

PICKERING SAFE STORAGE – CHALLENGES AND OPPORTUNITIES

C. Adams¹, J. Clemo¹ and D. Jarron¹

¹ Ontario Power Generation, Pickering, Ontario, Canada

christine.adams@opg.com, jane.clemo@opg.com, don.jarron@opg.com

Abstract

As the Pickering Nuclear Station end of life approaches, planning continues for the Pickering Safe Storage Project (SAFSTOR). The project team will plan and execute the transition of the station from its current operating state, to its SAFSTOR state, in which the facility will remain until dismantling and demolition activities commence after a 30 year lay-up period.

The goal of the project will be to minimize hazards on site by defuelling the reactors of spent fuel, dewatering systems containing tritiated heavy water, and removing from service systems no longer required to support the operation of the station. Although the station will no longer generate power for the safe storage period, an operational footprint will be required to continue to support operational and regulatory requirements, such as the removal of fuel from the irradiated fuel bays, storage of heavy water, and ongoing monitoring and security requirements.

The purpose of this paper is to provide insights into some of the challenges faced, as well as opportunities being explored for a larger multi-unit nuclear power plant as it prepares for permanent shutdown and eventual decommissioning.

This paper will specifically explore challenges which arise in finding the most effective, efficient and environmentally responsible solutions for the ongoing management of groundwater, surface water, service water and liquid waste streams which will continue to be generated by the facility in SAFSTOR.

1. Introduction

The Pickering Nuclear Generating Station (PNGS) is an 8 unit, (formerly) 4,100 MW nuclear generating station located on the north shore of Lake Ontario in Pickering Ontario, approximately 30 km northeast of the City of Toronto (Figure 1). Two of the Pickering units (Units 2 and 3) were placed into a permanent safe storage state in 2010 following the business decision to not refurbish the units for extended operation. The 6 remaining operating units have a combined capacity of about 3,100 MW.



Figure 1 Northeast facing view of the Pickering Nuclear Generating Station

In advance of the permanent shutdown of the facility (currently slated for 2024), planning has been initiated for the Safe Storage Project as well as the eventual decommissioning of the nuclear facility.

The mandate for the Safe Storage Project (herein referred to as “the Project”) will be to safely plan and execute the transition of the station from its current, 3,100 MW electricity generating state, to its predetermined SAFSTOR state, in which the facility will remain for the 30 year SAFSTOR period until demolition activities commence.

Following permanent shutdown, each reactor will be defuelled, with all spent fuel transferred to the irradiated fuel bays (IFBs). Once placed in the IFBs, the spent fuel will require wet storage for a minimum 10 year period before it can be transferred out of the bays to the dry storage facility. As such, the fuel bays will continue to remain in operation, cooling and monitoring the fuel, and facilitating the ongoing loading of fuel into dry storage containers for no less than 10 years once defueling activities have been completed.

Heavy water will also continue to be stored on site. Approximately 3,000 Mg of tritiated heavy water will require long to medium term storage on the site. As the Pickering inventory will provide

the loss make-up supplies to the OPG fleet, periodic transfer of D2O within the site as well as off site will also need to be accommodated.

Support systems will also continue to be required to meet regulatory requirements, such as fire protection, environmental monitoring, radiation monitoring and security systems.

The challenge for the Project will be to reconstitute remaining station systems to meet all regulatory requirements and environmental standards while minimizing the physical and operational footprint of the facility to be sustainable for the 30 year SAFSTOR period.

While all the services and systems required in SAFSTOR currently exist on site, they may not be feasible or economical in the current configuration to utilize in SAFSTOR. In many cases, the equipment may be oversized and not practically scalable to suit the SAFSTOR demand. For example, the circulating water requirements to meet the operation demands for the station are in the order of 200,000 L/s, whereas the total anticipated safe storage service water requirement is expected to be less than 1,000 L/s.

Additionally, the design of the existing station relies heavily on interdependent relationship among the various systems, where the output of one system is a necessary input to another system. These interdependencies will make it difficult to selectively utilize systems (or aspects of systems) in SAFSTOR. For example, the existing high pressure service water system relies on the operation of the low pressure service water system, which in turn relies on the the operation of the screenhouse. Conversely, the operation of the screenhouse relies on the high pressure service water to backwash the screens and the warm, high volumetric flow rate of the service water discharge from the reactor buildings for frazil ice protection in the winter months.

Adding to the challenge of how to optimally configure the station in SAFSTOR are the potential environmental impacts of each configuration, which must be understood and considered. In support of project planning, a Predictive Effects Assessment (PEA) is underway which will qualitatively and quantitatively assess how Project activities and SAFSTOR operations will impact the environment, as compared to the baseline conditions established for the station.

This report highlights some of the areas being explored as a part of the PEA, including the surface water and groundwater modelling efforts, and how the results are expected to inform project planning and foreseeably impact the SAFSTOR configuration.

2. Decommissioning Strategy and the Safe Storage Project Overview

The ‘deferred’ decommissioning strategy has been selected as the most suitable option for decommissioning OPG’s nuclear generating facilities, which involves a 30 year SAFSTOR period following the end of commercial operations prior to dismantling the facility and site restoration (Figure 2). The deferred strategy was chosen over the ‘prompt’ decommissioning option based on a number of considerations. The most significant benefits included:

- The overall reduction in radiation exposure to workers supporting dismantling and demolition activities by allowing for natural decay of short-lived radionuclides over a nominal 30 year lay-up period.

- Additional time is provided to implement the long-term waste disposal strategies for low and intermediate level waste generated as a result of dismantling activities, as well as used fuel.
- Decommissioning funds will continue to grow over the safe storage period by deferring expenditures associated with decommissioning activities. This is funding that has been set aside (in a segregated decommissioning fund) since the station went into operation.

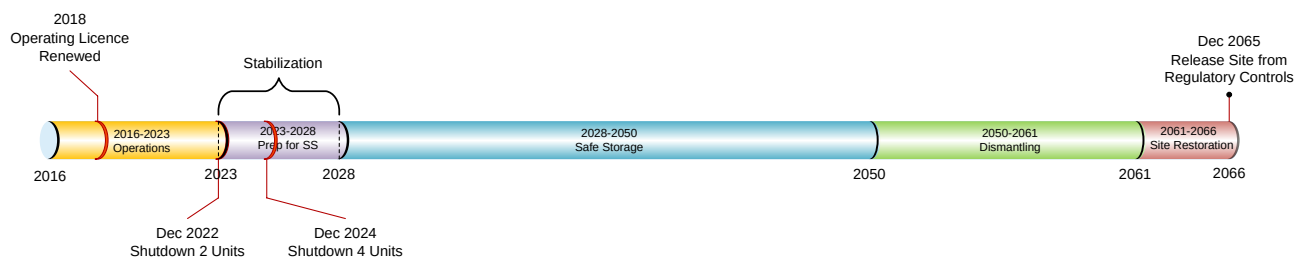


Figure 2 Overview of the Proposed Decommissioning Planning Timeline for PNGS

In order to ensure that the decommissioning strategy remains economically viable, that is, that the ongoing operational and maintenance costs are less than the rate of growth of the decommissioning fund, every effort must be made to ensure the most efficient and economical configuration over the SAFSTOR period.

Planning efforts are currently underway, exploring both the regulatory and system drivers which will shape the operational footprint of the station over the SAFSTOR period. Per the current understanding of these requirements, systems required to remain in-service over the SAFSTOR period include:

- Irradiated fuel bays (including sufficient cooling, purification, monitoring equipment and the means to continue to transfer spent fuel to dry fuel storage containers).
- Select heavy water storage facilities across the site, storing upwards of 3,000 Mg of tritiated heavy water.
- Spent resin storage and handling systems.
- The Pickering Waste Management Facility, including the ability to continue to receive, package, process and store dry storage containers containing spent fuel.
- Environmental monitoring equipment for intermittent (or continuous) monitoring of select atmospheric and liquid emission streams.
- Active and inactive drainage systems, including the means to collect, store, treat and discharge liquid waste streams.
- Heating and ventilation systems to maintain minimum temperatures in all in-service (or partially in-service) areas of the facility, as required.
- Radiation monitoring and fire protection equipment, as required.
- Security systems.

- Auxiliary systems which will be required to support the above noted operational systems including, but not limited to, power supplies, air supplies, service water, domestic water and demineralized water supplies.

While significant efforts have been undertaken thus far to understand and refine the regulatory and system requirements, the focus of the Project has now shifted to explore the most efficient and effective means to meet the requirements.

3. Project Considerations

The following subsections describe briefly some of the factors and considerations which must be weighed in making decisions regarding system reconfiguration.

3.1 Size of System

The relative size of the SAFSTOR system requirements as compared to the existing equipment on site must be considered, as well as how flexible or scalable the existing systems may be. In most cases, the SAFSTOR system requirement, be it fuel bay cooling requirements or building heating/ventilation requirements, will be less than existing requirements, and in some cases only a fraction of the current demand. The capital costs of investing in newer, appropriately sized equipment must be compared to the ongoing costs of operating oversized systems for the nominal 30 year lay-up period.

3.2 Station Efficiencies and System Interdependencies

Just as the Project is attempting to reconfigure the station with efficiency in mind, the design of the existing station is no different. There are many examples where the station takes advantage of the heat, water and electricity which is generated (or available) on site to maximize efficiencies. For example, a percentage of the electricity that is generated by the turbines is redirected back to the station to meet operational requirements. Also, in the winter months, a portion of the low grade steam is extracted from the turbine generators to supply building heating to the powerhouse.

Other systems perform multiple site functions, such as the high pressure service water system, which would largely not be required in the SAFSTOR period, except that it also supplies emergency fire water to the Pickering B station and also backwash sprays for the greenhouse.

Many of these resources will no longer be produced by the station in SAFSTOR, thereby requiring the station reconfiguration to be reconsidered as a whole, rather than system by system.

3.3 Aging Management

The safety and economic impacts of utilizing existing equipment as compared to investing in newer equipment must be considered, including the design life of existing systems as well as preventative maintenance requirements and expected reliability.

3.4 Environmental Impacts

The environmental impacts will also be carefully considered and weighed when comparing various SAFSTOR configurations in order to manage and minimize the risk of adverse impacts to the environment.

The potential for environmental impacts of Project activities and ongoing SAFSTOR operations are currently being explored by environmental risk assessments undertaken by the project.

4. Safe Storage Project Predictive Environmental Risk Assessment

All station operations and their potential for adverse effects on the surrounding environment are assessed by means of an Environmental Risk Assessment (ERA). The results of the ERA are used to identify environmental monitoring studies and/or mitigation measures required to manage these predicted effects. The station Environmental Monitoring Program (EMP) is used to gather the scientific data to confirm the effectiveness of the measures to mitigate the predicted effects. The ERA and EMP are reviewed and updated on a five year cycle to ensure the site characterization of the baseline conditions remain relevant and interim changes to the station are screened to ensure they remain bounded by baseline conditions, and are assessed further, as required.

The Project will proactively assess the impact of any proposed changes to be implemented at the station by undertaking a Predictive Effects Assessment. The assessment will identify and quantify the gap between current and SAFSTOR operations and determine whether the changes are likely to bring about a net positive impact to the environment, or whether the proposed SAFSTOR operations have the potential to exceed the existing baseline conditions established for the station.

In most cases, there will be a net positive benefit to the environment, with fuel removed from the reactors, the risk of significant radiological emissions will be eliminated (or reduced) and decreasing operational activities will generally result in an overall reduction to atmospheric and liquid emissions. However, some SAFSTOR configurations will have to be carefully considered prior to implementation, as the relative impact of proposed scenarios will only be evident once the analyses have been completed.

The following sections highlight some of the environmental impacts to be evaluated by the Predictive Effects Assessment, the results of which will influence SAFSTOR design decisions.

4.1 Water Intake and Discharge Configuration

Currently, the water intake and discharge requirements to support plant operations are high, with large volumetric flow rates needed for cooling and other purposes. The condenser cooling water system alone, which is a once through, open water system, requires roughly 25,000 L/s of flow (per unit) to supply adequate cooling in order to condense low grade steam which has passed through the turbine generator. Reactor systems, as well as the irradiated fuel bays and other conventional systems, rely on the service water cooling system, which supply 5,000 to 6,000 L/s of flow (per unit). Figure 3 below illustrates a high level schematic of the current water balance for the station.

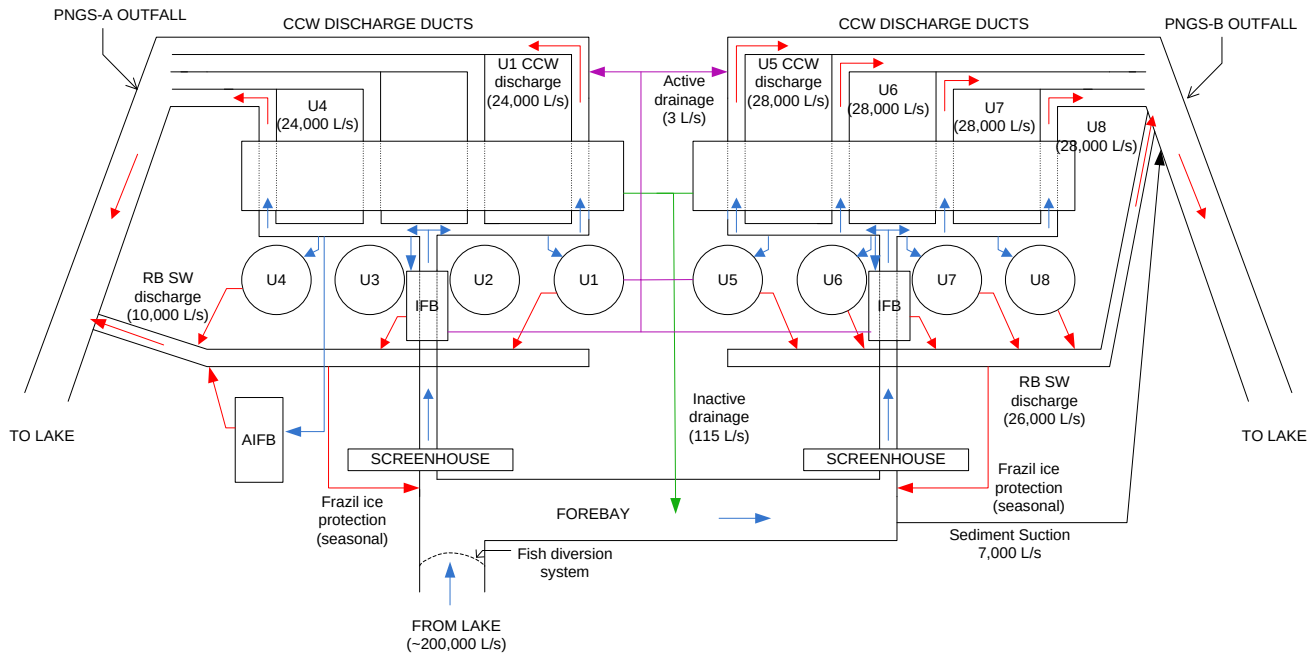


Figure 3 PNGS Water Balance Schematic

The water intake requirements and discharge characteristics will be vastly different in SAFSTOR, when the need for condenser and reactor cooling water flows are eliminated. Service water requirements will be mainly limited to cooling water flows for the IFBs, as well as a few additional (minor) streams such as compressors cooling or pump cooling/lubrication. Based on current estimates, the SAFSTOR service water demand will be less than 1% of current demand. A schematic of the expected SAFSTOR flows are illustrated in Figure 4 below.

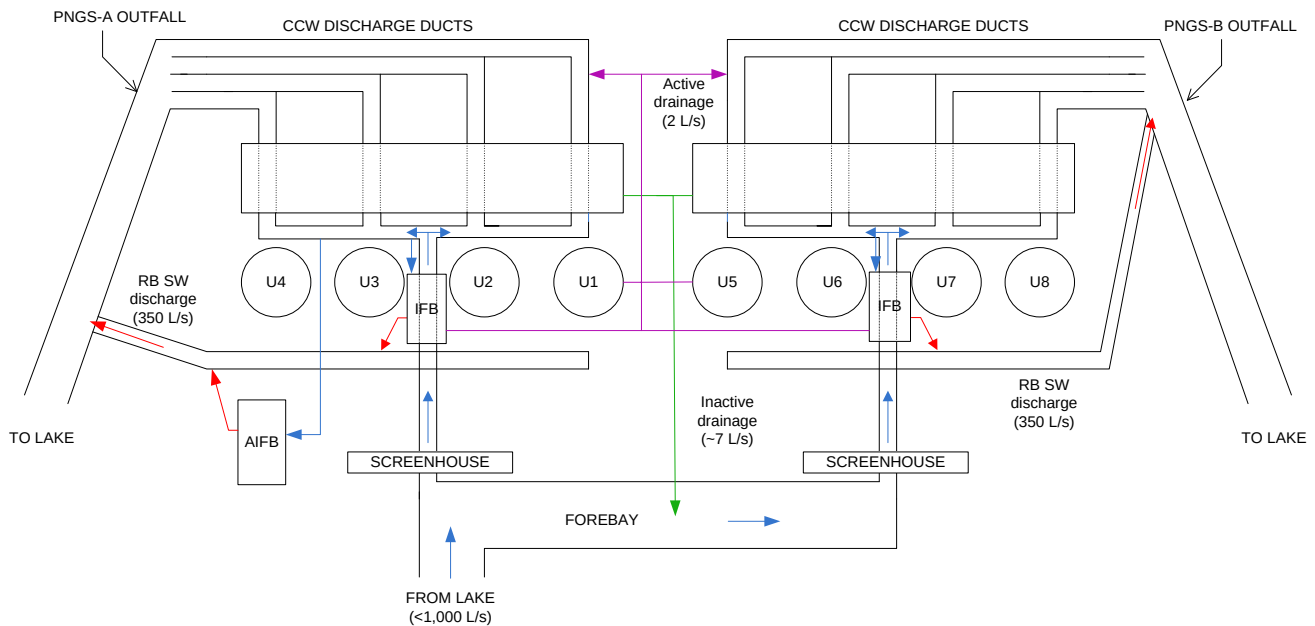


Figure 4 PNGS SAFSTOR Water Balance Diagram

In deciding how to most efficiently configure the station to meet these demands, there are obvious challenges that the project must overcome including:

- The existing screenhouses and service water systems are all oversized, with the smallest low pressure service water pump having a capacity of about 1,500 L/s.
- Ice build-up in the forebay and screenhouses in the winter months will have to be addressed following station shutdown by providing an alternate source of freeze protection.
- The Pickering A (Units 014) and Pickering B (Units 058) service water systems are currently completely independent, thereby requiring either integration of the two, or the continued operation of both screenhouses.

Some of the not so obvious challenges which will also have to be understood and addressed in developing the water intake and discharge strategy for the station will stem from the environmental implications of the proposed changes. As part of the PEA, surface water modelling will be undertaken in order to explore how changes to both the intake requirements and the characteristics of the discharge will impact the surrounding environment, as well as how the station will comply with regulatory requirements in SAFSTOR.

The following subsections provide a brief overview of some of the scoping work being completed as part of the SAFSTOR PEA surface water modelling initiatives.

4.2 Changes to Lake Mixing Properties

The regulations which govern the conditions for lake water extraction and effluent discharge back to the lake include both provincial and federal laws. Environmental Compliance Approvals are granted by the provincial authority (Ministry of the Environment and Climate Change), which restricts the temperature and conventional contaminant concentrations of effluent discharges, while the radioactive releases are regulated by the Canadian Nuclear Safety Commission (CNSC) by means of enforcing Derived Release Limits (DRLs) under operating licence conditions.

The purpose of the DRLs, which apply to atmospheric as well as waterborne discharges, are to limit the radioactive exposure to the public to within the annual dose limit set by the regulator [1]. The dose calculations by which the DRLs are calculated are extremely complex and dependent not only on the characteristics of the emission streams from the facility, but the characteristics of the surrounding populations, the pathways through which surrounding populations may be exposed to said releases, as well as the factors which influence atmospheric and liquid dispersion of the sources.

By significantly altering the mixing characteristics at the outfall, not only will the existing DRLs need to be revisited for the station, but the methodology for calculating the limits will have to be reviewed for applicability to the SAFSTOR configuration. The existing methodology, as outlined in [2] and [3], has been developed and refined over many years and is based on high volumetric discharges resulting from condenser cooling water flow rates which create turbulent outfall streams and rapid mixing conditions in the lake.

Surface Water modelling will assist in understanding how these changes in the vicinity of the outfall will impact mixing patterns in order to inform how the DRL calculations for the SAFSTOR period

might be approached. This information will in turn inform decisions about how the Project can most responsibly manage waterborne discharges over the SAFSTOR period.

4.3 Changes to Thermal Properties at Outfall

Thermal impacts to local aquatic communities will also have to be understood. Despite complying with station's Environmental Compliance Approval for industrial sewage works, which limit's the temperature differential of the condenser cooling water to no more than 11° C greater than the lake temperature, local fish populations will have acclimatized to the thermal plumes surrounding the outfall structures. The potential for adverse impact to these communities due to thermal changes resulting from units shutting down will be assessed as part of the PEA, and mitigating measures implemented, as required.

4.4 Fish Impingement Mitigation Techniques

Along with the high volumetric flow rate of water continually diverted through the PNGS screenhouses comes the risk of impingement to fish populations. In 2009, to mitigate against fish impingement, OPG installed a fish diversion system, as illustrated on Figure 3.

The system consists of a barrier net installed in the mouth of the forebay which is maintained in place by divers, who must manually remove algae and debris. The net is installed every April and removed every November, as lake conditions in the winter months make it unsafe for divers to maintain the nets. The diversion system was shown to successfully reduce impingement by greater than 80% on an annual basis [4].

The ongoing need for fish impingement mitigation will be reviewed as part of the PEA. It is anticipated that the risk of impingement would be reduced commensurately with decreasing volumetric flow rates drawn into the screenhouses. Based on the results of the PEA, the strategy for impingement will be re-evaluated and updated, as required.

4.5 Changes to Forebay Conditions

Per the current configuration at the Pickering site, discharges to the forebay, including stormwater or inactive drainage streams (refer to Figure 4), are also heavily influenced by the high volumetric flow rates drawn in through the screenhouses, which create mixing in the forebay and inevitable recirculation of forebay discharges back through the powerhouse and into the outfall.

In SAFSTOR, once the need for circulating water flows have been reduced to a fraction of the current flow rates, these mixing and recirculating conditions will no longer exist. As part of the PEA, the forebay will be modelled to understand how potential SAFSTOR configurations may impact the quality of water in the forebay, assuming inactive effluent streams continue to be discharged to the forebay (such as heating boiler blowdown, stormwater and groundwater discharge, or other conventional system waste streams).

5. SAFSTOR Groundwater Management Strategy

Another component of the SAFSTOR PEA includes completing a Groundwater Management Impact Assessment. Localized areas of groundwater contamination (tritium) exist within the Protected Area of the Site. Although the sources of these historical releases have been identified and eliminated through implementation of the station's groundwater monitoring and management program, the residual contamination will remain on site [5].

Groundwater flow patterns in the Protected Area are influenced by the artificial hydraulic sinks on site, primarily, the foundation drainage system/sumps located in the basement of the powerhouse, as well as the sump collecting surface water and shallow groundwater adjacent to the vacuum building structure (located south of the reactor buildings). These hydraulic sinks have large capture zones, collecting groundwater in the vicinity of the power house that would otherwise follow the local flow pattern in a southerly direction to Lake Ontario [5].

The areas of localized tritium contamination, mobilized by groundwater, are also controlled by the influence of the hydraulic sinks on site, which slowly capture the groundwater in the area of influence. The groundwater drawn into the foundation drains is monitored for contaminants and station liquid effluent releases are controlled to ensure they are within the station's DRLs.

The assessment involves developing a three dimension groundwater flow model of the site as well as a contaminant fate and transport model. Once baseline conditions for the site are established, the model will be used to project how the tritium concentrations and distribution will change over the course of the SAFSTOR period (and beyond), accounting for groundwater flow patterns, natural attenuation and dispersion mechanisms.

The purpose of the assessment is to inform the Project as to how potential changes (including physical or operational), may affect groundwater flow patterns on the site which may in turn influence the potential for environmental impact, thereby allowing the Project to make informed decisions about how to safely manage and control groundwater residual contamination.

6. Summary

The Pickering Safe Storage Project is a complex, multifaceted project to plan and execute the transition to the next lifecycle phase of the facility. As a result of planning efforts to date, OPG is developing a sound understanding of project scope, including system and regulatory drivers, which will continue to be challenged and revisited as planning progresses and the strategy and scope are refined.

Understanding potential environmental impacts is a significant and essential part of project scoping. Results of the Predictive Environmental Assessment will allow OPG to make informed decisions in the early phases of project planning to ensure OPG will meet regulatory requirements.

Although there is a significant amount of work that lays ahead, including understanding and reconciling the safety, environmental and economic drivers, OPG remains optimistic of the opportunities which will also be made possible by the holistic approach to planning.

Opportunities include:

- A more in-depth site characterization and understanding of the interactions between site operations and the surrounding environment;
- More efficient and sustainable site operations;
- Maintaining a strong relationship with the community through stakeholder engagement and preserving OPG's reputation of responsible corporate citizens through environmental stewardship
- An overall net positive benefit to the environment.

7. References

- [1] Radiation and Protection Regulations, Nuclear Safety and Control Act, SOR/2000-203
- [2] Canadian Standards Association Standard N288.1-08 "Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities", September 2008.
- [3] Candu Owners Group Inc. "Derived Release Limits Guidance" (COG-06-3090-R2-I), November 2008, Section 5.0, pp. 103-113.
- [4] "Baseline Environmental Report for Pickering Nuclear ", Prepared by ECOMETRIX Incorporated and Golder Associates Ltd., February 2016 (draft).
- [5] "Baseline Conditions for Groundwater Management Impact Assessment, Pickering Nuclear Generating Station", Prepared by CH2M Hill Canada Limited, April 2016 (draft)