducted on the project. This exercise evaluated additional configurations and locations, including a location outside the protected area, but the current location adjacent to the HWMB/TRF remained the preferred location.

[21] With OPG's decision not to proceed with Pickering B Life Extension, the Pickering Project was no longer deemed necessary.

5.2.2 Additional Storage in an Existing Structure

OPG examined the potential to store additional heavy water within existing Darlington station structures to avoid the need for building the D2O Storage Project. Two locations were considered. The first was construction of one additional 50 m^3 storage tank at each Darlington unit, which would have provided an additional 200 m^3 of storage (4x50 m^3 tanks in total). This option was rejected because the resulting storage could have only been used for PHT heavy water, and, in any event, would not have been sufficient to meet the identified needs for additional storage.

OPG also considered creating additional storage in the Off-Gas Management System room in the HWMB. While OPG calculated that this room was large enough to accommodate eight 20 m^3 tanks or a single large 100 m^3 tank, the practical difficulties associated with removing the existing carbon steel tanks in the room, creating access for the new tanks and seismically qualifying the room could not be overcome. Moreover, the space available within the HWMB was inadequate to meet the storage space requirements discussed above.

5.2.3 Construction of a Refurbishment Only Storage

In 2012, as part of the Full Release Definition BCS, OPG considered the alternative of only including the 1,700 m^3 of storage necessary for refurbishment and omitting any storage for operational improvement or the TRF life extension.

This alternative was ultimately rejected because 400 m^3 of incremental storage was required to improve the efficiency and effectiveness of the TRF operation. Optimization of the TRF was viewed as necessary to improve OPG's overall ability to manage its D2O inventories to support continuous station operations before, during and after the refurbishment period and the TRF life extension. Without additional storage for the TRF life extension, OPG faced the risk of having to complete a costly refurbishment of the existing TRF or the construction of a new TRF to meet ongoing regulatory detritiation requirements for the Darlington moderator and PHT system.

5.2.4 Construction of a Drum Warehouse

In 2012, the Full Definition BCS included another alternative to construct a "drum warehouse" inside the protected area. This alternative would have used drums to store 1700 m^3 of DRP heavy water, and still required construction of a smaller D2O facility to meet operational improvement needs and for TRF life extension.

This alternative was rejected because it would have had an unacceptable impact on the DRP critical path. It was estimated that two months of round the clock drumming would be required to drain the PHT system and moderator and another two months of round the clock drum purging would have been required to re-fill the moderator and PHT system post-refurbishment. This time and associated cost would have added to the critical path of each unit's refurbishment outage with an estimated total generation revenue loss of $480M.

In addition to the lost revenue, this alternative would have required an estimated 7,200 drums designed to store radioactive heavy water at a cost of $1,000/drum. The need to store these drums would have required OPG to construct a structure that included many aspects of the D2O Storage Project such as a seismic dike, emission controls, heating and cooling and other safety features.

6.0 DEVELOPMENT OF THE D2O STORAGE PROJECT

Upon issuance of the project charter for the merged project, OPG also began undertaking the preliminary work necessary to better define the project and understand its risks and costs. In December 2010, developmental funding previously released under the operational improvement project was directed to initial project development for the D2O Storage Project. This release was intended to:

- Generate design requirements to be used in a Request for Proposals ("RFP");
- Create a Conceptual Design Report;
- Continue front-end planning;
- Establish a contracting strategy;
- Prepare a Partial Release BCS; and

- Issue an RFP for Scope Definition, Modification Planning and Detailed Design and select preferred vendor.

Throughout 2010 and 2011, OPG advanced the D2O Storage Project by continuing investigations into its location, design configuration and cost.

OPG reviewed operating experience from heavy water storage tank projects at Pickering and Bruce as part of the evaluation process. OPG had a discussion with Bruce Power and conducted a site visit to review operational experience regarding Bruce Power's much smaller project to add additional heavy water storage inside an existing building. That project experienced cost increases, an 18-month stoppage, an external investigation, numerous scope additions and a change in the contracting approach when the project resumed. OPG also reviewed an external operating experience report that collected information on issues related to heavy water management at the HWMB and their resolution. This report was compiled as part of preparation for the earlier operational improvement project.

In April 2011, OPG convened a value-engineering workshop. The purpose of this workshop was to examine ways to improve project performance and reduce cost while continuing to adhere to all applicable safety and design standards and codes. The workshop's goals were to:

- review the alternatives being considered and attempt to augment them;
- assess the effectiveness of the solutions being proposed; and
- develop additional concepts and refine existing ones.

A major focus of this workshop was to re-evaluate the potential sites for the project. After reviewing all potential sites identified, participants agreed that the site adjacent to the HWMB was superior from a cost and operational perspective, despite the constructability, site preparation and environmental issues identified. One of the other alternatives that scored well was to split the refurbishment storage from the operational improvement storage, but that alternative was ultimately rejected as more expensive and less practical than the current project location. The workshop concluded that the current project location was the preferred site.

In late 2011, OPG engaged Faithful & Gould ("F&G") to prepare a Class 3 estimate[22] of the construction costs of the D2O Storage Project based on the then-existing preliminary design, if possible. OPG requested that if F&G could not prepare a Class 3 estimate, that it explain the factors that prevented it from doing so.

In early 2012, F&G presented its "overnight estimate"[23] of forecast construction costs, which excluded interest, escalation and contingency. This estimate also excluded additional design costs and any engineering costs. The estimate was based on the then-existing preliminary design information. F&G reported that its construction cost estimate was within the range of +50% -30% and could be considered a Class 4 estimate (per the AACE Estimate Classification system). The report's assessment indicated that much of the information necessary to support a Class 3 estimate was yet to be developed. Among the items the report identified as necessary for a Class 3 estimate were specification and data sheets, and equipment, civil and structural drawings. F&G's estimated overnight cost for construction only was $64.6M, based on the project information available at the time.

Given the evolution of the D2O Storage Project subsequent to the 2007 Trow geotechnical study discussed above in Section 4.2, OPG hired EXP, a division of CH2M Hill Canada Limited and the successor company to Trow, to perform a supplemental geotechnical study. The purpose of the supplemental study was to further evaluate the subsoil and groundwater conditions at the site. The study team placed additional boreholes and, based on an assessment of the borehole data, provided an engineering report with geotechnical

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[22] A Class 3 estimate refers to the classification system for quality requirements, as defined by the Association for the Advancement of Cost Engineering (AACE International), a non-profit association that is a recognized authority in project and program cost and schedule management. A Class 3 estimate requires that between 10 and 40% of a project's full definition be completed and has an associated accuracy cost range of between -20% and +30%. In contrast, a Class 4 estimate requires that between 1 and 15% of a project's full definition be completed and has an associated cost accuracy range of between -30% and +50%.
[23] An "overnight estimate" is the cost of constructing the project without any interest or escalation, as if the project were constructed "overnight."

recommendations pertinent to the design and construction of the structure being proposed for the site. The results of this supplemental study were consistent with those of the original study, as were the design and construction recommendations.

OPG also began soil and water testing at the D2O Storage Project site to test for the presence of tritium on the proposed site of the D2O Storage Project. OPG had done sampling following a 2009 spill at the Injection Water Storage Tank, which indicated elevated tritium levels in the soil and groundwater in the area north of the site.

To determine if the tritium had migrated to the project site, OPG installed monitoring wells and drilled boreholes to monitor tritium levels in groundwater and soil. Sampling within the footprint of the D2O Storage Project construction showed that the tritium levels observed, while above background levels, did not exceed Ministry of the Environment ("MOE") standards. Sampling also established that the soil and bedrock were within MOE standards for disposal in an approved landfill. Radiological testing confirmed that the excavated soil was well below the unconditional clearance levels specified by the CNSC and posed no hazard to employees transporting the soil to the laydown area discussed below (see Section 8.4.1) or to the public.

7.0 CONTRACTING FOR THE D2O STORAGE PROJECT

7.1 Initial Contracting Efforts

While OPG was beginning to evaluate the project's preliminary design it also began considering contracting strategies. The project team proposed a strategy that began with external engineering, followed by procurement by OPG, and then construction by an external contractor. This approach was proposed because it would allow OPG to establish the building footprint, begin procuring long lead nuclear-grade materials, and develop a schedule. An RFP was distributed to six potential proponents in May 2011. The RFP sought engineering services for all phases of the project (i.e., preliminary, detailed, construction support, commissioning, available for service ("AFS") and close out). OPG received four proposals in response to the RFP. OPG considered these proposals, but ultimately decided to cancel the RFP as it was not satisfied with any of the technical proposals.

Over the remainder of 2011, OPG refined the documentation for the project and created the technical specifications for a second engineering services RFP. The second engineering services RFP was issued in late 2011. The RFP featured a more developed scope of work ("SOW"), which provided greater detail on OPG's expectations for the project and also included certain mandatory criteria that proponents had to meet in order for their proposal to be considered. OPG received three proposals, but its initial review of compliance with the mandatory criteria determined that none of the proposals complied. As a result, OPG suspended further evaluation of the proposals and cancelled the RFP.

7.2 Contracting Under the ESMSA

7.2.1 The ESMSA

At the same time that OPG was issuing RFPs for the D2O Storage Project engineering, it also began the process of engaging qualified contractors to work on the DRP under an Extended Services Master Service Agreement ("ESMSA"). OPG issued an RFP for ESMSA contractors in June 2011 with a closing date in September 2011. The ESMSA is a form of contract that establishes a set of terms and conditions with one or more pre-qualified contractors, enabling OPG to significantly shorten the procurement cycle for obtaining engineering, procurement, or construction services, or any combination of these three services, as required. Ex. D2-02-04 (pp. 23-25) discusses DRP's use of ESMSA contracting in detail.

OPG's main objectives in using the ESMSA were to (i) optimize contractor and OPG resources, (ii) continuously improve contractor quality and performance in the areas of safety, cost, schedule adherence and human performance; and (iii) maximize value for money. A key aspect of the ESMSA is the performance fee, which is a risk-sharing arrangement where a contractor's overall performance on all its ESMSA work is considered in calculating the total compensation for any completed ESMSA work.

Through the ESMSA competitive bid process, OPG evaluated the technical abilities of the responding contractors and their pricing proposals. Based on this evaluation, OPG selected two experienced and qualified ESMSA contractors: ES Fox and Black & McDonald ("B&M").

OPG established ESMSAs with each firm in 2012. The initial contract term under each ESMSA was for five years with options for extension (see Attachment 2d - B&M ESMSA dated February 15, 2012 and see Attachment 2e - B&M ESMSA Amendment #1 dated June 28, 2013).[24]

7.2.2 Initial Competitive Procurement for the D2O Storage Project under the ESMSA

With the selection of two qualified ESMSA contractors and the cancellation of the engineering RFP discussed above, OPG determined to undertake the D2O Storage Project on an Engineer, Procure, and Construct ("EPC") basis within the ESMSA framework. This approach was chosen to enable OPG to gain operational experience with both EPC contracting and the ESMSA framework on a large and complex project prior to starting unit refurbishment. The D2O Storage Project was OPG's first large and complex EPC project to be executed under the ESMSA.

OPG began the competitive solicitation for the D2O Storage Project by issuing a work request to each of the two qualified ESMSA contractors, ES Fox and B&M. The work request envisioned a two-phase project:

- Phase 1: included site preparation, completion of Scope Definition/Modification Planning, detailed engineering, and specification and ordering of materials that required long lead time to procure ("long-lead materials").
- Phase 2: included procurement, construction and commissioning, and turnover to OPG.

The SOW that formed part of the work request also outlined OPG's required schedule, deliverables and procedures. The schedule showed the Phase 1 contract being awarded in June 2012, the Phase 2 contract being awarded in May 2013, and completion of the project in April 2015. The completion date was timed to have the facility available six months in advance of the earliest potential start date for the refurbishment of Unit 2, which was then considered to be October 2015. The work request also included OPG's preliminary design requirements and a conceptual design report, both of which provided proponents with additional information on the project's scope and design objectives.

[24] The term has since been extended to 2027.

The work request was issued in March 2012 and responses were due in April 2012. The work request set out the criteria that would be used to evaluate the proposals and the weighting assigned to each criterion. Evaluation of key project personnel and the team's experience, was weighted 25%. Risk management and contingency plans were weighted 15%. Overall quality of the proposal was weighted 10%. The performance fee for engineering was weighted 30% and the overall project cost estimate was weighted 20%. This weighting resulted in OPG placing equal emphasis on the proposals' technical factors and cost, as each of these two categories represented 50% of the scoring.

OPG first evaluated both proposals based on the technical criteria and concluded that both proposals should progress to the next stage, the pricing evaluation. The results of the initial evaluation placed ES Fox ahead on technical criteria and B&M ahead on price.

OPG determined to engage in negotiations with both teams to bring their pricing proposals into better alignment. At the conclusion of the negotiations, the significant price advantage of the B&M team's proposal resulted in it receiving a higher overall score and, on that basis, winning the contract. The RFP process that selected B&M was fair, equally weighted bid price and technical factors, and aligned with the processes that OPG used for other RFPs under the ESMSA for DRP prerequisite projects.

8.0 DESIGNING AND CONSTRUCTING THE D2O STORAGE PROJECT

8.1 Project Execution by Black & McDonald: Overview of the Project Plan and Timelines

On June 22, 2012, OPG issued a purchase order ("PO") to the B&M team to begin work on the D2O Storage Project under the ESMSA contract (see Attachment 2f - B&M Purchase Order #217807 Rev. 11 – Final Revision).[25] The B&M team included first tier subcontractors RCM Technologies Canada Corporation ("RCMT") for engineering and EllisDon for excavation and

[25] As discussed below in Section 13.3, prior to finalizing the agreement with B&M, OPG approved the Full Release Definition BCS.

construction of the seismic dike. The initial PO contemplated three phases of work, but funded only Phase 1:

- Phase 1 covered detailed engineering, including scope definition and modification planning during the period from July 2012 through early July 2013.

- Phase 2 covered site preparation and procurement of long-lead materials. Site preparation included activities such as clearing the site, daylighting and relocation of buried services, relocation of argon and oxygen tanks. This phase also included the start of caisson wall installation and excavation, and miscellaneous civil substructure work, but these activities could not begin until the DRP EA was approved and OPG completed the civil design packages, both of which were expected to occur by the end of 2012.[26] Phase 2 included all the work to be executed from September 10, 2012 to June 30, 2013 that was not part of detailed design (i.e., Phase 1). The Phase 2 work was to be executed under a Partial Execution Business Case Release and funded by a PO Revision.

- Phase 3 covered all remaining construction, procurement, engineering support, and close-out. The work in Phase 3 was to be executed under a Full Execution Business Case and funded by a PO revision.

8.2 Initial Planning and Design

The task for Phase 1 of the D2O Storage Project was to design the new facility. This included preparing supporting documentation such as calculations, technical specifications, drawings and change documentation to form a baseline for the new facility. The design details were to be covered in the applicable Design Engineering Change packages.

[26] In actuality, the EA was accepted by the CNSC in March 2013. Environment Canada Website https://www.ceaa-acee.gc.ca/050/evaluations/document/87565?culture=en-CA

8.2.1 The Context of Design Changes within Darlington

The D2O Storage Project design activities were carried out under OPG's Engineering Change Control ("ECC") process. The ECC process ensures all modifications to nuclear plant systems, structures, and components are planned, designed, installed, commissioned, and placed into service within the safe operating envelope,[27] design basis, and plant licensing conditions. OPG's operating licence from the CNSC requires that it maintain a change control process that addresses all modifications.

Any change to a Darlington system, structure, or component, which affects or alters its design, function, or method of performing its function must follow OPG's modification process. This process ensures all modifications to the nuclear plant are documented and reviewed prior to approval to evaluate their risk and ensure they improve or maintain operability, maintainability, radiological and conventional safety, regulatory or license compliance, and are produced at an acceptable cost to OPG. The process also requires that every design is prepared, verified, and approved by the contractor agency in accordance with approved procedures, applicable regulatory and design requirements, codes, standards, and industry practices.

The modification process also ensures that the configuration of the plant and the associated documentation is controlled to create a match between the physical plant and plant documentation. This match is necessary to allow the plant to be safely and efficiently operated and maintained, and to enhance the ease and efficiency of future modifications.

OPG established Acceptance Points covering all of the deliverables listed in SOW for the D2O Storage Project. An "Acceptance Point" refers to the formal transmittal of documentation from the contractor to OPG for a proposed change. The contractor typically need not stop work at an Acceptance Point, except where a hold point is required as per OPG governance or the contractor's Quality Assurance program. Under this process, every design proposal and engineering change for the project was reviewed and signed off by OPG.

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[27] The "safe operating envelope" comprises OPG's internal standards to ensure the plant operates within its design basis (the conditions that the plant is designed to meet) and in accordance with all conditions in the plant's operating license issued by the CNSC.

OPG also required a Modification Outline for the D2O Storage Project. A “Modification Outline” is the package of information that defines the scope of the project in terms of what the contractor is responsible for and what specialist skills are required to complete the modification. The Modification Outline also defines the risk level of the project as well as the level of involvement required of Subject Matter Experts such as seismic or Human Factors Engineering (“HFE”) experts. Additionally, it identifies approvals required from regulatory bodies, such as the CNSC or Technical Standards and Safety Authority (“TSSA”) and the level of OPG oversight and approval required for acceptance by OPG.

All modifications require HFE analysis to ensure that the design supports the tasks of the people who will use it. OPG requires all designers to ensure that the interfaces between people and equipment comply with current HFE guidelines and OPG prototypes in use at Darlington. It also requires that designs represent a user-friendly interface that will support error-free operations and maintenance tasks. The D2O Storage Project HFE analysis predominately addresses the changes to the instrumentation and control panels in the HWMB control room, but also covers the overall D2O Storage Project. Every design was required to be screened against OPG’s HFE requirements and those designs involving material HFE considerations require review and sign-off by an HFE specialist.

Any significant modification must undergo OPG’s constructability, operability maintainability and safety (“COMS”) review process whereby a series of meetings are held with OPG personnel representing the relevant areas of Darlington to assess each design against the COMS criteria. COMS is intended to ensure that each modification to a Darlington system, structure, or component is as constructible, operable, and maintainable as is reasonably achievable, while ensuring that safety considerations are not compromised during the modification’s construction, operation, or maintenance. At least two COMS reviews occur, in preliminary and final engineering, but additional COMS reviews may take place as required by project complexity. During AFS, a review of safety, operability, and maintainability is again undertaken.

8.2.2 Design Work

The D2O Storage Project mobilization began in early July 2012, with the initial focus being project design. Within the first few months, it became clear that ramping up the design process would take more time than the schedule anticipated. As discussed above, OPG has a rigorous change management process that requires a thorough analysis and sign-off for all design changes, irrespective of whether they are initiated by a contractor or OPG, to ensure they do not compromise plant safety, are fit for their intended purpose and undergo a COMS review. In addition, the design tasks themselves were complex given the equipment and systems that needed to be integrated within the D2O Storage Project facility and the numerous interconnections between the D2O Storage Project facility and the HWMB/TRF.

In light of these interconnections, the TRF dedicated the equivalent of 2.5 full time employees to the project to review submittals, proactively engage on issues, attend most project meetings, and meet with the B&M team. This level of involvement was essential because the HWMB/TRF is a one-of-a-kind facility, whose operations and configuration had to be fully considered to effectively design the D2O Storage Project. Review by TRF personnel resulted in many examples of good input and “catches,” which prevented errors or omissions from propagating very long into the design cycle and reduced future rework and costs.

The design effort was extensive and challenging. All of OPG’s preliminary design documents needed to be verified and, in some cases, revised. For example, the initial design concept for the D2O Storage Project contemplated that it would be attached to the HWMB/TRF. When this proved infeasible because of the technical complexity and risk of tying the footings supporting the two buildings together, the D2O Storage Project was designed as a stand-alone building located 7 m to the west of the HWMB/TRF. This change resulted in increased design and construction costs.

The initial quality of the Modification Design Requirements documents that OPG received did not meet the requisite standards. Given the D2O Storage Project’s tight integration with the HWMB/TRF, OPG’s acceptance process also had to evolve to ensure that documents were reviewed by the appropriate internal groups in an efficient and focussed manner. These factors all led to the October 29, 2012 milestone for completing modification design being pushed back by almost two months.

8.3 OPG's Commitment to Safe Construction

Safe construction of the D2O Storage Project was OPG's highest priority. Thousands of OPG employees, contractors' personnel and skilled trades worked on the project during its construction. No other aspect of project construction was as important as their safety. Safety incidents, whether or not they resulted in injury, were reported, analyzed and used as examples to reinforce safe work practices so as to reduce their likelihood of recurrence.

When a contractor's safety performance, as indicated by incidents having a high maximum reasonable potential for harm ("HMRPH") and observed lack of adherence to safe behaviours, was below standard, OPG required the contractor to undertake a root cause investigation and implement corrective actions. When this proved insufficient, OPG required a detailed safety assessment, which OPG reviewed, challenged and worked with the contractor to revise. When the contractor's safety performance continued to lag, OPG prohibited the contractor from receiving new POs under the ESMSA contract.

Safety performance is included in the calculation of the performance fee payments under the ESMSA. An ESMSA contractor with two or more HMRPH incidents at OPG in a year sees a reduction in its performance fee payout under the Safety category for all ESMSA work in that year. Having three or more HMRPH incidents counts as a human performance incident, which reduces the performance fee payout under the Human Performance category.

Throughout the project's construction, no serious injuries (i.e., injuries resulting in lost time or hospitalization) were sustained by the people building it.

8.4 Site Clearing and Preparation

The initial step in construction was to clear and prepare the site. The project site contained trailers that had housed TRF personnel. These trailers were emptied, disconnected from the

HWMB electrical, communication and public address systems, and removed from the site. As the IT system serving the trailers also served other users, they were first disconnected from the trailers and then rerouted. Following trailer removal, the asphalt that covered portions of the site was broken up and removed.

8.4.1 Soil Management

At the time of the RFP, OPG was still investigating potential soil contamination issues as discussed above. In order to ensure comparable bids between respondents, the RFP for the D2O Storage Project instructed the proponents to assume that the project would involve uncontaminated soil that could be disposed of in a conventional landfill. Soil testing revealed low levels of tritium in some of the soil. The presence of low levels of tritium above the free release limits of the Darlington license required ongoing testing and that the excavated soil be placed in a laydown area so any remaining tritium could dissipate prior to permanent soil disposal.

The soil from daylighting the first 3 m and from excavating the trench for the low pressure service water (“LPSW”) (discussed in Section 8.5.2 below) was transported to a soil laydown area C13, which was constructed within the Darlington protected area. Based on borehole sampling, this soil was not expected to be above allowable tritium amounts. This soil was tested and allowed to dry and then disposed of in a conventional landfill or stored in totes for eventual movement to the F1 soil laydown area, located outside the Darlington protected area, which is discussed below. Soil from the first 3 m also was used as backfill in the LPSW trench.

To create a lay down area to accommodate the soil and bedrock generated by the project, OPG increased the scope of its PO with B&M to construct the F1 soil lay down area. The F1 area was located outside of the protected area to the northeast of the Darlington station on a site OPG owns.

The soil laydown area consisted of two concrete cells. Each cell had an engineered base including geotextile filters to prevent sediment release as the soil dried. The excavated bedrock and soil unlikely to contain tritium were placed in one cell, while soil requiring turning to allow the off-gassing of tritium was placed in the other cell. Access to F1 area was controlled and it only accepted soil generated from within the Darlington protected area. Deliveries to F1 were drained, tested and monitored to protect against contamination during transport.

The F1 area had a maximum capacity of 34,000 m^3 of soil. It was constructed with a slope that caused water released from the soil to be collected into two subsurface holding tanks (each holding approximately 160 m^3). This water was subsequently moved to above-ground tanks for testing and ultimate release. As cells were filled with soil, they were covered with tarps to keep out rain and snow to limit the volume of water flowing to the tanks.

In 2016, the F1 area was closed and restored. Some of the concrete blocks used were recycled on site, while others were disposed of along with the geotextile material and drainage piping and tanks. The soil was first used to fill the F1 cells. The remainder of the soil was transported to a permanent disposal location on the Darlington site, spread out and planted.

8.4.2 Dewatering

Owing to the fact that much of the project involved excavation and construction well below the water table (located between and 2 and 2.5 m below the surface), dewatering was a substantial component of project activity. A dewatering system was required for all significant excavations, including the major trenching to relocate buried services, the seismic dike and the pipe chase. For the seismic dike, water was pumped from the HWMB box drain and from five porous wells drilled around the excavation. The water was collected, tested for tritium and conventional contaminants, and treated as necessary. The water treatment system consisted of a series of settling tanks and sand/carbon filters to remove oil, grease, and other organic compounds. Once treated, the water was discharged into the Circulating Water Pumping System at a location below other Darlington loads to avoid impacting station systems.

Controls were put in place during the construction phase to prevent extracted ground water or sediment from washing into the site's yard drainage system. Dust and sediment control measures also were incorporated to minimize suspended sediment concentrations in surface water as required by applicable environmental guidelines.

The dewatering system had to be monitored at all times (i.e., 24/7) while in use and dewatering had to be coordinated with other site activities. This required that dewatering personnel be onsite overnight during construction and in advance of construction activities to remove any water that had accumulated and ensure that the dewatering system was working properly.

The dewatering pumps were sized to allow for pumping water from the lowest water level encountered during construction (more than 15 m below the surface). The dewatering system was also configured for winter operation including insulation and heat tracing. The system was designed to meet the maximum dewatering flows that were required during excavation of the seismic dike of 2,400 liters per minute and 3,456,000 liters per day.

8.5 Relocation of Buried Services

8.5.1 Buried Services

There were numerous buried services (e.g., water, electrical, gas and communications) that intersected the D2O Storage Project site and the underground pipe chase connecting the project to the HWMB. OPG reviewed station drawings and conducted a scan to determine their location and extent. Some services were active, while others were abandoned. The active services were rerouted around the project. The abandoned services were cut and capped at the project site boundaries and then any material within the project was removed to avoid interference with the excavation.

8.5.2 Low Pressure Service Water Pipe

The LPSW pipe is a 30-inch diameter steel pipe that carries cooling water discharged from the HWMB/TRF to the Emergency Service Water discharge shaft. It is required to be in service whenever the TRF and Heavy Water Upgrader are operational as it provides cooling to 19 major components and sub-systems. The LPSW pipe required rerouting because it crossed the footprint of the D2O Storage Project site. To move the LPSW pipe, the argon tank had to be relocated to create room to work on the LPSW pipe where it entered the HWMB. The fire protection and helium lines also had to be moved to avoid interference with LPSW pipe work.

In January 2013, OPG analyzed three options for the reroute. The first was the hot tap approach, which involved using valves and bypass piping to reroute the LPSW pipe while the TRF remained in service. The second was to advance a TRF outage to June 2013 in order to maintain the D2O Storage Project construction schedule. The third option was to delay the LPSW pipe reroute to the TRF outage scheduled for October 2013. OPG analyzed the advantages and disadvantages of each option and, based on operational considerations and cost, initially recommended the hot tap approach with the understanding that if the project was delayed more than eight weeks, the cost advantage of the hot tap approach would erode and the LPSW pipe reroute would occur during the scheduled TRF outage in October.

By mid-February 2013, OPG concluded that the project was unlikely to be ready to execute the hot tap approach in May of that year. Since delaying the hot tap would eliminate its cost advantages, OPG elected to employ conventional isolation of the line during the scheduled TRF outage. The project opted to delay the start of the LPSW pipe work because this approach had a lower cost and allowed time to complete the design, dewatering, shoring and trenching work necessary to execute the LPSW pipe reroute.

Work on the LPSW pipe trench began in September 2013. Installation involved excavating a 6 m deep trench, setting up complex bracing to shore the trench walls (given the size and depth of the trench) and dewatering. Only after the trench was excavated, braced and dried, could work safely begin on the LPSW pipe.

Figure 10 – LPSW Pipe Trench Prior to Installation of the New Pipe

In many locations, the LPSW pipe originally had been laid in quick setting concrete, which had to be chipped away before the pipe could be replaced. The pipe was then cut into sections and removed to allow rerouting. Angles (generally 45 degrees to minimize loads) and new sections then were positioned in the trench by crane, welded together, coated and fitted with cathodic protection to prevent corrosion. When the relocation was complete, unshrinkable fill was placed beneath the pipe, the new pipe was tested and inspected, the trench backfilled and the bracing removed.

Figure 11 – Positioning an LPSW Pipe Angle

The line reroute was completed over six weeks at the end of 2013. The tie-in of the LPSW pipe to the HWMB/TRF occurred at the end of November 2013 during the TRF outage. The LPSW pipe became available for service in January 2014.

After the LPSW pipe became available for service, OPG conducted a review of the LPSW pipe relocate to investigate the reasons why it was delayed. One of the review's major conclusions was that the amount of work required for the LPSW pipe relocation was initially understated. OPG's early design documents did not sufficiently distinguish the relocation of this very large pipe from other buried service relocation work and the contractor failed to include sufficient scope to execute this complex task in its bid.

The review also noted that schedule delays had the impact of moving the work into the winter, which added further challenges to completing the relocation. The LPSW pipe reroute ultimately resulted in a two-month delay in the TRF outage and delayed the start of installing the project's caisson wall and excavating the seismic dike.

8.5.3 Tie-ins for Piping Connections

During the TRF outage, the project also installed some of the tie-ins to the moderator and the primary heat transport supply systems for connection to and from the new storage tanks once the D2O Storage Project was completed. The tie-ins were designed and implemented to minimize impacts on the existing loads in the HWMB/TRF during the tie-in installation and throughout construction of the D2O Storage Project, and to ensure maximum operability requirements in transferring heavy water between the systems.

8.5.4 Other Buried Services

While the LPSW pipe was the most significant buried service, the following services also had to be moved before excavation could begin:

- Standby Generator Cable Duct within the project's footprint. This cable duct accommodates the system connections between the Standby Generator Fuel Building #1 and the Oil Storage tanks including the electrical cables for sump pumps, transmitter signals and fire alarms and control cables.
- Inactive drainage line that travels from HWMB across the project. This 6" line and the catch basin it connected into required removal.
- The Yard Drainage line is a 600 mm diameter corrugated steel pipe that travels along the western edge of the project site. It required removal to allow for excavation.
- A Fibre Optic Local Area Network Cable goes through the project footprint. It connected the TRF Trailers (which were removed from the project site) the Inactive Liquid Waste Storage Building/Sheet Metal Shop and the Reactor Maintenance Building to the Darlington computer network. Because the latter two locations remained in operation, this cable was relocated.
- A Fire Protection Line traveled between the HWMB and the project site. The path of the line interfered with the proposed modification of the LPSW pipe and was temporarily relocated to allow the LPSW pipe relocation to take place.

- The Argon Tank and Line, the Oxygen Tank and Line and the Helium Supply System all had to be moved because they interfered with the excavation of the project footprint or the relocation of the LPSW pipe, as discussed above.

In addition, the following abandoned services had to be removed from the project site prior to excavation:

- Steam (12”) and Condensate Return (3”) lines that ran across the project footprint. They were part of steam supply to Darlington Units 1 and 2 during construction and then abandoned.
- Air (6”) and Water (8”) construction lines traveled through the project footprint. They were previously cut and capped, but had to be removed.
- A Miscellaneous Fire Line from prior construction was removed.

8.6 Installing the Caisson Wall and Excavating the Seismic Dike

8.6.1 <u>Caisson Installation and Tie-backs</u>

Before excavation of the D2O Storage Project site could begin, the project installed a retaining wall system consisting of 160 caissons.[28] To create this system, a series of 1 m diameter holes were drilled into the earth, about 1.5 m apart, and approximately 15 m deep. The holes were then filled with concrete. Once the concrete had set, another series of 1 m holes were drilled in between the first set. A vertical steel pile was then lowered into each of these holes for structural strength, and these holes were also filled with concrete. When installation was complete, the installed concrete cylinders combined to form a continuous array of interlocking reinforced concrete shafts to retain the soil surrounding the excavation and reduce water ingress.

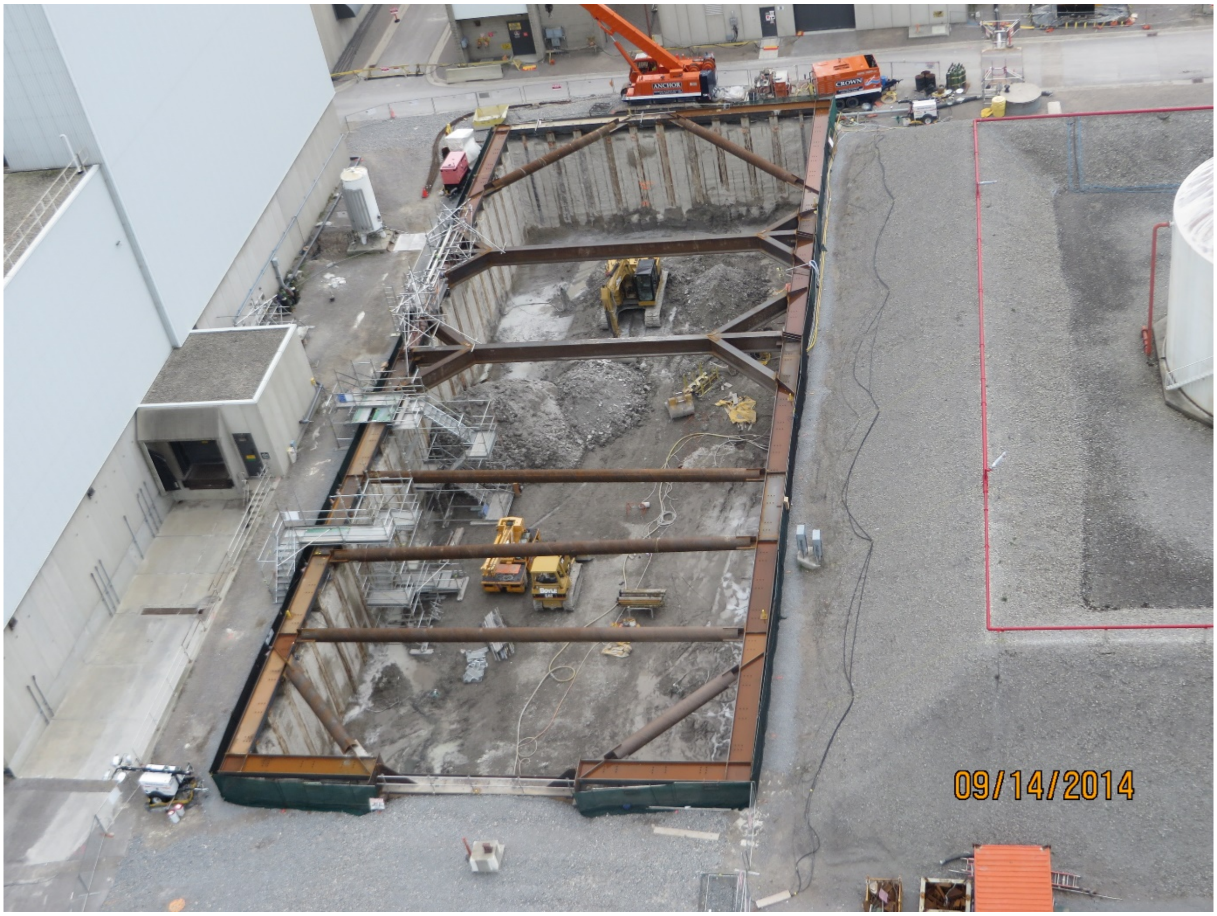
[28] Caisson walls are generally used to support excavations adjacent to existing structures or for structures sensitive to ground movement. They improve safety for people working within excavations and help reduce the penetration of groundwater.

Figure 12 – Caisson Installation North Side of the Project

As excavation exposed the caisson wall, it was secured with rows of tie-back anchors drilled through the concrete piles into the soil behind the wall for stability. When the excavation reached lower levels of the caisson wall, additional rows of tie-backs were added, which penetrated bedrock. Water ingress through some of the tie-backs led to additional pumping and grouting requirements. The project installed a total of 189 tie-backs ranging in length from 9 m to 18 m.

Internal bracing consisting of wailers, struts and corner angles was used to increase the stability of the caisson walls and prevent movement. The struts used in the internal bracing were designed with sufficient spacing between them to allow room for the large D2O storage tanks to be lowered through the bracing for placement in the seismic dike.

Figure 13 – Caisson Wall with Wailers, Struts, and Angle Braces during Excavation



8.6.2 Excavation

Construction of the D2O Storage Project required that the site be excavated to solid bedrock. The rock anchors that enable the facility to resist seismic and hydrostatic pressure had to be placed into solid bedrock to be secure. Excavation began encountering fractured bedrock between 12 m and 14 m, but continued until it reached solid bedrock.

The volume of material excavated was roughly 22,000 m^3. This total volume consisted of excavated soil (approximately 16,500 m^3), soil from relocation of the LPSW pipe (approximately 1,100 m^3), and some 4,500 m^3 of bedrock.

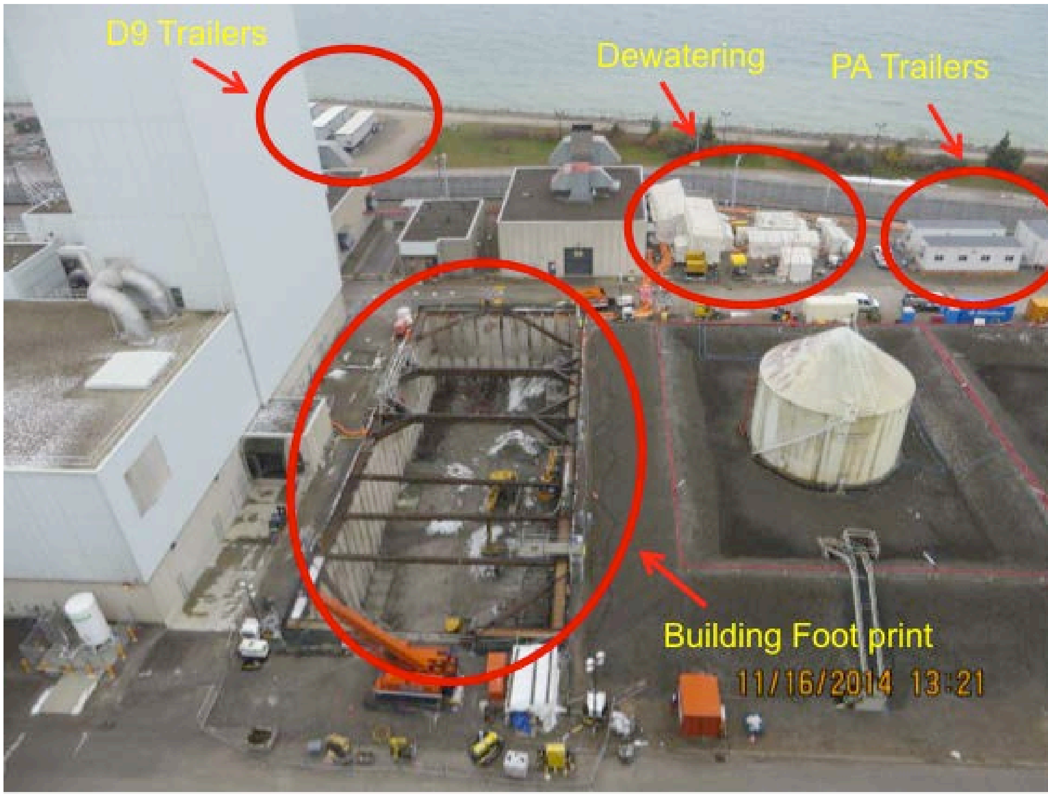
8.7 Temporary Trailers

OPG had initially expected to be able to locate staff from B&M, EllisDon and RCMT on the Darlington site. When this proved impractical in light of other DRP staffing needs, OPG added a temporary space requirement to the project scope. B&M began developing the design plan for the temporary trailers in the spring of 2014.

Temporary trailers were located both within and outside of the protected area as shown in Figure 14 below. The project installed two protected area trailers and a washcar at a location southwest of the project site. The trailers had to be securely positioned and provided with electricity, communications, fire protection and water to the washcar before they could be used.

To house additional staff, the project also installed three 60-foot by 12-foot trailers along with one 23-foot by 10-foot self-contained washcar at the D9 site south of the project and outside the protected area. The installation included concrete blocks for trailer support and stairways and walkways for access. This site was ultimately expanded to include two additional 60-foot by 12-foot rental office trailers. These trailers had to be securely positioned and provided with communications, fire protection and water to the washcar. A diesel generator was installed to provide electricity.

Figure 14 – Trailer Locations and Dewatering Equipment



8.8 Continuing Difficulties Completing Design

As discussed above, owing to the complexity of the project and changes to its design, RCMT found that the engineering effort was more extensive and challenging than it had anticipated. The experience with creating and verifying the preliminary design documents raised questions about whether the May 15, 2013 milestone for design completion was realistic in light of RCMT's capacity to produce quality designs and OPG's capacity to review them in the time available. As discussed in the next section, B&M continually pushed out the timing for design completion. Ultimately, the RCMT designs were completed some two years after the original deadline (see Section 10.3).

8.9 Efforts to Recover Project Cost and Schedule

By spring 2014, with the project schedule extending and cost rising, OPG became increasingly dissatisfied with B&M's performance on the D2O Storage Project. The failure to meet the schedule for delivery of design documents and the delay in completing the LPSW relocation had pushed the construction schedule and increased costs. OPG was having difficulty getting B&M to commit to a new schedule and a firm estimate of cost at completion. Moreover, with the move into the excavation phase of the project, OPG also observed that the working relationship between B&M and EllisDon, which was responsible for both excavation and construction of the seismic dike, was not well-coordinated. In addition, the schedule delay meant that construction of the seismic dike would occur during winter, exposing the project to additional weather delays.

In June 2014, OPG instituted weekly project performance meetings between OPG's Projects & Modifications management team and B&M. Senior management and members of the DRP management team also participated in these meetings.

Throughout 2014, OPG consistently pressed B&M for a fully developed cost estimate and project schedule, prepared on a consistent basis. As shown in the chart below, B&M's EPC contract cost estimate increased substantially month after month. The information provided with these estimates was not sufficient to allow OPG to verify the basis for the forecast increases.

Chart 3 – B&M's Growing Estimates of EPC Project Costs

Date	EPC Contract at Completion ($M)
Execution BCS (May 2013)	65.7
January 2014	123.5
February 2014	133.1
April 2014	224.9
May 2014	253.7
July 2014	282.1
September 2014	286.6*

*Includes the cost savings from scope reductions approved in June 2014 (see Section 8.10)

In July 2014, OPG retained F&G to work with OPG and B&M to jointly develop a firm estimate of project cost at completion. This process produced an overall estimate at completion of $345M, which included all forecast and incurred costs, except capitalized interest, and $20M in contingency. Included within this total amount was $227M in EPC costs to complete, which was comparable to B&M's April 2014 estimate, but some $60M lower than the final estimate B&M submitted in September 2014, as shown in Chart 3, above.

B&M was similarly unable to establish a schedule for completing the project. In March 2014, B&M had agreed to a schedule completion date of March of 2016. Reviews completed in September of 2014 indicated that the base case construction plan could be completed by end of year in 2016. Subsequent discussions in October 2014, aimed at linking performance payments to schedule milestones, indicated a further delay in the available-for-service date to August 2017.

OPG was also growing concerned about B&M's safety performance. Between January and June 2014, three HMRPH events were recorded against B&M, one of which was related to the D2O Storage Project. These incidents resulted in a Safety score of zero under the ESMSA scorecard. While none of these incidents involved injury, pursuant to the ESMSA terms, the high number of HMRPH events cascaded the safety events into a significant Human Performance event in B&M's ESMSA scorecard.

8.10 Scope Review

In an effort to improve the schedule and control cost, in late April 2014, OPG, RCMT and B&M initiated an exercise to review the scope of the project. The review considered the ability to:

- Remove office space;
- Eliminate foundation box drains;
- Reduce piping and valves;
- Eliminate the backup diesel generator;
- Remove seismic dike sprinklers; and/or
- Replace maintenance communication system with radio repeaters.

The review resulted in a recommendation to eliminate the office space. Planning for post-refurbishment anticipated that office space created for DRP would become available to be turned over to the Darlington site. TRF personnel could relocate to those offices in the future. Elimination of office space had other favourable implications for the project scope. It meant that the completed facility would generally be unoccupied, and as such, would no longer require washrooms. Removing the office space also eliminated the need for a separate air handling system and radiological zone for the offices. OPG estimated that the office removal would save $2.5M and eight weeks of non-critical path schedule time.

Representatives from TRF Operations and the project held a meeting to review the transfer piping functional requirements. As a result of this review the amount of piping between the D2O Storage Project facility and the HWMB/TRF was reduced by replacing some pairs of unidirectional piping with bidirectional piping and by using buffer tanks for some infrequent transfers. These changes reduced the amount of piping by approximately 900 m and eliminated numerous valves and other components. The project estimated that these changes saved $1.9M and four weeks of critical path schedule time.

Other scope changes were also approved. The box drain and its tie-in to the HWMB sump were determined to be unnecessary because of the installation of the construction dewatering system and groundwater monitoring boreholes, which saved about $0.3M and five weeks of critical path schedule time. Communication and sprinkler systems were also eliminated because there are no significant combustible loads in the D2O Storage Project and, as noted above, the elimination of the office space meant that the building would not be regularly occupied. These two changes saved a combined $0.4M and eight weeks of non-critical path schedule time.

Given the cost increases and schedule extensions the project was experiencing, the scope review exercise was a reasonable step to reduce project complexity. The approved scope reductions simplified construction and reduced cost. In total, they were forecast to reduce project cost by $5.3M and remove nine weeks from the project's critical path schedule.

Two items considered for scope reduction were not approved. The back-up diesel generator was retained due to insufficient back-up power availability at Darlington and minimal overall cost savings due to rework that would have been required to the facility's electrical and instrument and control system designs, which were already more than 80% complete. The project also evaluated the potential for reducing the number of rock anchors required, but concluded that all 221 rock anchors were necessary to meet the seismic design requirements.

OPG also requested that RCMT examine the technical viability of raising the D2O Storage Project building's foundation from the original design elevation of 87 m, which was selected to match the elevation of the HWMB/TRF, to a higher elevation of 94.8 m. OPG sought to examine this approach as a possible mitigation of ongoing water ingress issues and the need to design and construct the buried pipe chase. RCMT's preliminary analysis considered the feasibility of elevating the building as currently designed within the building's footprint. On this basis, RCMT concluded that it could not endorse a decision to elevate the building's foundation because of concerns about the resulting structure's stability. OPG accepted this conclusion.

8.11 Termination of Black & McDonald and Settlement

8.11.1 Termination

In September 2014, OPG convened a series of meetings with B&M as a final attempt to reach a firm agreement on cost and schedule for the D2O Storage Project. OPG had concluded that unless B&M assumed greater risk for the cost of the completed project, there could be no cost certainty. B&M and its Tier 1 subcontractors were willing to set a target price for completion and reduce their recovery of the performance fee under the ESMSA if the target price was exceeded. However, they were unwilling to assume any financial responsibility for cost overruns if the project's cost exceeded the target price.

In an attempt to recover the project schedule, OPG instructed B&M to have EllisDon begin double shifting, but several weeks after this instruction had been issued, it was still not implemented. While OPG explored methods of improving the working relationship between EllisDon and B&M, none were acceptable to B&M.

Negotiations with B&M continued into October. B&M offered the additional concession of eliminating the performance fee in the event the target price was exceeded, but remained unwilling to accept any responsibility for increases in the target price itself. OPG continued to reject this approach.

After evaluating the merits of continuing with B&M, OPG terminated B&M's D2O Storage Project PO on October 16, 2014. The termination letter cited issues with B&M's performance in carrying out its obligations related to estimating, scheduling and managing the D2O Storage Project and with meeting the standard of care established under the ESMSA in performing the project. The letter instructed B&M to co-operate with OPG in transitioning the D2O Storage Project and meet the next day to review OPG's transition plan.

B&M replied to OPG indicating several circumstances that B&M claimed excused its performance on the project and indicated that OPG had failed to follow the ESMSA requirements for termination for cause. It concluded that if OPG wished to terminate the contract for convenience, B&M would facilitate the transfer of the work, project information and any materials procured. Over the next month, OPG and B&M worked together to transition subcontractors, equipment rentals, materials and project documentation to OPG, which assumed the role of general contractor.

8.11.2 Settlement

At the time B&M was terminated from the D2O Storage Project, the parties were already in discussions regarding the recourse sought by both parties for commercial issues relating to this and other projects. B&M and its subcontractors had numerous claims for outstanding payments and claims relating to performance fees under the ESMSA. After the termination, OPG added contractual damages arising from the inadequacy of the work on the D2O Storage Project. Through negotiation and verification of each party's claims, most of the claims advanced were reduced, eliminated or set off against each other. Ultimately, OPG, B&M and its main subcontractors reached global settlements for all of the claims among the parties.

In August 2016, OPG and B&M entered into a Settlement Agreement, which resolved outstanding claims between them under the ESMSA. This Settlement Agreement included all claims related to the D2O Storage Project as well as a few claims from other projects. B&M submitted numerous requests for payment of outstanding invoices and other claims on behalf of itself and its subcontractors for work on the D2O Storage Project and other ESMSA work. Some of the claims had estimated values and others were unspecified. For those items with dollar values, the B&M matters related to the D2O Storage project had an estimated value totaling $30.1M and those related to other ESMSA work had an estimated value totaling $1.5M. OPG countered with its own claims against B&M and B&M's subcontractors, some of which had estimated values while others were unspecified. OPG's claims had estimated values totaling $23.5M. OPG accepted some of B&M's claims and rejected others including claims for additional performance fee payments.

To settle the outstanding claims, OPG paid B&M about $3.4M. B&M agreed to provide Canadian Union of Skilled Workers ("CUSW") members with about 60,000 hours of work to settle a CUSW grievance that claimed B&M failed to properly allocate electrical work between

CUSW and the International Brotherhood of Electrical Workers while performing work for OPG. B&M also agreed to assume the defense and cost of a lawsuit by Via Rail and indemnify OPG against any judgement or settlement costs arising from that action. The Settlement Agreement also confirmed that it resolved all prior period claims identified in the agreement and barred B&M from asserting any additional claims related to the settled matters.

OPG negotiated a separate release with RCMT and B&M that covered outstanding invoices and other claims for work done by RCMT on the D2O Storage Project and other OPG projects. The RCMT invoices covered by this release related to work RCMT performed as a subcontractor to B&M and work directly for OPG. RCMT also claimed $5.3M in additional performance fees, which OPG rejected. OPG made a counter-claim against RCMT based on the findings of an external audit of its billings, which RCMT disputed. To settle all the outstanding RCMT claims and OPG's counter-claim, OPG made a payment of $3M to satisfy $5.1M of outstanding RCMT invoices and did not pay any additional performance fees.

OPG also negotiated a separate release with EllisDon and B&M related to unpaid EllisDon invoices. These invoices covered EllisDon's work as a subcontractor to B&M and EllisDon's work directly for OPG. Under this agreement, OPG paid two outstanding EllisDon invoices totaling $2.4M, of which $2.2M was for the statutory holdback owing at the completion of D2O Storage Project work and $0.2M was for performance fees earned. Pursuant to the release, EllisDon cancelled invoices totaling $0.6M and B&M paid OPG $0.2M for claims related to EllisDon's billings while a subcontractor to B&M.

9.0 PROJECT EXECUTION BY OPG AND THE SECOND PROJECT PROCUREMENT

9.1 Assumption of Subcontracts and Retaining ES Fox

Upon termination of the B&M contract, OPG assumed the role of general contractor and exercised its right under the ESMSA to assume the contracts between B&M and its Tier 1 subcontractors, EllisDon and RCMT. OPG also awarded 14 POs to B&M's Tier 2 subcontractors and coordinated their work as the general contractor. These contracts and POs were put in place to ensure continued progress on the project while OPG undertook to engage a new general contractor.

To replace work that was previously performed by B&M and to meet emerging project needs, OPG executed two SOWs under its existing ESMSA contract with ES Fox. The first was to support ongoing excavation by EllisDon. This work included hoisting and rigging, installation and maintenance of temporary staircases and scaffolding to support excavation, support for dewatering, installation of lighting to allow work at dusk and at night, and general construction support. The second SOW related to the temporary trailers acquired for contractor staff (as discussed above), tie-in work to be undertaken in the HWMB/TRF and work on items to be embedded in the seismic dike concrete (see Section 9.3), such as drainage, grounding and conduits. ES Fox also took charge of the unused materials that B&M had procured for the project.

9.2 Sub-Slab and Rock Anchor Installation

EllisDon continued its work on the excavation as a subcontractor to OPG. As fully discussed below, water ingress was one of the major challenges during the excavation, sub-slab pouring and rock anchor installation. Despite the extensive and continuous dewatering activities carried out on the project, it is virtually impossible to exclude all water when undertaking work so far below the water table and drilling through the caisson walls and the sub-slab into bedrock.

By December 2014, the excavation was beginning to remove fractured bedrock. Upon completion of excavation in early 2015, installation of the concrete sub-slab began. The sub-slab is a 250 mm thick unreinforced concrete pad that rests on bedrock and is used to prevent weathering of the bedrock, level the site, provide a working surface and act as a base for the waterproof membrane that sits underneath the reinforced concrete structural foundation slab. As discussed below, the foundation slab forms the bottom of the seismic dike.

The sub-slab was installed in two pours with the southern 60% of the project area covered by the first pour and the northern 40% covered by the second. Water ingress was a continuing problem. Water entered the site through tie-backs in the caisson walls, the rock anchors and, most significantly, through upwelling beneath the 40% sub-slab where hydraulic pressure led to significant uplift (between 2 and 8 inches). The uplift broke the sub-slab into pieces, some with bedrock attached to their undersides. As a result, the 40% pour had to be removed. A drainage system was then installed beneath the 40% slab before it was re-poured. The need to re-pour the 40% northern sub-slab added one month to the scheduled completion of the sub-slab, but by resequencing pouring of the walls, the project was able to recover schedule.

After the sub-slab was completed, 221 rock anchors were installed. Rock anchors are threaded steel rods, approximately 7 m long, which extend at least 4.3 m into solid bedrock. The rock anchors are inserted into sleeves placed into holes drilled in the bedrock and filled with waterproof cement grout. Despite the initial grouting, some rock anchors leaked water into the excavation. This water had to be pumped out, additional holes drilled around the rock anchors, and additional grout injected. Once the grout had cured, the rock anchors were tensioned to firmly integrate them with the underlying bedrock.

Figure 15 - Rock Anchor Sleeves with Wood Forms and Waterproof Membrane

A steel bearing plate was welded to the top of each pipe holding a rock anchor. A steel washer was then placed on each anchor and a nut was threaded on top. Wooden forms were constructed around each rock anchor to allow access to the nuts after the foundation slab concrete was poured. When the concrete had cured, the forms around the rock anchors were then removed. The nuts then were locked down on the washer and steel bearing plate. As a final step, additional concrete was poured over the rock anchors to complete the foundation slab.

Figure 16 - Rock Anchor after Foundation Slab Pour with Nut, Washer and Steel Bearing Plate

The winter of 2014-2015, when excavation was completed, rock anchors were installed and seismic dike construction took place, was exceptionally cold.[29] Insulated tarps were purchased along with the rental of wall and ground heating equipment to heat the concrete slab and the caisson walls to avoid deflection from frost. Movement of the caisson wall was monitored weekly using targets mounted on the walls. The cold weather also delayed rock anchor drilling and grouting due to freezing of the grout lines.

Figure 17 - Ground Heaters and Caisson Frost Protection Tarps

Prior to pouring the foundation slab, OPG began installing the waterproof membrane on top of the sub-slab. This membrane acts as a barrier to water ingress into the bottom of the seismic

[29] In Toronto, the winters of 2013-14 and 2014-15 when site clearing, excavation and seismic dike construction were occurring, were both exceptionally cold. Winter 2013-14 was the fifth coldest winter in the 60 years between 1956 and 2015 and the second coldest in the 30 years between 1986 and 2015. Winter 2014-15 was the sixth coldest over the same 60-year period and the third coldest over the same 30-year period. "Evolution of Winter Temperature in Toronto, Ontario, Canada: A Case Study of Winters 2013/14 and 2014/15" Conor I. Anderson and William A. Gough, Journal of Climate, July 2017, Vol. 30, No. 14 Department of Physical and Environmental Sciences, University of Toronto Scarborough, Scarborough, Ontario, Canada https://journals.ametsoc.org/doi/full/10.1175/JCLI-D-16-0562.1?mobileUi=0&

dike. It is made up of sheets of specialized sealed plastic taped together. Taping the membrane sheets requires a minimum temperature of -4ºC, which, given the cold winter, prevented installation until mid-March 2015.

9.3 Seismic Dike Foundation Slab and Walls

While OPG was finalizing retention of a new EPC contractor, as discussed in Section 10.1 below, EllisDon, ES Fox and subcontractors continued working on the seismic dike base and walls. The foundation slab is the structural base of the seismic dike, consisting of a 1 m thick reinforced concrete slab that rests on the waterproof membrane discussed above. Prior to pouring the concrete, rebar and drainage piping was placed to be embedded within the concrete slab. Like the sub-slab, the foundation slab was installed in two pours, 60% on the south side and 40% on the north. This allowed work to continue on the south side of the project while OPG resolved the water ingress issues on the north side sub-slab.

Figure 18 - Rock Anchor Sleeves with Forms, Rebar and Drainage Pipe Prior to Foundation Slab Pour

The need to resolve water ingress under the 40% sub-slab necessitated resequencing the wall pours. Work advanced on the south wall, while drainage was being installed for the 40% sub-slab. After the waterproof membrane and rebar were installed on the south wall, ES Fox installed items to be embedded in the concrete such as grounding and plates. Wooden forms were constructed for the walls in preparation for the concrete pours.

Pouring of the concrete walls occurred over the summer and fall of 2015 with the lower portions of the walls being poured first on the south, southeast and southwest portions of the project. In September 2015, plywood forms started to deform under load during the concrete pour for the upper half of the south wall. When movement exceeded the allowed tolerance, the contractor was forced to stop mid-pour.

Figure 19 - Installation of the Top Half of the Seismic Dike South Wall

The partially poured south wall had to cure before the contractor could begin to chip away the unconsolidated section of poured concrete, install additional dowels and repair any damaged rebar in preparation for re-pouring the remaining portion of the south wall. To mitigate the resulting schedule impacts, EllisDon developed a recovery plan, which included resequencing the wall pours and double shifting to complete the interior and exterior walls of the seismic dike.

While the south wall was being readied, new form work was constructed and concrete pouring resumed for the remaining exterior and interior walls and the two stairwells. When shrinkage cracks emerged in the exterior walls, polyurethane was injected to seal them to limit the ingress of ground water. The remaining walls were poured without incident throughout the fall of 2015.

9.4 Seismic Dike Topping Slab

In preparation for the installation of the D2O storage tanks, a 0.2 m reinforced concrete topping slab was poured on the foundation slab. The topping slab serves as the floor of the seismic dike. It is sloped at a 1% grade away from the walls to the drains in the center to address potential spills. The topping slab was coated with epoxy, as were the lower portion of the seismic dike interior walls. The epoxy protects the floors and facilitates cleanup in the event of a spill. Following the pouring of the topping slab, anchors were installed to secure the storage tanks.

10.0 PROJECT EXECUTION BY THE SNC-LAVALIN/AECON JOINT VENTURE

10.1 Retention of an EPC Contractor to Complete the Project

In late December 2014, OPG issued a work request under the ESMSA contract to select a new EPC contractor to complete the D2O Storage Project. The work request was sent to the two remaining ESMSA contractors, ES Fox and CanAtom. CanAtom was added as a third ESMSA contractor in December 2014 to increase the capacity to perform refurbishment work and add competition among the ESMSA contractors (see Attachment 2g - CanAtom ESMSA dated December 19, 2014 and Attachment 2h- CanAtom ESMSA Amendment #1 dated July 7, 2015 and Attachment 2i - CanAtom ESMSA Amendment #2 dated January 1, 2017).

The work request contained the following rated criteria for evaluating the responses. Technical merit (all non-price factors) comprised 75% of the score and included:

- the quality of the project team (20%),
- the detail and duration of the proposed schedule (20%),
- demonstrated understanding of the project's technical details (15%),
- quality of proposals to increase the value/lower the cost of the project (15%), and
- risk identification and contingency plan (5%).

Price comprised the remaining 25% of the score.

The increased weighting of technical merit in this work request, as compared to the first work request issued in 2012, reflected the fact that as design, engineering and construction progressed, the project's complexity was better understood. As a result, OPG assigned greater weight to the technical aspects of the work request.

The work request also incorporated terms from the ESMSA agreement that had been negotiated with CanAtom. The ESMSA agreement signed with CanAtom incorporated new terms that were subsequently reflected in amendments to the ES Fox and B&M ESMSA agreements to create substantially similar agreements among the three ESMSA contractors.

Responses were received from both ES Fox and CanAtom at the end of 2014. Both responses were accepted and scored early in 2015. Both pricing proposals were deemed non-compliant. Moreover, the pricing proposals were not developed on the same basis and were inconsistent in their acceptance of the ESMSA requirements. In a follow-up meeting with ES Fox, it became clear that ES Fox had not based its proposal on the version of the ESMSA signed with CanAtom, as was required by the work request. OPG decided to negotiate with both proponents for improved proposals that were fully compliant.

In March 2015 both contractors submitted improved proposals. Both proposals were rescored. CanAtom's revised proposal scored higher on both technical and price factors. As a result, CanAtom was selected as the new EPC contractor and discussions began on the terms to be embodied in a PO for work on the project.[30]

10.2 CanAtom Begins Work Pursuant to a Limited Notice to Proceed

While OPG and CanAtom negotiated the PO terms, CanAtom was awarded a Limited Notice to Proceed ("LNTP"). This LNTP, issued on April 17, 2015, allowed CanAtom to begin work on the project in advance of the final PO in order to maintain the project schedule. The LNTP authorized CanAtom to undertake the following key tasks:

- Development of the project schedule and costs components;
- Procurement activities for long-lead and critical path materials and equipment (including valves);
- Completion of outstanding engineering packages;
- Takeover of engineering packages from RCMT in a structured manner to ensure a smooth transition and future cooperation; and
- Set up and mobilization of the project organization.

The LNTP had a maximum value of $5M and an expiry date of June 5, 2015. All amounts paid under the LNTP were to be included in the final price negotiated for the PO.

As negotiations over the PO continued, the LNTP was extended and the maximum value was increased to $12.6M. The extension allowed CanAtom to continue working on the project, including continuing to develop a detailed schedule and other project documents, and to begin procuring long-lead materials. The extension also authorized CanAtom to begin accepting materials procured by OPG, fabricating pipe spools,[31] and installing piping in the HWMB.

The PO for the project was issued to CanAtom on August 18, 2015 for $160M, which was within the $381M budget approved in the 2015 Superseding Release Execution BCS (see

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[30] In March 2015, while OPG was completing its assessment of the proposals submitted by CanAtom and ES Fox, OPG executed the 2015 Superseding Release Execution BCS, which brought the total project funding to $381.1M (see Attachment 2p).

[31] A spool is a welded piping assembly fabricated to fit in a specific location. To the extent possible, having spools fabricated in a shop, rather than performing the cutting and welding at the project site is preferable from the perspective of both cost and quality.

Attachment 2j – CanAtom Purchase Order #251088 Rev. 15 – Final Revision and see Attachment 2p – 2015 Superseding Release Execution BCS). The PO incorporated a detailed SOW negotiated by the parties.

10.3 Review of RCMT Design and the CanAtom's Proposed Modifications

In spring 2015, RCMT was completing the remaining design engineering packages and CanAtom was beginning to review them. In May of that year, CanAtom started to question the design of the seismic dike top slab and the superstructure for the project building. CanAtom's position was that the building, as designed, had not been shown to meet applicable codes and would be unstable during construction. RCMT responded to the issues that CanAtom raised by maintaining that the current design met applicable codes, incorporated standard construction techniques and that maintaining lateral stability during construction was a typical responsibility of the construction firm.

By July 2015, CanAtom proposed modifying the RCMT design for the seismic dike top slab and building superstructure. CanAtom claimed the top slab required redesign because the original design was not based on the appropriate nuclear-related building standard and was not properly connected to the building's structure. To correct these claimed deficiencies, CanAtom proposed a 700 mm reinforced concrete composite slab, connected directly to the supporting steel through shear studs and eliminating the 300 mm formwork slab that was part of the RCMT design. Implementing this change required changes to the supporting beams, stairwell walls, piping supports and electrical cable trays.

CanAtom also claimed that the building superstructure required redesign because it failed to meet the applicable code for wind loading and would be difficult and costly to construct. CanAtom's proposal was to eliminate the structural pre-cast concrete panels and replace them with a conventional steel frame building with architectural (non-load bearing) panels. Under this approach the building's steel frame and bracing, rather than structural concrete panels, would be used to resist lateral loads from wind and seismic activity.

CanAtom's proposal required revising the building's entire superstructure, including steel beams, columns, bracing and the connections between the superstructure and the building's floors and walls. CanAtom stated that adopting these changes would allow more efficient and safer construction and provide greater access to the building during construction because the panels closing the building could be completed later in the schedule. CanAtom committed that: "The engineering cost to redesign the building can be reconciled with the savings in the construction costs; therefore will not change our performance fee submitted July 3rd 2015."

OPG asked one of its external design review engineers to examine the RCMT design in light of the issues raised by CanAtom. This engineer undertook a high-level review and concluded that the RCMT design was unusual in that it lacked lateral bracing for the steel superstructure and, as such, would require significant effort to erect temporary support structures in order to construct the building. The reviewing engineer also indicated that there was no documentation to show that the precast panels relied on for structural integrity had been adequately reviewed against wind and seismic loads. The reviewing engineer concluded that adopting a design where the steel superstructure was used to meet all loads and the precast panels were solely used for architectural, rather than structural, purposes would minimize construction delays and engineering effort.

Based on CanAtom's explicit confirmation that the proposed design changes would not increase the project's cost or delay it, OPG accepted CanAtom's redesign proposal. As OPG's acceptance of CanAtom's redesign occurred prior to OPG and CanAtom agreeing on a final contract price in the signed PO for the project, OPG viewed the redesign cost as having been captured in the initial performance fee work negotiated for the project. This fact was explicitly noted in OPG's acceptance memo.

10.4 CanAtom Assumes Control of the Project Site

Beginning in the summer of 2015 and continuing through the fall, CanAtom was engaged in completing design work, procuring long-lead equipment and setting up piping fabrication for the project. Procurement fell behind schedule as CanAtom was challenged to ramp up this activity and the associated quality program. CanAtom was also delayed in achieving the staffing necessary to meet its piping fabrication targets. CanAtom identified constructability issues with the piping design produced by RCMT that required field changes and some redesign work, which put further pressure on the schedule for piping fabrication. CanAtom developed a recovery schedule to address these delays and OPG provided personnel to help advance testing and fabrication.

In November and December of 2015, CanAtom began working at the project site doing preparatory work for piping installation, first in the HWMB and then in sections of the seismic dike as they were completed by EllisDon. Full handover of the project site to CanAtom occurred in mid-January 2016. While this was later than originally anticipated, OPG did not view this as a cause of delay because of CanAtom's difficulties in ramping up the piping fabrication process, discussed above. In OPG's view, CanAtom would not have been ready to begin the full range of scheduled tasks in the seismic dike had it been granted access on the original turnover date.

D2O storage tank delivery began in November and was completed in December 2015. The first tank was installed in the seismic dike in late December 2015. The tanks were trucked to the site from OPG storage, hoisted by cranes, lowered into the seismic dike through the struts and positioned as required. Tank installation continued during early 2016 and was completed in May of that year.

Figure 20 - Lowering the First D2O Storage Tank Into the Seismic Dike

In January 2016, CanAtom began installing the supports for the piping to connect the tanks to each other and the HWMB/TRF. Construction of a temporary partial dome to shield the exposed seismic dike from the weather was completed in February 2016.

Throughout the first half of 2016, piping fabrication was delayed. CanAtom established a second recovery schedule in January 2016, but by March, it was already behind this recovery schedule. Performance stabilized somewhat over the spring, and at the end of May, OPG was estimating an AFS date for the project in early May 2017. In June 2016, another revised recovery schedule was required because the project was continuing to lag behind the earlier schedule. Despite the ongoing delays, the targeted AFS date remained early May 2017.

As a result of the slow start of procurement and fabrication, and the inability to properly translate the project's complexity into an achievable recovery schedule, most project milestones were late. The original schedule had all equipment lowered into the basement, which was a predicate for installing the top slab of the seismic dike, by February 2016. This milestone was achieved at the end of July 2016. Similarly, the concrete pour for the top slab of the seismic dike that was scheduled to occur in early April 2016 was completed in early August of that year.

10.5 Piping Installation in the Seismic Dike

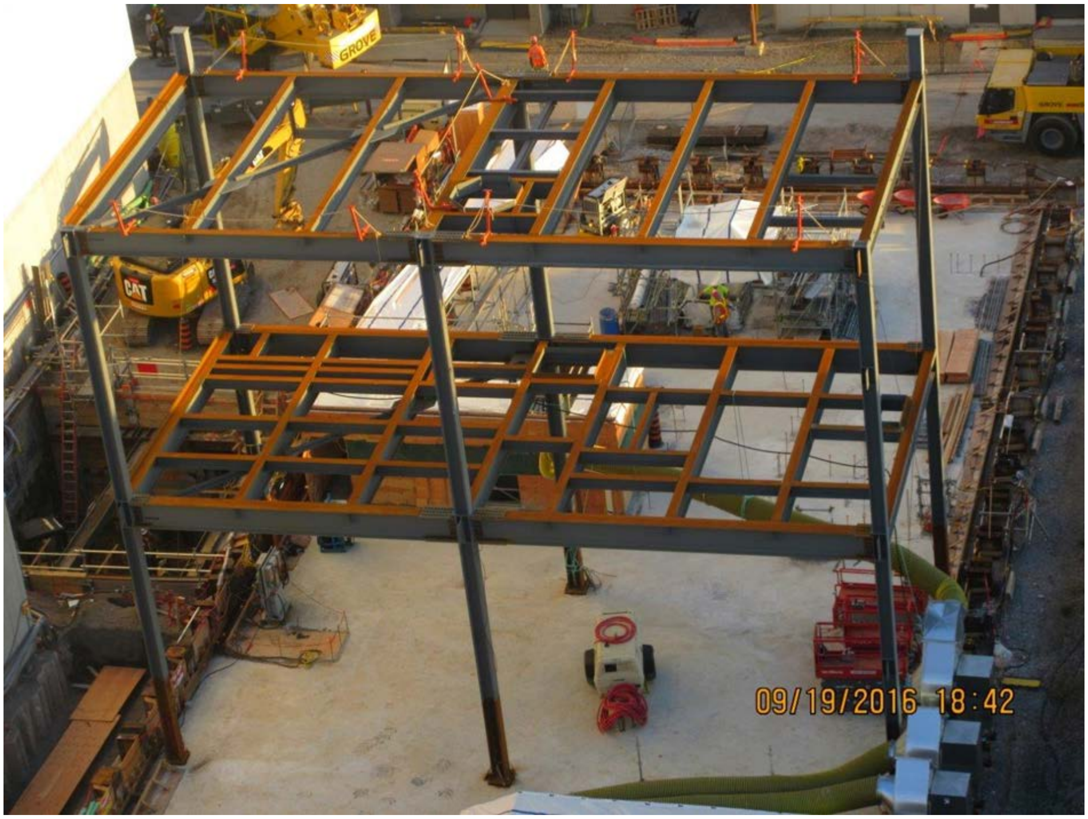
At the heart of the difficulties in keeping the project on schedule was the fabrication of piping spools and installation of almost 10,000 m of piping. The piping work was complex and exacting (see Figures 5 through 8, above), involving detailed engineering, precise placement of piping, thousands of individual welds and connections to tanks, valves and pumps and hundreds of racks and hangers. In late November 2015, CanAtom's schedule showed completion of all piping and pumps in the seismic dike basement by early July 2016. By February 2016, the completion date for this task had moved to mid-October 2016, largely due to delays in piping spool fabrication.

10.6 Pouring the Seismic Dike Top Slab and Erecting the Building Frame

Construction of the upper two floors of the D2O Storage Project building could not begin until the seismic dike top slab at elevation 100 m was poured as this slab served as the base of the building's superstructure and its ground floor. As noted above, this was delayed by about four months.

Erection of the building steel superstructure was also delayed from the original schedule because of the delay in pouring the slab. The PO originally had erection of the building superstructure starting in May 2016. The June 2016 recovery schedule showed this task starting in August 2016. The task began one month later in September 2016.

Figure 21 - Erection of the Building Structural Steel



Once this task began, however, the work proceeded smoothly. The steel was installed in a period of approximately three months, which was within a few days of the duration for this task shown in the recovery schedule.

10.7 Pipe Chase Excavation, Shoring and Construction

Excavation of the pipe chase began in August 2016 at about the same time as the elevation 100 m slab was poured. The excavation was initially accomplished via a hydrovac to allow daylighting of buried services. The most significant buried service was the foam fire line used in the fire protection system for the standby-generator fuel oil tanks located adjacent to the D2O Storage Project site. This line had to be exposed and supported during construction. During this time, a temporary supply of fire-fighting foam was provided. The other buried services were either supported during construction or removed. Finally, abandoned portions of the nitrogen and argon lines that had been previously rerouted were cut, capped and removed from the pipe chase footprint.

Once the buried services were addressed, excavation proceeded. As was the case with the LPSW pipe trench discussed above, the depth of the pipe chase trench required that it be shored and dewatered. During excavation, the seismic dike walls were monitored for displacement to ensure any movement was within specified design tolerance levels.

Upon completion of excavation, a sub-slab was poured and allowed to cure. The support for the pipe chase, consisting of 16 micro-piles driven down to solid bedrock to achieve seismic stability, was then installed. Waterproof material was placed above the sub-slab prior to installing rebar and building the forms for pouring the concrete pipe chase floor. This was followed by installing rebar, building forms and pouring concrete for the pipe chase walls and ceiling. These too were covered with a waterproof membrane.

To connect the pipe chase to the D2O Storage Project, an entrance was cut in the caisson wall surrounding the seismic dike, which allowed access to the entry way that had been created when the seismic dike wall was poured. To connect with the HWMB, holes were drilled through its seismic dike to allow piping to run between the two buildings. Upon completion of the pipe chase structure, the trench was backfilled and work began on installing the hangers, racks and piping within the pipe chase. To address seepage where the pipe chase connected to the HWMB, epoxy injections were subsequently required.

The pipe chase was a challenging engineering and construction task, which needed to be precisely executed to align with both the D2O Storage Project and the HWMB. The work was undertaken in a constricted area at the same time that the steel superstructure for the D2O Storage Project was being erected. Construction of the pipe chase was completed in January 2017.

10.8 Storage of Unit 2 Heavy Water During Construction

In October 2016, in advance of draining the heavy water from Unit 2, OPG developed options for the storage of Unit 2 PHT and moderator heavy water given that the D2O Storage Project remained under construction. Given completion of the seismic dike and the installation of piping necessary to connect five PHT tanks, OPG first considered the option of using the D2O Storage Project as temporary storage. This option was ultimately rejected.

Use of the D2O Storage Project would have required installation of a number of temporary systems, such as leak detection and radiation monitoring, to safely store radioactive heavy water in the building, which would have added to the project's cost. Furthermore, the presence of heavy water in the building would have adversely affected ongoing construction progress to complete the facility.[32]

Instead, OPG decided to temporarily store the heavy water drained from Unit 2 in the HWMB. Accomplishing this required OPG to minimize heavy water inventories in the HWMB, repurpose some HWMB tanks and ship some heavy water to Pickering and Bruce. Attachment 5 details the actions OPG took to create safe, temporary storage for Unit 2 heavy water in a manner that minimized the cost and schedule risks to the D2O Storage Project.

While OPG was able to temporarily create sufficient storage in the HWMB for one unit's heavy water, the approach employed occupied all of the available storage at the HWMB. Once the HWMB moderator tanks were full, the station faced greater challenges in the event of an emergency situation that required a moderator drain because there was no ready place to store additional heavy water.

In April 2019 and January 2020, D2O was removed from the HWMB and restored to the Unit 2 moderator and PHT systems, respectively.

[32] Once heavy water had been placed in the D2O Storage Project building, at least part of the building would have been classified as Zone 3 (denoting an area that contains radioactive systems) requiring workers entering the classified area to undergo radiation monitoring upon entry and exit.

10.9 Completing the Building Envelope, Pouring Floor Slabs and Constructing the Causeway

At the end of 2016, as construction of the pipe chase was drawing to a close, CanAtom began installing the decking for the second floor (elevation 107.8 m) in preparation for pouring the concrete floor slab at this elevation and the elevation 104 m platform. Once the second floor slab was cured, CanAtom began lifting the available pieces of mechanical and electrical equipment onto the buildings' second floor. Owing to the size of these pieces of equipment, placing them in the building was more easily accomplished before the building was fully enclosed with concrete cladding.

Early in 2017, CanAtom began installing the precast concrete panels used to enclose the building. These panels were quite large, approximately 2.4 m wide, averaging more than 8 m high (the height varied between floors), and 0.3 m thick. This work involved lifting the panels and bolting them to the steel superstructure. It proceeded over several months to completion in March 2017.

Figure 22 - Concrete Panel Installation on the East Side of the D2O Storage Building

During this same time period (early 2017), construction also began on the causeway that runs between the D2O Storage Project and the loading dock in the HWMB. This causeway is used to transport D2O storage drums and equipment between these two buildings. It also contains the instrumentation and control cabling that runs between the project and the control room in the HWMB.

10.10 Construction Slowdown and Redesign Dispute

In October 2016, CanAtom issued Project Change Notice ("PCN") 67. This PCN sought a cost increase of $37.4M for engineering redesign and delays to procurement and construction arising primarily from the changes to the building's steel superstructure and the ground level (elevation 100 m) slab atop the seismic dike. This notice was OPG's first indication of the magnitude of the additional cost claim, despite frequent reports from CanAtom on the status of the project.

The drivers of PCN 67 were the significant cost and schedule impacts from changes CanAtom proposed to the structural steel frame and concrete slab in July 2015, as discussed above (see Section 10.3). Implementing these changes required an extensive redesign effort and modified the concrete seismic dike top slab, structural steel, steel connections and associated elements of the project.

In addition to the funds requested by PCN 67, by December 2016, CanAtom had issued several other smaller PCNs, which together totaled about $7.5M. Thus, by the end of 2016 CanAtom was claiming some $45M in additional costs.

A series of meetings occurred early in 2017 to better understand the basis for CanAtom's cost claims and to explore ways to jointly mitigate them. Through commercial discussions between the parties, OPG accepted responsibility for about $7.5M for claims related to scope or estimation issues, leaving some $37.5M in dispute. This sum related primarily to redesign of the steel superstructure and seismic dike top slab.

OPG refused to accept the costs of the redesign. OPG's position was that it had agreed to the redesign based on the CanAtom's confirmation that it would not adversely impact the project's cost and schedule and, in any event, the engineering and project management costs claimed were excessive. As noted previously, OPG also took the position that since this design change occurred before finalizing the SOW underpinning the PO with CanAtom for the project, all costs related to the design change were already included in the negotiated PO amount.

To resolve this dispute, CanAtom offered to extend the project completion date to reduce future costs by decompressing the schedule, but OPG rejected that offer because the projected savings were less than its estimated carrying costs from the longer schedule. Other than this change, CanAtom was unwilling to accept material reductions in its cost claims.

At the end of January 2017, CanAtom informed OPG senior management that: (1) its billings were approaching the PO maximum, which would require CanAtom to stop working; (2) OPG had failed to formally respond to PCN 67; and (3) failing a response, CanAtom would be required to begin demobilization by mid-February in order to avoid over-spending the approved PO.

OPG responded by formally rejecting PCN 67 and advised CanAtom that the ESMSA contract prohibited any work stoppage or delay based on commercial disputes. OPG's response also stated that it did not agree with CanAtom's claimed need to redesign the seismic dike top slab and superstructure and therefore rejected responsibility for the $37.5M in increased costs. Finally, OPG indicated that it was obtaining a third party review of the need for the redesign and would reassess its position once it had obtained the third party review.

To allow work on the project to continue while the dispute was being resolved, OPG issued a Consent to Proceed ("CTP") to CanAtom for $11.1M. This funding was made available to continue work on project planning and critical path execution activities, but payment was conditioned on OPG receiving a cost savings plan by March 3 and a revised project cost estimate and schedule to be completed by March 27, 2017.

In early March 2017, OPG and CanAtom agreed to a D2O Recovery Plan that provided for a six-week slowdown in project work between March 6 and April 17, 2017. The Recovery Plan required CanAtom to:

- Provide periodic reports;
- Retain High Bridge Associates, Inc. ("High Bridge") to provide OPG with the cost, schedule and remaining scope to complete the D2O Storage Project;
- Reduce its Project Management Team from 175 individuals to 74.5 full-time employee equivalents;
- Complete Comprehensive Work Packages ("CWPs") to execute the remainder of the project;
- Resolve any remaining engineering issues;
- Complete the procurement process for purchased material to the extent possible;

- Complete detailed planning and provide a detailed schedule for completing the project; and
- Perform ongoing construction including piping, positioning and installation of mechanical equipment and building completion activities.

Soon after establishing the D2O Recovery Plan, OPG was advised by CanAtom of an error in its cost accrual, which resulted in CanAtom under-reporting the amount outstanding on the project by approximately $10M. OPG responded by retaining KPMG to audit CanAtom's costs and, as an interim measure, increased the PO amount by $6.4M to pay a portion of CanAtom's under-reported costs on a without prejudice basis. Because CanAtom's anticipated costs through the end of April 2017 exceeded the project's approved funding, OPG senior management authorized the allocation of $9M in DRP contingency to the D2O Storage Project as bridge funding pending approval of additional project funding through a superseding BCS.

At the end of March 2017, High Bridge produced its detailed estimate of the work remaining on the project, which was based primarily on the remaining quantities of major commodities as ascertained from project documents and validated through discussions with CanAtom project personnel. To ensure independence, High Bridge avoided reviewing CanAtom's estimate of the cost to complete the project. The estimate of the remaining costs were based on completing the remaining scope over approximately 18 months. After discussions with CanAtom and OPG, High Bridge's final estimate of the cost to complete the project was $99.5M plus $9M in contingency.

OPG was dissatisfied with the CanAtom's progress on the tasks it agreed to complete during the slowdown period and with its increasing estimates of the cost to complete the project. On April 21, 2017, OPG notified CanAtom that it was prepared to terminate the PO for cause and instructed CanAtom to halt work on the project. OPG and CanAtom began planning the transition of the project back to OPG while continuing to negotiate a resolution of the outstanding commercial issues. During this period, OPG reviewed three alternatives for completing the project.

The first was to negotiate a new contract with CanAtom. Under this option, OPG and CanAtom would re-estimate the cost to complete the project on a fully transparent and collaborative basis. Once a mutually agreed estimate was developed, OPG would use that estimate to negotiate a lump-sum commercial arrangement including reductions to resolve outstanding commercial issues and compensate OPG for delay. The new contract would form the basis for restarting the project.

The second alternative was to complete the project with a new contractor. OPG's plan to advance this option was to begin preliminary discussions with vendors to determine if they were able to do the work, interested in completing the project, and willing to sign a contract that put them at financial risk for project completion. Once two vendors meeting these criteria were identified, OPG planned to work collaboratively with each of them to determine each contractor's best estimate of project cost and schedule, and most favourable contract terms to limit future price risk. At the conclusion of this process, OPG would contract with one of the two vendors.

OPG's third alternative was to complete the project as the general contractor. Under this alternative, OPG would utilize the existing subcontractor for electrical work and would contract with a new vendor to perform the remaining mechanical, and instrumentation and control work. Similarly, any remaining engineering work that emerged would also be contracted. The remaining civil work would either be contracted or OPG would complete this work itself.

Ultimately, OPG decided that the option of having CanAtom complete the project represented the best course of action. There were four principal reasons for this decision. First, OPG was concerned about engineering continuity and design acceptance with a new contractor given OPG's experience when CanAtom took over the project from B&M. Second, OPG was concerned about its ability to hold CanAtom accountable for the warranty and performance of items constructed by CanAtom if another entity was brought in to complete construction. Third, as discussed in the next section, OPG was able to reach a settlement with CanAtom that both resolved all outstanding issues on a favourable basis and resulted in a target cost/maximum cost contract with a firm limit on OPG's maximum cost to complete the remaining scope of the project. Fourth, none of the other firms with whom OPG had preliminary discussions were willing to enter into a contract where they assumed financial risk for project completion.

10.11 OPG Reaches a Comprehensive Settlement with CanAtom

On June 27, 2017, OPG and CanAtom signed a comprehensive settlement agreement that created a framework to resolve all outstanding disputes and established the path forward to compete the project. The settlement contains three major subsections. The first addresses payments for work up to April 21, 2017, when OPG instructed CanAtom to stop work on the project except for transition tasks. The second addresses the transition period from April 22, 2017 up to and including June 26, 2017, the day before the settlement was effective. The third section establishes a target cost/maximum cost for completing the project from the effective date of the settlement onwards and a discount to be applied to the cost of completion.

As part of the settlement, the payment for past work covered all costs incurred or committed by CanAtom up to April 21, 2017, including overheads, but excluding the performance fee (approximately $10M), which CanAtom agreed to forego. All costs not previously accepted were subject to verification by OPG. Subsequent agreements in 2018 confirmed the maximum payment to CanAtom for documented work through April 21, 2017 would be $175.7M, which consisted of $164.7M for costs invoiced prior to the settlement and up to a maximum $11M for un-invoiced costs.[33] Ultimately, OPG and CanAtom negotiated a figure of $7.2M for the un-invoiced costs. This amount represented final settlement of all pre-April 21, 2017 payments requested by CanAtom and set-offs claimed by OPG.

OPG's claims included those arising from the KPMG audit, which had found, on a sampling basis, $2.1M in potential overbillings. KPMG characterized the resulting percentage of potential overbilling (2.8%) as being within reason based on their experience on other similar audits where 2-3% recoveries are typically found – given the size and nature of this cost reimbursable contract.

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[33] The total amount invoiced was $175M, but after subtracting the performance fee, the amount to be paid for invoiced costs was $164.7M.

For the transition period from April 21 to June 27, 2017, the settlement provided that CanAtom would receive a lump sum payment of $1.8M to cover the cost of its reduced activities during this period. This amount did not include any overhead or performance fee.

For work undertaken on or after June 27, 2017, CanAtom agreed to complete the remaining scope for the D2O Storage Project on a target/maximum cost basis. The target cost was used as the starting point for calculating the sharing of cost savings and cost overruns; the maximum cost set an upper limit on what OPG would pay no matter what the final cost. The negotiated target cost was $80M, which was $20M less than CanAtom's estimate ($100M) of the cost to complete the remaining work on the project without contingency. CanAtom's estimate was consistent with the final estimate prepared by High Bridge ($99.5M without contingency), as discussed above in Section 10.10. The maximum cost to OPG under the settlement formula was $90M, some $10M less than the estimated cost to complete the project. OPG also negotiated a $20M discount on the cost of the remaining work, so OPG's effective maximum cost for completing the remaining scope was $70M, which was $30M less than the estimated completion cost.

The settlement included a graduated sharing arrangement based on the actual cost of the project relative to the $80M target, which was known as "gain/pain sharing." Amounts from $20M to $15M below the target were to be shared 80% to CanAtom and 20% to OPG. Amounts from $15M to $5M below the target were to be shared equally between CanAtom and OPG. The range from $5M below the target to $5M above constituted a dead-band where no sharing would take place. Amounts from $5M to $15M above the target were to be shared equally between CanAtom and OPG. Costs greater than $15M above the target were the sole responsibility of CanAtom. This sharing arrangement, the resulting contract price and final cost to OPG after the discount are illustrated in Chart 4 below.

Chart 4 – Target Cost/Maximum Cost Agreement

Completed Cost Range ($M)*	CanAtom/OPG Split of Difference (%)	OPG Contract Price ($M)	OPG's Cost after $20M Discount ($M)
60 – 64	80-20	69 – 69.8	49 – 49.8
65 – 74	50-50	70 – 74.5	50 – 54.5
75 – 85	Dead-band	75 – 85	55 – 65
86 – 95	50-50	85.5 – 90	65.5 – 70
95+	Contract Maximum	90	70

*Rounded to even $M to simplify presentation.

The settlement also provided that if CanAtom successfully completed the D2O Storage Project, it would be awarded additional commissioning work on the completed project at the ESMSA rates in effect at the time the commissioning contract was signed.

11.0 PROJECT COMPLETION

11.1 CanAtom Resumes Construction

Following the signing of the settlement at the end of June 2017, OPG and CanAtom entered into discussions on the scope of work and schedule that would underpin project completion. The first task under the negotiated LNTP was to define a limited SOW to be completed in the summer and fall of that year. This work, known as "Summer Work," primarily encompassed tasks that were required to seal the D2O Storage Project building, prepare the project for completion by procuring and placing equipment in advance of installation, and complete other prerequisite activities such as lighting and grounding installation. OPG approved the use of $15M from DRP contingency to fund ongoing project costs while a new BCS was being developed and approved to support project completion under the settlement.

The expectation was that CanAtom would complete the Summer Work over the remainder of 2017 and begin mobilizing the team that would complete the remaining project scope in 2018, when management team members then actively engaged on other DRP work were expected to become available.

Summer Work began in late August 2017. The activities to be completed were divided into a series of staged gates with payment milestones attached to each gate. A maximum amount of costs, including allowable overhead, was established for each gate in each month and payment was not made until the work was completed. The actual costs to be paid each month was then discounted by 17% to recover an initial $1.5M mobilization payment and by 25% to reflect the $20M discount in the settlement agreement. Based on these discounts, OPG was required to pay no more than 58% of the cost of the work completed each month.

During the fall of 2017, OPG and CanAtom were also developing the timing and schedule for the full restart of the project and its completion. The agreed schedule had installation of the remaining equipment and systems starting in mid-January 2018with substantial completion of the project by year-end. Commissioning was scheduled to begin in December 2018 and conclude with the project being made available for service at the end of April 2019. The parties also agreed on enhanced project reporting and monitoring. OPG committed to reviewing project progress based on OPG site personnel feedback and field verification to identify any emerging issues.

In October 2017, OPG estimated the project's cost to date at about $388M including all internal and external costs. The internal and external projected cost to complete the project was about $110M. The total of these figures, $498M, formed the basis for the project's final business case issued in February 2018 as discussed below in Section 13.7 (see Attachment 2q - 2018 Superseding Release Execution BCS). A management reserve of about $11M was included to account for any additional cost.

By October 2017, CanAtom was behind on the scheduled tasks. CanAtom attributed its lack of progress to resource constraints related to the availability of skilled trades. OPG required CanAtom to increase its project supervision in an effort to get the work on track. OPG extended the completion date for the summer work until February 2018 and added new tasks and performance gates.

11.2 Project Phase 2 – Completion Pursuant to the Revised Statement of Work

At the end of February 2018, OPG and CanAtom agreed on a detailed revised SOW to complete the project under the negotiated contract. This initiated Phase 2 of the project, the drive to completion. The revised SOW required CanAtom to complete all remaining engineering, planning, procurement, construction, pre-commissioning check-out and test work, and prepare the manuals required by the project. The revised SOW also reiterated CanAtom's fundamental responsibility, which was to complete all actions required to ensure the project was entirely finished, fully functional, and fit for its intended purpose. The agreed timeframe for substantially completing all the major structural work and systems required for the D2O Storage Project was the end of 2018.

CanAtom issued a revised Risk Management Plan, intended to govern the identification and mitigation of project risks going forward in Phase 2. The plan required CanAtom to identify project risks, analyze them and to capture them in a revised risk register. CanAtom was also required to develop and implement appropriate mitigation strategies and actions, which would represent practical and feasible solutions to reduce the probability or consequences of identified risks.

In March 2018, OPG accepted the revised Project Execution Plan ("PEP") for Phase 2. The PEP established how CanAtom proposed to execute, monitor and control the project. The goal of the PEP was to achieve the D2O Storage Project objectives on time and within the budget, while maintaining the required quality and safety standards.

By April 2018, CanAtom's performance began to raise concerns about its ability to deliver the project on schedule. Among OPG's key areas of concern were:

- Failure to deliver a detailed schedule for project completion.
- Extension of the forecast date for substantial completion by at least three months.
- Failure to deliver enhanced project controls and reports.
- Late delivery of CWPs and plans.
- Ineffective project oversight.

- Poor productivity and failure to achieve project milestones.

In response to these concerns, OPG and CanAtom established a joint task force to review the schedule for completing the project and reschedule specific tasks to avoid overcrowding. The tight working space available and the multiple trades needed to complete the project combined to lower productivity. To reduce scheduling conflicts, the project moved all trades working in the building to two 10-hour shifts, five days a week. CanAtom also established a limit of 100 trade workers per shift. OPG began dedicating managers to help CanAtom remove project bottlenecks. CanAtom projected the target date for construction completion as May 2019, but OPG continued to maintain that it expected CanAtom to adhere to the committed substantial completion date of year-end 2018.

In summer 2018, progress toward completion started to improve and CanAtom's projected date for construction completion advanced to March 2019. By fall 2018, while various elements of the project were being completed, including the receipt of all remaining equipment on site, there were ongoing changes in the managers assigned to the D2O Storage Project as CanAtom focused on completing the DRP's RFR project. As a result, the progress improvements experienced earlier in the year did not continue. Given the importance of the ongoing critical path work on the RFR project at this time, and the fact that there was no urgent need to complete the D2O Storage Project because the need to store Unit 3 heavy water was then forecasted to occur in April or May of 2020, OPG agreed that this focus was appropriate.

By early 2019, construction progress slowed substantially as CanAtom came to the conclusion that it should focus on completion of engineering and comprehensive work packages to advance construction more efficiently. Despite CanAtom's financial incentives to complete the project, the projected date for construction completion had moved back to May 2019 and the projected CanAtom cost to complete the project grew to $106M, well in excess of the $90M guaranteed maximum price before the $20M discount. Senior executives from both companies comprising CanAtom began attending the bi-weekly meetings with OPG in an effort to get the schedule back on track. Even in the face of a mounting projected loss, CanAtom was unable to achieve its forecast productivity levels and meet the schedule.

Throughout the spring of 2019, progress on the project continued to be slower than forecasted. The target for construction completion moved to July 2019. CanAtom's costs continued to accumulate. By mid-May 2019, CanAtom's accrued cost was $103.4M and the forecast cost at completion was $120.3M, some $30M above the target maximum before discount.

OPG's focus during this period was to work cooperatively with CanAtom to finish project construction and prepare for commissioning. To that end, the parties brought in an external facilitator to better align their efforts to work together to complete the project. These activities were seen as more important than continuing to insist that CanAtom maintain a schedule that it clearly could not meet. CanAtom senior management was fully involved in schedule discussions and had been for months. They were very well aware that the project was costing CanAtom about $2M for every week completion was delayed. This binding contractual mechanism provided a substantial incentive to finish the project as soon as possible.

So long as the project was expected to be finished in time to receive heavy water from the Unit 3 refurbishment, then forecasted to occur in April of 2020, OPG's priority was on completing all the remaining elements of the project safely and with quality, and preparing the testing and documentation required for commissioning. In May of 2019, OPG was forecasting that the building would be ready to accept D2O in October 2019, well in advance of the then projected need date for Unit 3.

By the end of June 2019, the forecast for construction completion was pushed to September 2019 for non-critical systems, but the forecast still had the building ready for D2O in October 2019. Completing critical path worked continued to be the main focus, but substantial activity also remained to close out completed work packages and prepare for commissioning.

In August 2019, the forecasted construction completion date moved to October and the project was expected to be able to accept heavy water in November. CanAtom's unrecoverable costs continued to run between $1.5 and $2M per week. The project continued to work down the remaining construction items, advance commissioning activities and close out documentation.

Construction completion was achieved in November 2019. At that time, almost all of the systems, equipment and the above ground portions of the building itself were placed into service. Additional monitoring and control systems and other miscellaneous equipment were placed in service in 2020 and the building was declared ready to accept heavy water.

At year-end 2019, CanAtom prepared an estimate of its cost to complete the D2O Storage Project. Using the $70M maximum guaranteed payment[34] and an additional $1.9M that OPG had agreed to pay for changes to project scope and a settlement of CanAtom claims to year-end 2019. CanAtom estimated its total cost at year-end 2019 to be $148.9M. This figure comprised $145.5M in accrued costs plus approximately $3.4M in pending or forecast costs. Given the maximum cost contract, CanAtom calculated its loss on Phase 2 work at approximately $77M as of year-end 2019.

12.0 COMMISSIONING AND RELATED ACTIVITIES

Commissioning is the process of testing every element of the D2O Storage Project to demonstrate that it works as intended and ensuring that all required documentation is provided. Pre-commissioning activities are activities undertaken to ensure that all elements of the project are ready for commissioning. Pre-commissioning activities and their costs were included within the target cost/maximum cost settlement with CanAtom. The costs of commissioning were outside of the settlement agreement and the subject of a separate agreement. Both the costs of pre-commissioning and commissioning with demineralized water are included within OPG's total project cost.

12.1 Pre-Commissioning

Pre-commissioning activities were performed by CanAtom under the target cost/maximum cost contract to verify that its work met the D2O Storage Project design and quality requirements and to ensure that the project was finished, fully functional, and fit for its intended purpose.

[34] The $70M comprises the $90M maximum guaranteed payment less the $20M discount agreed to in the Settlement Agreement as discussed in Section 10.11.

As part of pre-commissioning, CanAtom ensured that all equipment, systems, facilities and works were capable of being performance tested during commissioning. This entailed issuing Inspection and Test Plans ("ITPs") that established the requirements for construction verification, and referenced applicable test procedures, standards and acceptance criteria. The ITPs also established requirements for testing by external parties, including pressure testing by the TSSA and electrical inspection by the Electrical Safety Authority. CanAtom performed post implementation testing of building services such as fire protection, telephone/LAN, public address, doors, hoists, water heaters, ventilation/HVAC systems in accordance with the ITPs and applicable external standards.

Pre-commissioning of the D2O storage system required CanAtom to hydrostatically test the D2O tanks and piping by filling and flushing all tanks and flushing all lines with demineralized water. This allowed CanAtom to perform operational pressure tests and leakage tests on the tanks and associated piping. During the filling of tanks, the level indications, including the low and high level alarm limits at the transmitter, were checked. Vent lines were pneumatically tested. CanAtom recorded pump discharge flow rates and pressures at several points to create pump performance curves.

The use of demineralized water allowed the testing to be done more quickly and without introducing heavy water into the facility which would have required radiation protection. However, the introduction of demineralized water required that the systems be flushed with high isotope heavy water to remove residual light water and place the system into an acceptable isotopic state prior to commissioning.

12.2 Commissioning

Consistent with the settlement agreement, OPG awarded commissioning work to CanAtom following completion of project construction. OPG retained CanAtom for commissioning and paid a total of $6.8M for this work. This amount was in addition to CanAtom's maximum cost contract under the settlement agreement, but is included in the $509.3M total project capital cost.

Commissioning was the final step in ensuring that the project functioned as designed. All tanks and pipework had to be pressure tested and verified as clean. All tie-ins were flushed with demineralized water, sampled and drained. Inspections and flushing ensured any remaining foreign material introduced during construction was found and removed. Flushing was completed on all piping with 0.8 mm commissioning strainers and no appreciable foreign material was found in the strainers. Cleanliness results met or exceeded chemistry standards.

Commissioning was done initially with demineralized water to test all systems and ensure cleanliness. The demineralized water was then completely removed and final commissioning was done with D2O. This final commissioning with the design process fluid, heavy water, was required to complete operational pressure testing for TSSA. Final commissioning of the PHT system was completed in November 2020. Final commissioning of the moderator and TRF product and feed systems will occur in early 2021.

13.0 BUSINESS CASE SUMMARIES FOR THE D2O STORAGE PROJECT

This section discusses the BCS that OPG issued for the D2O Storage Project. As OPG gained greater understanding of the project's complexity and the project's scope changed to accommodate project needs, the estimated cost of the D2O Storage Project increased. As stated in Section 2.4 and demonstrated in the discussion above, the initial project cost estimates from B&M were unrealistically low for the project's ultimate scope and complexity. Similarly, CanAtom substantially underestimated the cost of the project when it assumed responsibility for its completion. The final BCS dated February 5, 2018 represents the cost of completing the project based on its final design and the challenges encountered during construction.

13.1 2006 Developmental Release Business Case Summary for the Operational Improvement Project

In November 2006, the DNGS D2O Storage and Drum Handling Project 16–31555, Developmental Release Business Case Summary" was prepared for the operational improvement project at Darlington ("2006 Developmental Release BCS") (see Attachment 2k).

The 2006 Developmental Release BCS approved $3.6M to complete preliminary design, initiate detailed design, initiate requests for quotation for long lead time materials, and develop a partial release business case. As noted above, work proceeded on these activities until the project was deferred pending a decision on Darlington refurbishment. Also as discussed above, of the $3.6M approved, about $0.6M was written off and the remaining $3M was rolled into the 2012 Full Release Definition BCS discussed below.

13.2 The 2011 Draft Developmental Business Case

In the spring and summer of 2011, the D2O Storage Project team prepared a draft DNGS D2O Storage and Drum Handling Facility (Capital) Developmental Business Case Summary ("2011 Draft Developmental BCS") (see Attachment 2I), which was neither submitted to nor approved by OPG's senior management. It is included here because it has been discussed in previous OEB applications.

The 2011 Draft Developmental BCS differed from the 2006 Developmental Release BCS in that it captured the increased scope to address Darlington refurbishment needs. The 2006 Developmental Release BCS had estimated the project cost based on the operational improvement scope of work, which included 400 Mgs of D2O storage, a new drum handling, cleaning, and testing facility, and office space. In addition to these requirements, the 2011 Draft Developmental BCS for the merged project includes 1,700 Mgs of storage to meet refurbishment needs (bringing total storage requirements to 2,100 Mgs). The 2011 Draft Developmental BCS estimated the funding required for preliminary engineering work at $11.1M and the total cost to complete the D2O Storage Project at $210.6M. Project completion was forecast to occur in October 2015.

The funding requested in the 2011 Draft Developmental BCS was to:

- progress modification planning;
- prepare engineering specifications for long lead time materials;
- undertake site-preparation planning;
- obtain a third party estimate to validate total project costs; and

- produce a Partial Release BCS for the detailed design of the D2O Storage Project.

The quality of the project cost estimate used for this BCS was “conceptual” because “zero to minimal” design work had been completed. It was shown as having an associated cost range of +60% to -25% (i.e., a costs range of $336.96M to $157.95M).[35] The estimate was based on engineering cost estimates previously done for the operational improvement project and indicated that a third party estimate and engineering proposal pricing would be used to prepare a future Partial Release BCS project estimate.

The estimate also considered operational experience based on two other heavy water tank projects in Ontario, which highlighted the cost increases experienced in projects installing comparatively small D2O storage capacity in existing buildings (something that was not feasible at the Darlington HWMB because of space restrictions). The Pickering D2O storage project installed four 90 m^3 tanks in an existing building with existing support services. This project was initially estimated to cost $11.2M. The project was delayed 18 months and ultimately cost $16.3M. The Bruce D2O project installed six 135 m^3 tanks in an existing building with existing support services. This project was initially estimated to cost $13M. At the time that the estimate for the 2011 Draft Developmental BCS was being prepared, the Bruce project was still ongoing, but it was anticipated to cost $40M and experience years of delay because it had been placed on hold for 18 months.

The 2011 Draft Developmental BCS was prepared by the project team and reviewed by Nuclear Finance, but did not advance for approval. It was replaced by the 2012 Full Release Definition BCS discussed in the next section.

13.3 June 2012 Full Release Definition Business Case Summary

In June 2012, prior to finalizing the agreement with B&M to undertake the D2O Storage Project, OPG’s senior management approved the Full Release Definition Business Case Summary

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[35] A conceptual estimate is a Class 5 estimate in the Association for Advancement of Cost Engineering (AACE) Cost Estimate Classification System. The uncertainty range for a Class 5 estimate is -50% to +100%.

Project 16–31555 (“2012 Full Release Definition BCS”) (see Attachment 2m). The 2012 Full Release Definition BCS approved funding for the definition phase (Phase 1) of the B&M EPC contract. The definition phase activities included work to complete scope definition, modification planning, preparation of engineering specifications for long lead time materials, detailed design, as well as internal costs for OPG’s contract oversight and preparation of a partial release execution BCS for the execution phase of the project.

The 2012 Full Release Definition BCS approved $15.7M for Phase 1. This amount comprised the fixed fee of $7.9M to be paid to B&M, $4.9M in OPG costs and $2.9M in contingency. The 2012 Full Release Definition BCS indicated that the project cost would total $108.1M. While cited, incorrectly, as a Class 2 (+20% to –15%) cost estimate, in fact the estimate was Class 5 (+100% to –50%) as it was based on the cost estimate in B&M’s proposal, which relied on the preliminary design work from the RFP documents.

To validate a bid and arrive at a Class 3 cost estimate, let alone the Class 2 indicated, between 10% and 40% of the design and engineering work needs to be completed and used as a basis of estimate. At the proposal stage of a project, very little design work, and none of the engineering, has been performed as the contract has not been awarded. In fact, completion of the D2O Storage Project’s design requirements was the first substantive milestone under the PO awarded to B&M.

First-of-a-kind projects like the D2O Storage Project are particularly challenging to estimate because they are unique. No direct benchmark cost information exists for such projects as would be available for frequently replicated projects like, for example, building a hospital or a distribution sub-station. Despite the lack of completed design, OPG accepted B&M’s estimate as it believed at the time that the committed performance fee of the EPC contract would mitigate risk via project efficiency gains due to the expertise and autonomy of the contractor.

13.4 August 2012 Partial Release Execution Business Case Summary

A month after the project kickoff, in August 2012, OPG approved the Partial Release Execution Business Case Summary Project 16–31555 (“2012 Partial Release Execution BCS”) (see

Attachment 2n), which released a total of $11.6M to support the ordering of long-lead materials, such as the nuclear grade stainless steel tanks and pumps, and the beginning of site preparation activities once the DRP EA was approved. This release supported the Phase 2 activities under the B&M EPC contract.

This 2012 Partial Release Execution BCS followed soon after the 2012 Full Release Definition BCS due to the need for funding to acquire long lead materials. Given that the project could not break ground until the DRP EA was approved and the target in-service date was April 2015, it was necessary to overlap the phases of the project to meet the scheduled in-service date.

OPG prepared a risk register for this release to evaluate and document the project's risks. Among the major risks identified were the potential for: (1) tritium in the soil and groundwater of the project site, (2) available OPG design and engineering support to be insufficient, (3) a delay in approval of the DRP EA, and (4) increased EPC contract costs due to discovery issues. OPG undertook a Monte Carlo simulation to calculate the levels of cost and schedule contingency over a range of probabilities for the risks identified. While these documents generally identified the types of risks that ultimately materialized, they understated the consequences of those risks for the project's schedule and cost.

13.5 2013 Full Release Execution Business Case Summary

In May 2013, OPG senior management approved the Full Release Execution Business Case Summary Project 16–31555 ("2013 Full Release Execution BCS") (see Attachment 2o) for $79.1M. This release increased the total anticipated spending on the project to $110M. The release was approved relatively soon after the 2012 Full Release Definition BCS and 2012 Partial Release Execution BCS were approved for Phases 1 and 2 of the project in order to mitigate schedule completion risk by providing funding to acquire materials and advance construction planning necessary for Phase 3 of the project.

As discussed above, the 2013 Full Release Execution BCS acknowledged that because of the complexity of the project, preliminary design was completed two months late. This delay compressed the time available for completing the detailed design which, combined with the additional scope that emerged during preliminary design, put the schedule for design completion at risk. At that time, however, OPG still believed that the construction schedule could hold because the design packages were scheduled to be completed in sequence with the construction start dates.

OPG re-ran the risk register and updated the costs for this 2013 Full Release Execution BCS. The total costs increased by $10.6M over the previous BCS. The increase was largely attributable to increased design, construction and materials costs due to increases in project scope. However, as OPG reduced the overall contingency requirement going forward, the total increase between this BCS and the previous one was only about $2M (i.e., from about $108M to $110M).

13.6 2015 Superseding Release Execution Business Case Summary

In early March 2015, OPG's senior management approved the Superseding Release Execution Business Case Summary Project 16–31555 ("2015 Superseding Release Execution BCS") (see Attachment 2p) for $270.9M, which brought the total funding released to $381.1M, including a contingency of $33.9M. [36] After terminating the EPC contract with B&M in October of 2014, OPG set out to confirm the scope, cost and schedule for the project prior to requesting additional funding. The release was approved after OPG had determined to engage a new contractor, CanAtom, to complete the project. The estimated cost of the project was based on: (1) the forecast cost of the new EPC contract, (2) the cost of the work already completed, (3) OPG's forecasted costs including interest, and (4) the cost to complete design and construction contracts that were not part of the EPC contract.

The 2015 Superseding Release Execution BCS contains an analysis of the sources of the increase in project cost. About two-thirds of the variance was attributable to the increase in the EPC contract cost since the last BCS. Other significant elements of the variance include construction and design contracts to complete work begun under B&M, increases in OPG's

[36] The $33.9M contingency was in addition to the $14.5M of contingency from the previous BCS that had been allocated to B&M for project cost increases

cost to support the project and increased interest. The 2015 Superseding Release Execution BCS contemplated an accelerated schedule to achieve a partial in-service date of June 2016 that would allow the project to accept heavy water from Unit 2 refurbishment, and full project completion in May 2017.

The 2015 Superseding Release Execution BCS also analyzes the reasons why project costs had increased. The factors identified, which have been discussed above, were:

- The change to a stand-alone building rather than a three-sided building attached to the TRF.
- Increased materials quantities for piping, valves and equipment due to design changes and the need to install stand-alone systems rather than tying into existing systems at the TRF.
- Increased construction costs due to changes from the preliminary to the final design
- The required installation of the pipe chase given the reconfiguration of the building and to address water-hammer issues found with the preliminary design.
- Additional cost to address tritiated soil and water.
- Underestimation of effort by the original contractor.

The 2015 Superseding Release Execution BCS also analyzed three alternatives for completing the project in light of its progress to date and compared them to the preferred alternative (Alternative 1).

Alternative 2 was to sequence the construction to accelerate only the work necessary to meet DRP needs and then employ a non-accelerated construction strategy to complete the balance of the project to serve TRF operations. Analysis of the cost and schedule of this alternative determined that this approach would result in a protracted construction period with project resources deployed for a longer duration and increased interest expenditures. The additional costs were projected to exceed any cost reductions that would be realized from reducing shift schedules. On this basis, OPG rejected this alternative.

Alternative 3 was to address Unit 2 heavy water storage needs outside the project and work to complete the project to have it available for Unit 3 and subsequent units. As with

Alternative 2, the additional costs were projected to exceed any cost reductions that would be realized from reducing shift schedules. On this basis, OPG rejected this alternative.

Alternative 4 was to suspend project construction and implement an alternate storage tank solution to meet the refurbishment needs of all four units. OPG determined that Alternative 4 was not viable because the alternate temporary storage plan while identified as suitable for storing Unit 2 heavy waters would present unacceptable operational and safety risks when considered as a long term solution. Moreover, the cost of erecting a temporary structure to hold heavy water and then constructing a permanent facility to address the TRF needs discussed above was prohibitive. For these reasons, OPG rejected this alternative.

13.7 2018 Superseding Release Execution Business Case Summary

In early February 2018, OPG's senior management approved the Superseding Release Execution Business Case Summary Project 16–31555 ("2018 Superseding Release Execution BCS") (see Attachment 2q) for an additional $117.4M, which brought the total released funding to $498.5M. OPG did not include any contingency in the 2018 Superseding Release Execution BCS, given the project's advanced state of construction, but did include a management reserve of $11.5M to recognize remaining cost uncertainty. With the management reserve, the total amount authorized for the project was $510M.

As with the 2015 Superseding Release Execution BCS, the 2018 Superseding Release Execution BCS analyzes the variances that led to increased project costs. Several of the factors identified above as most significantly contributing to the increase in project cost, including increased project scope and underestimation of cost, continued to be major factors in the increased cost of the EPC contract, which makes up the bulk of the cost increase approved in this BCS. The other major factors identified in the 2018 Superseding Release Execution BCS as increasing project cost are:

- Increased interest costs due to the schedule extension.
- Increased OPG project management costs due to the schedule extension and the transition to a new contract.

- Increased cost for OPG engineering due to the schedule extension.
- During the transition, OPG determined that certain manuals and procedures should be developed and documented by the TRF. These costs did not appear in the prior BCS.
- Costs that OPG incurred when it acted as the General Contractor for the project.

14.0 CONCLUSION

Designing, engineering and constructing the D2O Storage Project was an extremely complex undertaking. This first-of-a-kind design required the development and integration of numerous systems in tight quarters to ensure the safety, constructability, operability, and maintainability of the project. Ensuring the seismic stability of the building, addressing the multiple streams of heavy water stored in the project, and minimizing the project's emissions were among the challenging design goals that the project met.

Constructing a seismic dike 15 m below ground and 12.5 m below the water table is inherently difficult. The presence of low levels of tritium in the site's soil and the water and the numerous buried services to be moved or removed added to the challenge. The fact that construction took place within the protected area of an operating nuclear station undergoing refurbishment added to the task of organizing dozens of welders, pipefitters, carpenters and electricians to work together within the tight confines of the project building.

The design complexity and challenging construction caused the project to take far longer than anticipated under the initial EPC contract, but that schedule was never realistic for a project of this complexity. As the project entered construction, it became clear that the early estimates of project cost and schedule, developed before preliminary design was complete, were significantly understated.

OPG managed the challenges in design and construction prudently. When the initial contractor on the project repeatedly failed to meet its schedule commitments and offered ever-increasing cost forecasts, OPG, after attempting to work with the contractor, terminated the contract. In response to rising cost claims by the second contractor, OPG stopped work on the project. Work was allowed to proceed only after the parties negotiated a comprehensive settlement that eliminated the performance fee for past work, substantially discounted the remaining work and established a guaranteed maximum price to complete the project.

Though project completion took about a year longer than the schedule underpinning the settled maximum price, OPG preserved the benefits of the settlement and paid no more than the agreed upon maximum for the work covered by the settlement. Ultimately, the second contractor's costs to complete the project wound up exceeding the maximum price after discount by more than $77M, all of which was borne by the contractor.

The project was the first major undertaking using an EPC contract under the ESMSA contracting structure. It was also the first large EPC contract managed by OPG's projects organization and undertaken within the Darlington protected area. The lessons learned on this project included: the fact that OPG should develop design requirements internally; engineering should be completed before preparing a final estimate of project costs and beginning construction; sufficient time must be allowed for executing first-of-a-kind project work; and maintaining an open, collaborative work environment between the contractor and owner is essential to successful project execution. These lessons have all proved valuable on subsequent project work at OPG, including on subsequent DRP projects.

The completed project will yield benefits to Ontario electricity consumers for decades, throughout the lives of the refurbished Darlington and Bruce generating stations. In the end, OPG's cost to complete the project reflects the true cost of constructing the D2O storage facility, as established by a team of independent experts. For these reasons, OPG should be permitted to include the remaining $494.7M of project cost in its nuclear rate base and to recover the corresponding revenue requirement impacts accumulated in the CRVA prior to the effective date for the payment amounts that include this project in rate base.

ATTACHMENTS

Attachment 1: Introduction to Heavy Water and its Use in CANDU Reactors

Attachment 2: D2O Storage Project Key Documents

- 2a - Project Charter: Adding Heavy Water Storage/Drum Handling Facilities dated October 13, 2005
- 2b - Project Charter: Refurbishment, Operational Improvement and Long Term D2O Storage dated August 18, 2010
- 2c - Project Charter: Refurbishment, Operational Improvement and Long Term D2O Storage dated June 20, 2011
- 2d - B&M ESMSA dated February 15, 2012
- 2e - B&M ESMSA Amendment #1 dated June 28, 2013
- 2f - B&M Purchase Order #217807 Rev. 11 – Final Revision (includes all previous revisions)
- 2g - CanAtom ESMSA dated December 19, 2014
- 2h - CanAtom ESMSA Amendment #1 dated July 7, 2015
- 2i - CanAtom ESMSA Amendment #2 dated January 1, 2017
- 2j - CanAtom Purchase Order #251088 Rev. 15 – Final Revision (includes all previous revisions)
- 2k - 2006 Developmental Release BCS
- 2l - 2011 Draft Developmental BCS
- 2m - 2012 Full Release Definition BCS
- 2n - 2012 Partial Release Execution BCS
- 2o - 2013 Full Release Execution BCS
- 2p - 2015 Superseding Release Execution BCS
- 2q - 2018 Superseding Release Execution BCS

Attachment 3: List of Acronyms Associated with the Project

Attachment 4: Timeline of the Major Project Milestones

Attachment 5: Temporary Storage of Unit 2 Heavy Water