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Report

Title:
SITE EVALUATION FOR OPG NEW NUCLEAR AT DARLINGTON - NUCLEAR SAFETY CONSIDERATIONS

Site Evaluation for OPG New Nuclear at Darlington - Nuclear Safety Considerations

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Revision Summary

Revision Number	Date	Author	Comments
R000	2009-03-26	L. Yu	Initial issue. Prepared by: L. Yu, S. Wong, A. Boisvert, Z. Catovic Verified by: R. Russell Reviewed by: L. Beresford Approved by: J. Marczak, C. Sellers
R001	2009-09-14	A. Freeburn	This document revision ensures consistency with the recently updated Site Evaluation technical reports listed in the introduction (Section 1.0). It also addresses comments that were received.

Executive Summary

The Darlington Nuclear (DN) site was recently selected by the Ontario Government as a site for a new Nuclear Power Plant (NPP) for the construction of up to 4800 MW of new nuclear generation.

Three technologies are under consideration for the New Nuclear at Darlington (NND):

- 3 x 1580 MW Areva US EPR (EPR)
- 4 x 1037 MW Advanced Passive Reactor (AP1000)
- 4 x 1085 MW Advanced CANDU Reactor (ACR-1000)

A number of site evaluation studies were performed in order to demonstrate that the NND site meets the requirements and expectations of the *Class I Nuclear Facilities Regulations* [R-2] and RD-346, "*Site Evaluation for New Nuclear Power Plants*" [R-3]. RD-346 has adopted the tenets set forth by the International Atomic Energy Agency (IAEA) safety requirements document NS-R-3, "*Site Evaluation for Nuclear Installations*" [R-13] and its associated guides. The evaluation was performed based on reactor designs enveloped by the three technologies noted above.

The design aspects identified and considered during the development of the site evaluation studies are based on preliminary conceptual design information and are for evaluation and illustrative purposes only. The actual design features will be specified during the detailed design stage of the project.

As identified in the original application for a Licence to Prepare the Site (LTPS) [R-1] , the site evaluation studies considered the following hazards:

- Meteorological events,
- Flooding hazards,
- Seismic hazards,
- Geotechnical hazards,
- External human-induced hazards,
- Hazards related to site characteristics and its influence on potential dispersion of radioactive materials.

These hazards were assessed in terms of risk to the new NPP and ultimately to the public and the environment. Additionally, the projected performance of the new NPP was evaluated against safety goals for the expected conditions at the site.

In each of the hazard areas, the risk was determined to be acceptably low or could be reduced to an acceptable level through design mitigation. The overall conclusion is that the NND site is suitable for the new NPP.

1.0 INTRODUCTION

The Darlington Nuclear (DN) site was recently selected by the Ontario Government as a site for a new Nuclear Power Plant (NPP) for the construction of up to 4800 MW of new nuclear generation.

To obtain regulatory approval for this site, Ontario Power generation (OPG) is submitting the following:

- A revised application for a Licence to Prepare the Site (LTPS) as identified to the Canadian Nuclear Safety Commission (CNSC) in N-CORR-00531-03717, "*Application for a Site Preparation Licence – New Nuclear Power Generation*" [R-1] and
- An Environmental Assessment to a joint review panel as mandated by the CNSC and the Canadian Environmental Assessment Act (CEAA).

In support of the LTPS submission, the site was evaluated in accordance with the expectations provided by the *Class I Nuclear Facilities Regulations* [R-2] and RD-346, "*Site Evaluation for New Nuclear Power Plants*" [R-3].

For planning purposes, three reactor technologies and configurations are under consideration for the New Nuclear at Darlington (NND):

- 3 x 1580 MW Areva US EPR (EPR)
- 4 x 1037 MW Advanced Passive Reactor (AP1000)
- 4 x 1085 MW Advanced CANDU Reactor (ACR-1000)

As detailed design information for the three reactor technologies is not available in this phase of the project, the information from N-REP-01200-10000, "*Use of Plant Parameters to Encompass the Reactor Designs Being Considered for the Darlington Site*," [R-4], is used where applicable in the site evaluation studies. The information in the *Plant Parameters Envelope* (PPE) report [R-4] defines the bounding impact of a new NPP at the Darlington site, considering the three reactor technologies listed above.

The site evaluation studies are, for the most part, independent of the reactor technology. In those cases where the site evaluation assessments were affected by the reactor technology, the evaluations were performed, wherever possible, by comparing the values of assessed parameters with the corresponding limiting values in the PPE [R-4]. The use of a composite PPE allows for an assessment of the environmental impact of a proposed plant design, formulated as a bounding construct from the various reactor designs currently under consideration.

The design aspects identified and considered during the development of the site evaluation studies are based on preliminary conceptual design information and are for evaluation and illustrative purposes only. The actual design features will be specified during the detailed design stage of the project. All statements and conclusions in the present report were based on a series of technical assessments performed by independent subject matter experts recognized in their respective fields and documented in a series of technical reports:

- Report NK054-REP-01210-00013, "*Site Evaluation of the OPG New Nuclear at Darlington Part 4: Evaluation of Meteorological Events*" [R-5],
- Report NK054-REP-01210-00012, "*Site Evaluation for the OPG New Nuclear at Darlington Part 5: Flood Hazard Assessment*" [R-6],
- Report NK054-REP-01210-00015, "*Site Evaluation for the OPG New Nuclear at Darlington Part 3: Summary of Seismic Hazard Evaluations*" [R-7],
- Report NK054-REP-01210-00014, "*Site Evaluation for the OPG New Nuclear at Darlington - Probabilistic Seismic Hazard Assessment*" [R-8],
- Report NK054-REP-01210-00011, "*Site Evaluation for the OPG New Nuclear at Darlington Part 6: Evaluation of Geotechnical Aspects*" [R-9],
- Report NK054-REP-01210-00010, "*Summary Report: Site Evaluation for Nuclear Installations at Darlington Site: Evaluation of External Human Induced Events*" [R-10],
- Report NK054-REP-01210-00016, "*Site Evaluation of the OPG New Nuclear at Darlington - Part 2: Dispersion of Radioactive Materials in Air and Water*" [R-11],
- Report NK054-REP-01210-00018, "*Site Evaluation of the OPG New Nuclear at Darlington - Additional Considerations*" [R-12].

1.1 Objective

As emphasized in RD-346 [R-3], the purpose of a site evaluation is to ensure that a nuclear power plant constructed at the site will not create an unreasonable risk to the public or to the environment. The present report provides a summary of the nuclear safety aspects of the site evaluation for the new NPP at Darlington.

As stated in RD-346 [R-3], "RD-346 represents the CNSC staff's adoption, or where applicable, adaptation of the principles set forth by the International Atomic Energy Agency (IAEA) in NS-R-3 [R-13]… The scope of RD-346 goes beyond NS-R-3 in several aspects…, which are not addressed in IAEA's NS-R-3 [R-13]." The following IAEA guides that support NS-R-3 [R-13] have also been adopted to support RD-346 [R-3]:

- NS-G-3.4, "*Meteorological Events in Site Evaluation for Nuclear Power Plants*" [R-14],

- NS-G-3.5, “*Flood Hazard for Nuclear Power Plants on Coastal and River Sites*” [R-15],
- NS-G-3.3, “*Evaluation of Seismic Hazards for Nuclear Power Plants*” [R-16],
- NS-G-3.6, “*Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power Plants*” [R-17],
- NS-G-3.1, “*External Human Induced Events in Site Evaluation for Nuclear Power Plants*” [R-18],
- NS-G-3.2, “*Dispersion of Radioactive Material in Air and Water and Consideration of Population Distribution in Site Evaluation for Nuclear Power Plants*” [R-19].

The present report provides a summary of the evaluation that was completed regarding nuclear safety considerations identified in RD-346 [R-3].

The NND site’s current baseline conditions were described in terms of geography, hydrology, seismology, meteorology, geology, geotechnical conditions and hydrogeology. These conditions, in conjunction with the identified hazards, serve as inputs for the assessment of risks and consequences the new NPP on the NND site would pose to the public and environment. Furthermore, it was prudent to identify possible initiating events and hazards that could lead to a situation in which the new NPP at the NND site would pose an unreasonable risk to the public, its employees and the environment. As in RD-346 [R-3], the present report divides hazards into two groups: natural; and, human-induced events. Each group was further divided into specific hazards for a detailed assessment.

The objective of the present report is to estimate quantitatively, wherever possible, potential impacts of the new NPP on the public and the environment. This includes a description of the potential for the dispersion of radioactive materials under both normal operation and accident conditions and emergency planning considerations. The site evaluation considers the entire life of the facility including projections of population growth. These quantitative results serve as basis for determining whether the NND site is suitable for the new NPP.

1.2 Quality Assurance

The Site Evaluation work was completed in compliance with the quality assurance expectations outlined in RD-346 [R-3]. Procedures were implemented to control the effectiveness of assessments and engineering activities performed in the different stages of the site evaluation process. Records of all work conducted during the site evaluation process have been maintained pursuant to relevant OPG Quality Assurance (QA) procedures, and subscribe to the quality attributes of OPG QA (i.e., that work be correct, complete, valid, traceable, and reproducible). A QA Plan [R-20] was established with AMEC-NSS before commencing work, and compliance is documented in the "*Quality Report for Darlington Site Evaluation Studies*" [R-21]. Contracted site evaluation work was conducted under a management system, which was consistent with the requirements of Canadian Standards Association (CSA) N286-05, "*Management System Requirements for Nuclear Power Plants*" [R-22].

2.0 DESCRIPTION OF THE SITE

The NND site lies east of the Darlington Nuclear Generating Station (DNGS), south of South Service Road, and west of St. Marys Cement Company on the shore of Lake Ontario. A detailed site description is provided in the *Evaluation of Geotechnical Aspects* report [R-9], which shows a drawing of the Darlington property including the existing DNGS and its exclusion zone as seen in **Figure 2-1**.

The baseline evaluation of the DN site was performed to describe the basic site parameters as well as serve as a platform for the hazard assessments in Section 3.0 to 5.0.

The following data are detailed in the subsections below:

- Location and topography – basic site description, elevations,
- Meteorology – winds, temperature, precipitation, snow pack, humidity and atmospheric pressure,
- Surface water hydrology – Coastal and riverine settings,
- Groundwater hydrology – Flows and monitoring,
- Geotechnical setting – Soil and rock profiles, site layout, foundation and earth structures under normal conditions,
- Regional population – current and projected distribution in the vicinity of the DN site,
- Use of land and water – present and future use of land and water resources in the vicinity of the DN site.

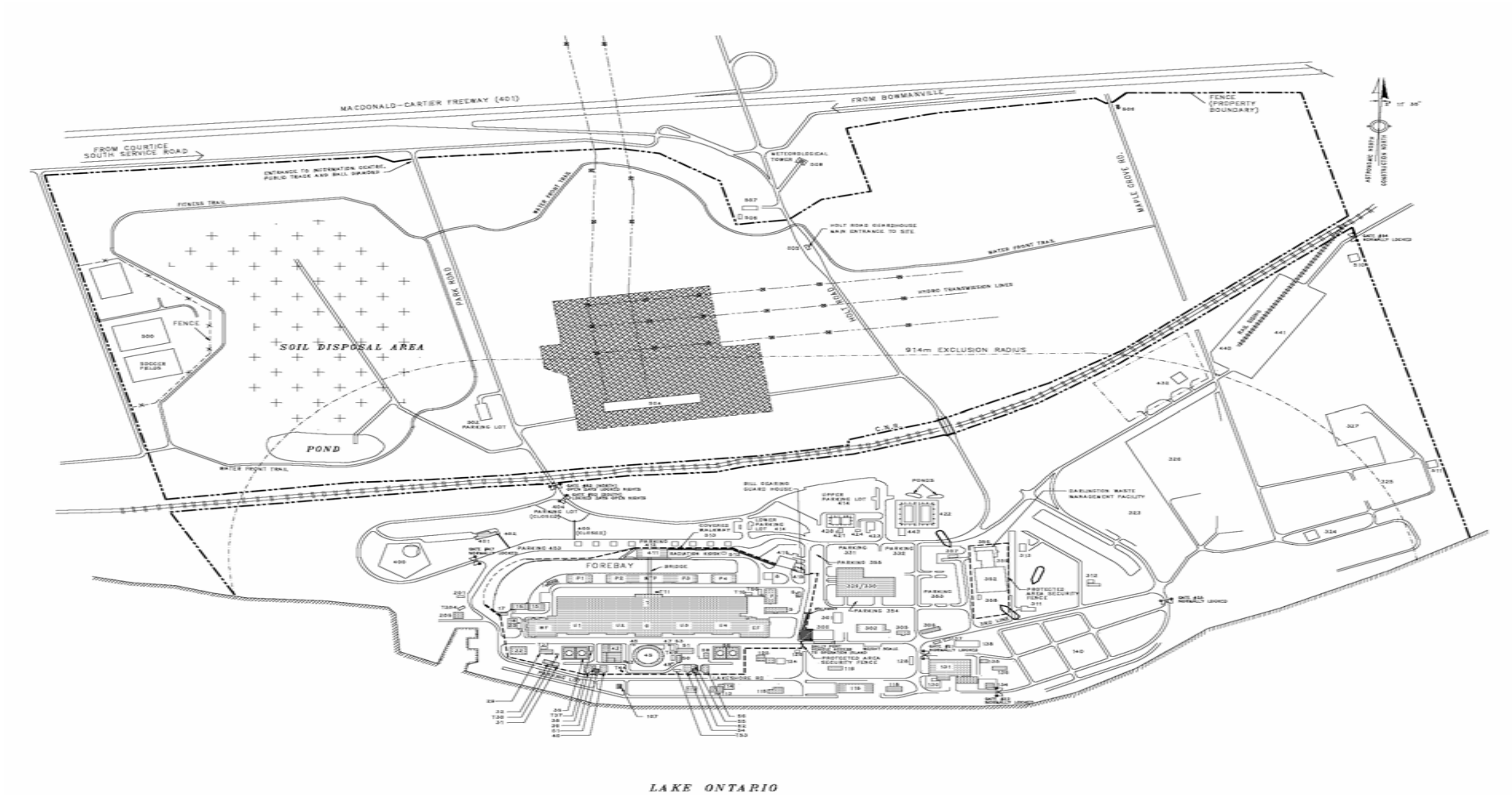

Figure 2-1 – Map of the DN Site

2.1 Location and Topography

The DN site is located on the north shore of Lake Ontario, in the Region of Durham near the Municipality of Clarington, about 60 km east-north-east from downtown Toronto. As shown in **Figure 2-2**, the site is bounded by South Service Road and the Macdonald-Cartier Freeway (Highway of Heroes / 401) to the north and Lake Ontario to the south. To the west, the site is bounded by Solina Road. The St. Marys Cement plant occupies the land east of the DN site. Canadian National Railway's (CNR) main line bisects the site in an approximate east to west direction. **Figure 2-2** also shows the Canadian Pacific Railway (CPR) mainline located north of the DN site.

The previously irregular terrain has been graded in the existing DNGS powerhouse area to an elevation of about 100 m. This site elevation of 100 m is equal to an elevation of 78 metres above sea level (masl). This elevation is also expected to be the level of the new power blocks, protected areas and possible cooling towers. The surface elevation rises towards the north with a mean site elevation of 122 m just south of the railway tracks and irregular ground from 120 m to 128 m elevation to the north of the tracks. To the east, the site for the OPG NND is composed of a gentle slope rising upward from an approximate elevation of 102 m to 112 m over a distance of 400 m. Further east, the existing ground elevations rise substantially to a height of about 130 m near the east site boundary. **Figure 2-3** shows the topographic contours of the site, with the flat area of the DNGS clearly visible at the bottom of the map on the shore of Lake Ontario.

Offshore from the DN site, the lake bottom slopes away gradually reaching a depth of 6 m at about 425 m from shore and 14 m at 1.2 km from shore. **Figure 2-4** shows the bathymetric contours of the Lake Ontario lakebed south of the DN site based on data reported in 1989.

The DN site is situated in an undulating to moderately rolling till plain overlying limestone bedrock. An undulating terrain usually increases atmospheric turbulence near ground level during times of moderate or strong winds, resulting in greater atmospheric dispersion at locations near the station.

Seismologically, the DN site lies within the western Lake Ontario region in the tectonically stable interior of the North American continent, which is characterized by low rates of historical seismicity.

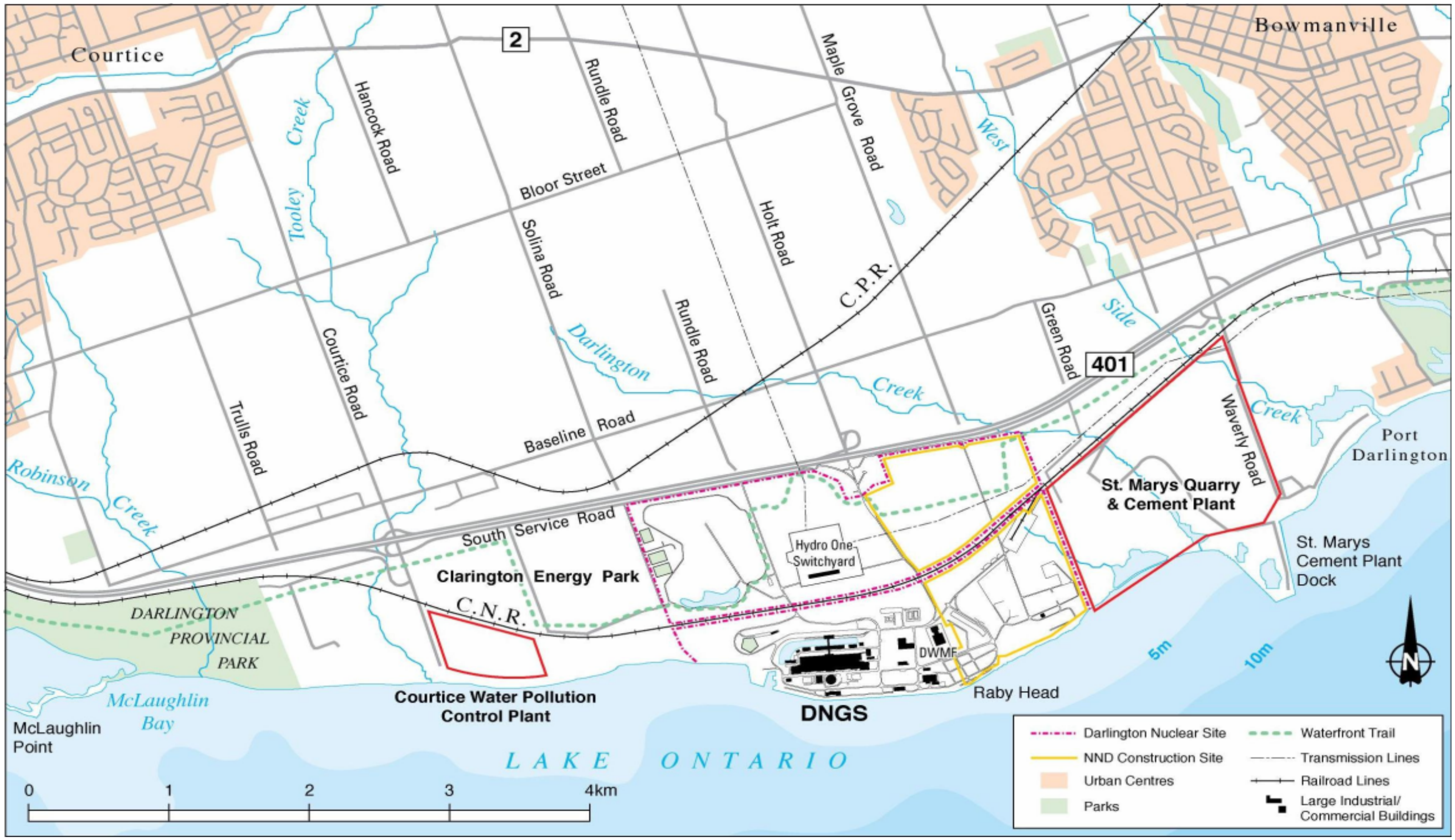

Figure 2-2 – DN Site

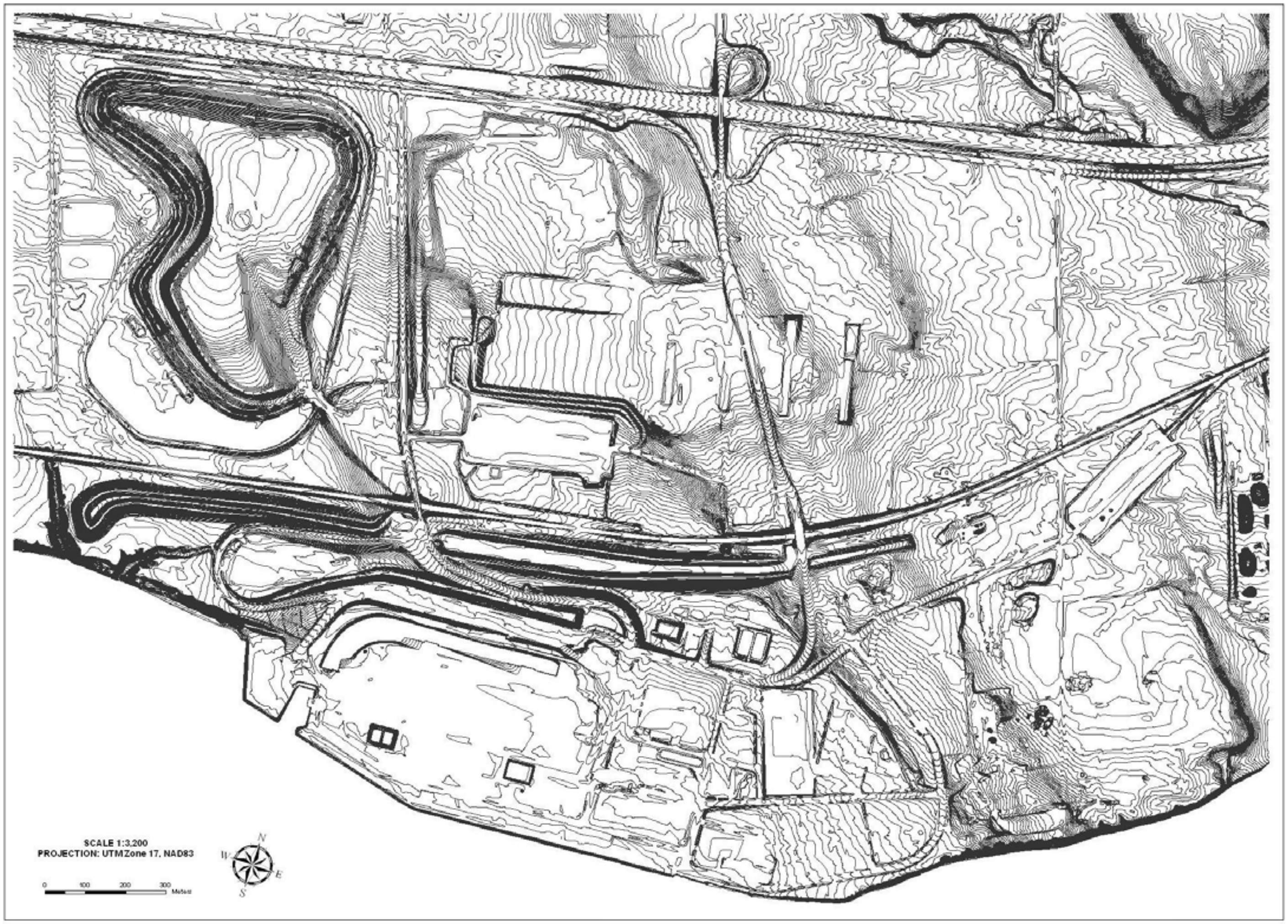

Figure 2-3 – Existing Topographic Contours

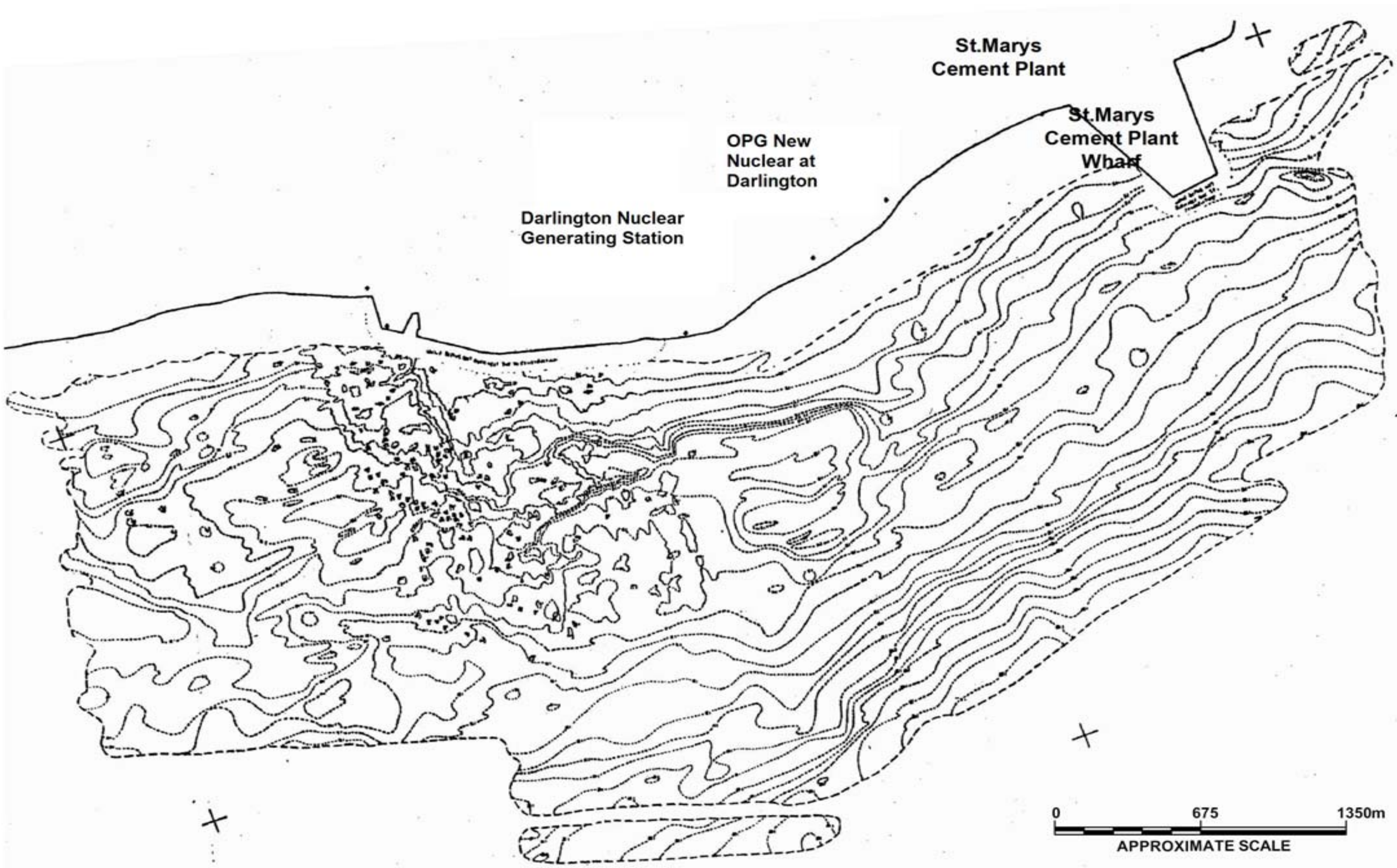

Figure 2-4 – Bathymetric Contours of Lake Ontario Lakebed South of DN Site

2.2 Meteorology

Meteorological data reported here are based on the *Evaluation of Meteorological Events* report [R-5], which extracted data from ten different Meteorological Service of Canada (MSC) stations as well as the DN site meteorological tower. The DN site meteorological tower is the closest, located just north of the existing DNGS powerhouse, and has been in operation since 1991. Wind speed and direction are measured at the standard height of 10 m and also at 50 m. Temperature is measured at a height of 10 m. It should be noted that due to calibration and / or instrumentation errors, some uncertainty exists concerning the quality of data obtained from the DN site tower after January 2001. For this reason, data from this tower are not used in the statistical analysis of Section 3.1.

The MSC stations used for the baseline analysis are listed in **Table 2-1** below along with their distance and general direction from the DN site. A subset of these stations was also used for the extreme value analysis. Data covering a 30 year period from 1975 to 2006 were obtained from the Ontario Climate Centre and the Environment Canada Climate website. Specific stations were chosen for their proximity to the DN site and for the availability of relevant measured data.

Table 2-1 – Summary of MSC Stations in the vicinity of the Darlington study area

Station Name	Distance from the DN Site (km)	General Direction from the DN Site	Length of Record (Years)
Belleville	110	East	89
Bloomfield	120	East	75
Cobourg STP	44	East	37
Oshawa Water Pollution Control Plant (WPCP)	9	West	38
Peterborough A	49	North	38
Thornhill Grandview	56	West	42
Toronto Island	60	West	40
Toronto Lester B. Pearson Int'l A	76	West	72
Toronto (Central)	59	West	107
Trenton	97	East	56

Lake Ontario has the largest influence on the climatology of the DN site. Winds during the spring and summer are predominantly out of the southwest in Southern Ontario, which generate a lake effect breeze along the north shore of Lake Ontario, keeping the temperatures slightly more moderate than areas further inland. The opposite holds true during the late fall and winter months as the lake water takes longer to lower its temperature compared to the surrounding landmass, allowing temperatures at DN site to be slightly warmer than locations just inland of the site.

Wind Speed

Wind speed was measured at the standard 10 m height from four different MSC stations and compared to data from the DN site meteorological tower, also measured at a 10 m height. The average hourly wind speed at the DN site follows the seasonal trend of stronger winds in the winter and lighter winds in the summer, similar to the surrounding regions. Daily variations see an increase in wind speed from the morning until mid-afternoon, followed by a decline until after sunset, before remaining stable over the course of the night.

Temperature

The area has warm summers and cold winters. Mean daily temperatures fall below zero in the winter months (December through March). The 16-year dataset from the DN site shows January to be the coldest month of the year with a mean daily temperature of -5.5°C. The coldest recorded hourly temperature was -30.5°C measured in 1993. In the summer, the warmest mean daily temperatures are measured in July at 20°C. A high of 31.5°C measured in 1995 was the warmest annual maximum recorded at the site. Air temperature at the DN site was measured by the sensor at a height of 10 m which differs from the standard 2 m height used by the other weather stations.

Temperature inversions occur when the usual pattern of air decreasing in temperature with altitude is disrupted by a layer of warmer air. This prevents air from rising which can allow smog to form and could affect the dispersion of radioactive materials or toxic gases. Measurements have been made for the past thirty years using upper air soundings at the Buffalo airport in New York. The measurement criterion for temperature inversion was a minimum increase in temperature of 0.5°C as altitude increases.

In the average year, a total of 246 inversions were found at an altitude of less than 1000 m. Two-thirds of the inversions occurred at an altitude of less than 500 m, while the remaining one-third were found between 500 m and 1000 m. The number of inversions is greater in the spring and the fall.

Precipitation and Snow Pack

Since precipitation amounts are not measured at every meteorological station site, including the DN site, the baseline data were taken from the nearest available stations that measure hourly values. Central Toronto, Toronto Pearson International Airport and Trenton all showed similar trends with peak rainfall occurring in July-August. The maximum peak precipitation rate from 1977-2006 was 40.1 mm/hour at the Toronto Pearson site with similar peak rates (within 1 mm/hour) measured at the other two sites.

Daily snowfall data were available between 1977 and 2006 for the months of October to May for all of the MSC stations in **Table 2-1** except Peterborough and Central

Toronto. Daily snowfalls of at least 18 cm have occurred at all these sites in the past 30 years during each of the months December, January and February. Closer to the DN site, the Oshawa station has never measured a daily snowfall of over 30 cm. The average Oshawa daily snowfall is between 3 cm and 5 cm from December through to March.

Precipitation amounts (both snow and rain) at the DN site are comparable to those observed in Toronto, as opposed to observations made further east along the shore of Lake Ontario, due to the more frequent formation of snow squalls at locations further east. Snow squalls at the DN site need winds to come in from the south, but winds from this direction usually bring an increase in temperature which is not conducive to the formation of snow squalls.

The same stations that measure snowfall also measure daily snow pack, which is the depth of the combination of new and old snow on the ground. At the Oshawa MSC station, the nearest to the DN site, daily snow pack is usually measured to be at its highest in January with a mean of 8.6 cm. The most complete data set, from 1977 to 2006, was compiled from the Toronto Pearson International Airport station where a 30-year mean monthly snow pack was found to be at its highest in January at 6.4 cm.

Humidity and Atmospheric Pressure

Four MSC stations were used to report relative humidity data and atmospheric sea level pressure. Summaries of 30-year data (1977-2006) were created for mean and boundary levels.

Mean monthly humidity percentages vary between 65-80% with the lower levels occurring during the months of spring and higher levels during the fall season.

Mean monthly atmospheric sea level pressure is consistently determined to be between 101 kPa and 102 kPa. Monthly determinations occasionally drop to 96 kPa and rise to 105 kPa, mostly during the winter months when atmospheric pressure is less stable.

2.3 Surface Water Hydrology

2.3.1 Coastal Setting

Information regarding the coastal setting is highlighted in the *Flood Hazard Assessment* report [R-6]. Lake Ontario is the easternmost of the Great Lakes and has the following physical characteristics: length, 311 km; average width, 85 km; average depth, 86 m; maximum depth, 244 m; volume, 1,640 km^3; and surface area, 18,960 km^2.

The Earth’s crust in the Great Lakes slowly rises with respect to sea level; therefore, lake level references are established every 25-35 years. The current reference is

International Great Lakes Datum (IGLD) 1985 and the chart datum for Lake Ontario is 74.2 m above the IGLD.

Lake Ontario water levels have been regulated since 1960 to reduce damages caused along the shores of the Lake and the St. Lawrence River. Since 1962, under the controlled regime, Lake Ontario mean water levels have annually ranged from a minimum of 73.83 m to a maximum of 75.73 m and have averaged 74.81 m. Seasonal changes have an annual cycle with the maximum levels occurring in June and the minimum levels in December.

Astronomical tides, changes in water level caused by the gravitational forces of the sun and moon, do occur in a semi-diurnal pattern on the Great Lakes. However, the largest spring tides are less than 5 cm in height and these minor variations are hidden by greater fluctuations in lake levels produced by wind and barometric pressure changes. Consequently, the Great Lakes and Lake Ontario are considered to be essentially non-tidal.

Lake Ontario water temperatures have been recorded, from 0.2 km to 2.2 km offshore from the DN site, since 1971. Temperatures were monitored at various depths from 1971 to 1989. Maximum daily mean temperatures recorded at 2 m, 8 m, and 21 m depths were 24.2°C, 22.9°C, and 21.3°C respectively. Major up-welling and down-welling events, resulting in temperature changes of over 10°C in a period of several days, were recorded each year during the 17 years the measurements were taken. In a typical year, events of this magnitude occurred about three times during July to September.

2.3.2 Riverine Setting

Two named riverine systems are located within the local regional drainage basin, namely Darlington Creek and Tooley Creek, both of which appear in **Figure 2-2** found above. The Tooley Creek watershed lies to the west of the DNGS with its discharge point approximately 4 km from the area intended for the OPG NND. The distance, infrastructure and topography between the Tooley Creek watercourse and the proposed NND site preclude Tooley Creek as the source of a flood hazard for the new site.

The Darlington Creek watershed lies to the north and east of the proposed OPG NND, traversing the St. Marys Cement site south of the CNR main line. A small intermittent tributary of Darlington Creek originates in the eastern area of the site. A study of future land use for this watershed shows no significant changes and thus there are no expected changes to water flow or chemistry. Darlington Creek is the only riverine system in close proximity to the proposed site. As such, the assessment of riverine flood hazard will be based on the flooding associated with Darlington Creek only.

2.4 Groundwater Hydrology

At the site, three distinct groundwater flow patterns were identified: one in the water table (shallow groundwater); one in the bedrock; and, one in the interglacial deposits located above the bedrock. The direction of the groundwater flow is downward toward Lake Ontario. Near the lake, the groundwater level appears to be close to the existing ground surface and is likely related to the water level in the lake.

Existing boreholes and monitoring wells were used for groundwater sampling at the DN site as a part of the OPG DNGS Radiological Environmental Monitoring Program [R-23]. In the beginning of 2007, there existed 12 monitoring wells, and nests containing 20 Solinst multilevel wells. One multilevel well has two intake zones in the bedrock and the other multilevel well has three groundwater intake zones in the overburden material. For the Environmental Assessment of the site, 71 new monitoring wells were installed as detailed in the *Dispersion of Radioactive Materials in Air and Water* report [R-11].

2.5 Geotechnical Setting

Details regarding subsurface soil / rock profiles, site layout scenarios, as well as foundation and earth structures assessments exist in the *Evaluation of Geotechnical Aspects* report [R-9].

2.5.1 Subsurface Soil and Rock Profiles

For the NND site, the subsurface soil and rock profiles have been obtained from the boreholes drilled within the site in late December 2007 and early 2008. These boreholes cover a much larger area than is to be used for the future construction of NND. The borehole data show a stratigraphy that does not point to any major anomalies that would indicate the available stratigraphy to be unsuitable for use as part of site evaluation. Since data from only four boreholes in the areas for new nuclear construction were evaluated in the *Evaluation of Geotechnical Aspects* report [R-9], descriptions and conclusions developed at this time will need to be reviewed during the confirmation stage as part of detailed design phase for NND.

Soil sampling was carried out by a procedure known as a Standard Penetration Test to determine the soil resistance to penetration and the soil types. Groundwater levels were monitored in the monitoring wells installed at and near the borehole locations at various depths.

There was no indication of liquefaction in the site overburden soil columns that were subjected to synthetic earthquake time histories corresponding to magnitude 6 and 7 earthquakes in the region surrounding the site. The one exception was in a soil column with a sand layer with a low Standard Penetration Test count. It was noted that the low count should be interpreted with caution due to groundwater seepage into the auger hole during drilling.

The subsurface soil profiles indicated by the boreholes consist typically of a thin layer of topsoil overlying native soils, which are predominantly sand and till deposits (mainly sandy silt). Other soil types (clayey silt, clayey silt till, silt, clay, sand and gravel) encountered in the boreholes are typically mixed within the sand and/or the sandy silt / sand till. The native soils are interglacial and till deposits. The native soils are underlain by shaly limestone bedrock. The shaly limestone bedrock is present in the upper 3 m to 5 m of the bedrock, below which the lower bedrock is mainly limestone.

2.5.2 Site Layout Scenarios

For illustrative purposes, two representative layout scenarios were considered for the geotechnical evaluation. These were selected from the site layout scenarios for the new power blocks and associated structures as part of the preliminary engineering study. They encompass the extent of foundation and earth structure requirements in the other layouts, and the assessments are discussed below. Note that the final layouts will be determined during the detailed design phase.

Scenario A: Four ACR-1000 Site Layout with Once-through Lake Cooling

The existing site to the east of DNGS would be excavated to form a flat area, approximately 400 m by 600 m in plan area, at elevation 78 masl for constructing four reactor units. Two tunnels would be constructed under the lake – proposed intake channel and proposed discharge channel. The reactor units would be founded on sound bedrock at the approximate elevation of 64 masl (embedment depth of approximately 14 m from the expected 78 masl grade level).

Scenario B: Two EPR Site Layout with Mechanical Cooling

The existing site to the east of DNGS would be excavated to form a flat area, approximately 300 m by 500 m in plan area for the proposed power block and approximately 400 m by 500 m in plan area for the proposed mechanical cooling towers, at elevation 78 masl. Mechanical draft cooling towers would be located close to the east site boundary. The reactor units would be founded on sound bedrock at the approximate elevation of 64 masl (embedment depth of approximately 14 m from the expected 78 masl grade level).

The foundations and proposed earthworks for both scenarios were similar in terms of general design requirements and soil/rock conditions. As such, the geotechnical aspects of the site evaluation for foundations and earthworks were assessed by using the governing value for each parameter provided for the scenarios that would affect geotechnical performance. Other parameters that had less governing effects on the geotechnical performance were indirectly considered by the governing parameters. For example, the highest bearing pressure required for the heaviest reactor foundation was considered in this site evaluation. Other lighter bearing pressures, from different reactor types, were then indirectly considered as well.

2.5.3 Foundation Assessment – Normal Conditions

Based on the results of assessing the soil/rock conditions present at the site for NND and the planned structures, the site was classified as a "rock and stiff soil site".

The reactor foundations will be founded on the sound bedrock that is present at the site. The embedment depth of the reactor foundations will be approximately 14 m below the final ground surface. As such, the reactor foundations will be stable against overturning, sliding and movements under static loading conditions, provided that the reactor foundations are designed according to the allowable bearing capacity and the design groundwater level.

All other foundations can be founded on shallow or deep foundations, depending on the localized soil and groundwater conditions, applied loads and structural requirements. The precise value of the allowable bearing capabilities will depend on the localized soil and groundwater conditions which will need to be determined in the confirmation stage. Excavation near the bedrock/overburden interface should monitor for methane gas and precautionary measures during construction should be taken accordingly. For permanent structures embedded in the bedrock, the possibility of methane gas should be addressed in the design.

2.5.4 Earth Structures Assessment – Normal Conditions

The following main earth structures were considered as part of the analysis.

- Natural slopes in the vicinity of the site for NND that will not be altered.
- Cut Slopes that will be constructed for the site.
- Fill slopes that will be constructed for the site.
- Dykes that will be constructed along the new shoreline for land reclamation (lake filling), if implemented.
- Retaining walls and/or earth-retaining structures that will be constructed around the reactor foundations.
- Embedded structures.
- Buried pipes and conduits that will be required for services for the site.

Based on the results of the assessment for the earth structures anticipated to be constructed at the site for OPG NND under normal operating conditions, the anticipated earth structures are expected to be stable against slope failure and significant movements. Additional field investigation programs at the planned earth structure locations will be necessary for detailed analyses and design as part of the confirmation stage. Based on the available information, the site for OPG NND is suitable for supporting the proposed earth structures due to its competent soil and rock conditions.

2.6 Population Distribution

Data collected on the population distribution within the 100 km circular zone surrounding the proposed site have been mapped to the distribution grid shown in **Figure 2-5**.

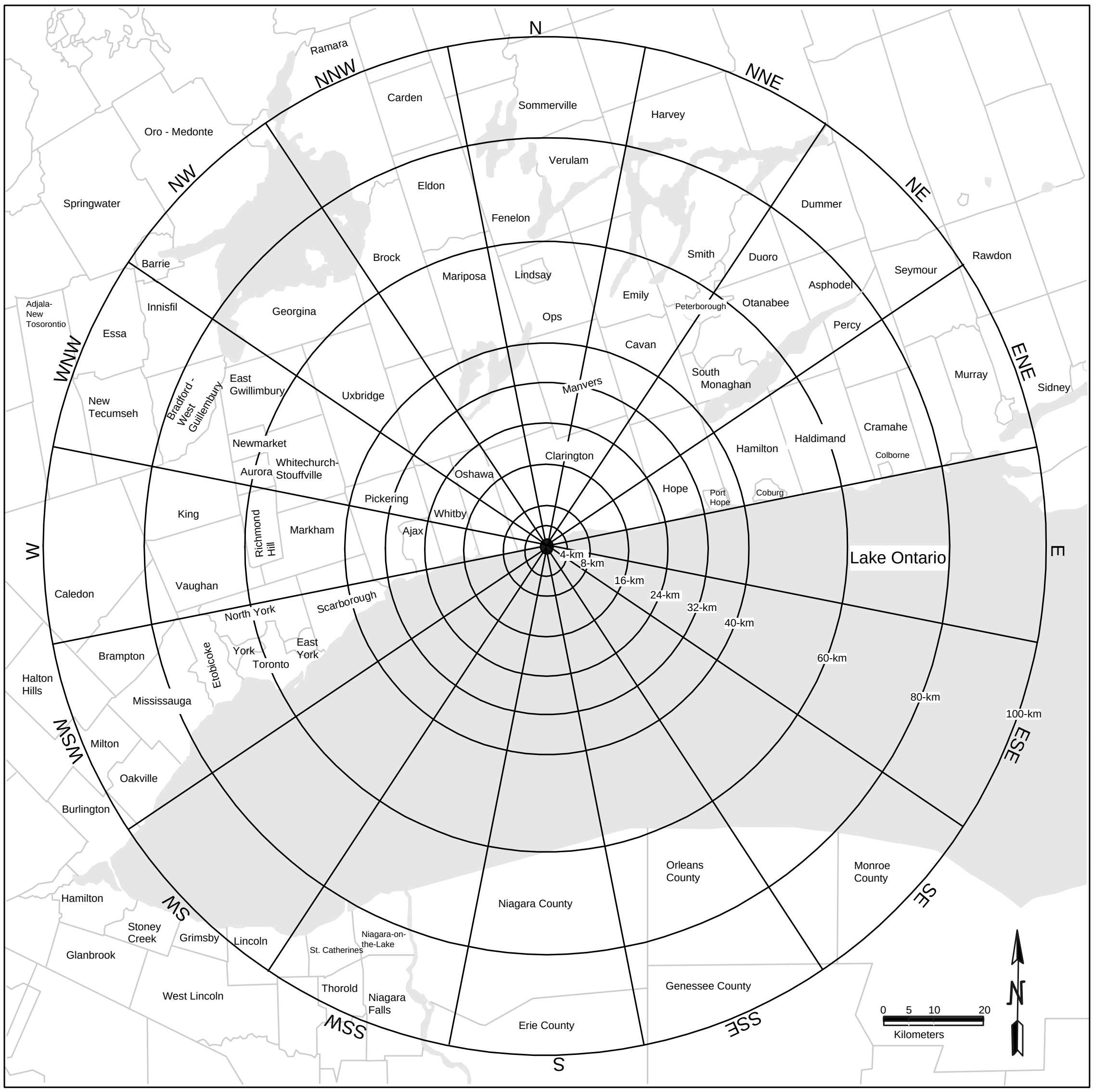

Figure 2-5 – Population Distribution Grid for the Area Surrounding the DN Site

<u>Present Population</u>

The population distribution for the region immediately surrounding the DN site was generated by Statistics Canada. The current population numbers based on the most recent census data from 2006 are provided in the Assessment of Environmental

Effects Technical Support Document [R-24]. A summary of the population data is provided in **Table 2-2**.

Table 2-2 – Summary of Current Regional Population Data

Distance from Site	Year 2006
0-2 km	44
2-4 km	7,961
4-8 km	51,213
8-40 km	640,204
40-100 km	6,382,086
Total (0-100 km)	7,081,508

The following general observations can be made for the population distribution in the vicinity of the proposed site:

- Relatively few people reside within 4 km of the proposed plant.
- The area within the immediate 8 km radius of the proposed plant is primarily rural with the exception of the City of Bowmanville.
- Population centres located beyond 8 km but within 40 km of the proposed plant include Pickering, Ajax, Whitby, Oshawa, and Port Hope.
- The population increases substantially in the region beyond 40 km of the proposed plant, which includes part of the City of Toronto.

Projected Population

The majority of residential growth is expected to be within the current urban areas of Courtice and Bowmanville through greater intensification of existing built-up areas to 2031. There are lands north of the CPR corridor in the vicinity of the DN site that have been identified for future residential growth between 2031 and 2056. Overall, the population distribution predicted for future years during the operational phase of the proposed plant are not expected to affect the feasibility of emergency planning at the proposed site. More discussion is provided in Section 5.4.

2.7 Use of Land and Water

The present and future use of land and water resources that may be used by the population or that may serve as a habitat for organisms in the food chain, were studied and characterized to support radiological pathway analysis and emergency planning.

Land Use

Lands used for agricultural purposes in the region are discussed in NK38-SR-03500-10001, "*Darlington Safety Report*" [R-25] and in the OPG report NK38-REP-03481-10002, "*Review of the Darlington Nuclear Site Specific Survey*" [R-26]. Inventories of site-specific agricultural data, which are pertinent to the food chain pathway radiological analysis, include vegetable and food crops, dairy products, and livestock. The industrial lands in the region are discussed in the *Darlington Safety Report* [R-25]. A new industrial site, Clarington Energy Park, has been proposed for construction to the west of the site and is expected to house facilities for the management of municipal solid waste, including incinerator and ash-processing facilities.

<u>Water use</u>

The use of water in the region for commercial and recreational fishing is discussed in the *Darlington Safety Report* [R-25] and the *Site Specific Survey Report* [R-26]. Ships ranging from small pleasure craft to large lake and ocean vessels traverse Lake Ontario. The larger cargo vessels move along shipping lanes located more than 10 km from the shore in the vicinity of the site. The ports at Whitby, Oshawa, and Cobourg are visited by small lake vessels. A pier is located east of the site, at St. Marys Cement, at which large lake vessels dock for loading and unloading.

3.0 ASSESSMENT OF EXTERNAL NATURALLY OCCURRING HAZARDS

External naturally-occurring hazards have the potential to place nuclear plant operations and emergency preparedness under stress. As part of the evaluation of the site for NND, identification and assessment of external naturally-occurring hazards have been performed to ascertain suitability of the site to host new nuclear units.

Assessment of the following hazards is detailed in the subsections below.

- Extreme weather – winds, temperature, precipitation, snow pack.
- Rare meteorological phenomena – wind gusts, tornadoes, tropical cyclones, lightning, freezing rain.
- Climate change.
- Flooding – coastal, storm surge and seiche, waves, riverine.
- Shortage of water supply – frazil ice, aquatic species.
- Seismicity – ground motion, surface faulting, volcanism.

3.1 Extreme Weather

Extreme winds, temperature, precipitation and snow pack were studied. A minimum of a 30-year data set of onsite measurements is necessary to perform an extreme value analysis. Where a 30-year dataset was not available, it was possible to extrapolate data using regression analysis in order to create a minimum 30-year dataset. Given that the DN site measurements do not cover a 30-year period, this became a necessary calculation before being able to perform the extreme value analysis.

For the cases of temperature and wind, the ten-year record of data collected at the DN site was used along with nearby MSC station data to develop a long-term analytical data set for the DN site. For precipitation and snow pack, where no onsite measurements are made, nearby MSC stations with climatologically similar regimes were used for the analysis.

The values presented in this section are independent of the possible variations due to climate change discussed in Section 3.3. Further details relating to extreme weather and rare meteorological events can be found in the *Evaluation of Meteorological Events* report [R-5].

Wind Speed

A 30-year data set was created by correlating the existing 10-year data from the DN site to 30-year data from Toronto Island, the nearest MSC station with a similar climatology that recorded sustained wind speeds for that period. An extreme value analysis was then performed on this new 30-year data set for the DN site. The results of this statistical analysis are predictions of maximum values for a set period in the future. A return period of 100 years is of most interest as it encompasses the entire lifecycle of the plant. Standard deviation is quoted as a measure of uncertainty on the calculation and all subsequent extreme value analysis. This exercise was done for the 10 m and 50 m heights. Wind gusts, which are not measured at the DN site, were also the subject of an extreme value analysis for the Toronto Island site.

Table 3-1 demonstrates that over the next 100 years, 15-minute average sustained winds speeds no greater than 80 km/h measured at 50 m can be expected at the DN site.

Table 3-1 – Summary of Extreme Value Predictions for Wind Speed for a 100 Year Prediction

Data Characteristic	Wind Speed (km/h)	Standard Deviation (km/h)
Maximum Wind Speed at 10 m at DN site	64	3.5
Maximum Wind Speed at 50 m at DN site	80	4.4
Maximum Wind Speed at 10 m at Toronto Island site	99	6.1

Temperature

Similar to the wind speed data, temperature measurements are only available at the DN site for a 10-year period. A regression analysis was done with both the Oshawa and Toronto Island sets of data in order to extend the DN site data into 2 different 30-year segments. The Oshawa and Toronto Island MSC sites were chosen for their similar microclimates to the DN site owing to their proximity to Lake Ontario. This was done for both annual maximum and annual minimum temperatures, creating four data sets in all.

Sources of error for the new data sets include:

- The distance between the DN and MSC sites;
- The difference in the height at which measurements were taken, MSC sites at 2 m and DN site at 10 m;
- The difference in sampling methods. MSC sites give instantaneous temperature values. The DN site gives 15-minute averaged temperature values.

Extreme value analysis was then performed to predict the maximum and minimum temperatures expected at the DN site over the next 100 years. The extreme values for both data sets are summarized in **Table 3-2**.

Table 3-2 – Extreme Value Predictions for 100-Year Temperatures at the DN Site

Data Set	Minimum Temperature (°C)	Standard Deviation (°C)	Maximum Temperature (°C)	Standard Deviation (°C)
Darlington Based on Toronto Island	-27.6	2.3	40.4	1.5
Darlington Based on Oshawa	-31.2	2.3	40.9	1.8

Precipitation

While precipitation at the DN site is not measured, MSC sites on Toronto Island and in Oshawa both have similar precipitation climates to the DN site.

An extreme value analysis was then performed at both sites for maximum daily precipitation. The values in **Table 3-3** show the results of this analysis.

Table 3-3 – Extreme Value Predictions for 100-Year Precipitation

Data Set	Maximum Daily Precipitation (mm)	Standard Deviation (mm)
Toronto Island	79.3	8.4
Oshawa	88.6	9.3

For snow pack, the closest MSC station with complete coverage over the last 30 years is the Toronto Lester B. Pearson International Airport. **Table 3-4** presents the result.

Table 3-4 – Extreme Value Predictions for 100-Year Snow Pack

Data Set	Maximum Snow Depth (cm)	Standard Deviation (cm)
Toronto Lester B. Pearson International Airport	62.0	8.6

3.2 Rare Meteorological Phenomena

Wind Gusts

Wind gusts of 120 km/h or more are exceptionally rare. **Table 3-5** displays the historical data available in the area surrounding the proposed site.

Table 3-5 – Events with Wind Gusts of 120 km/h or more

Station	Record	# Gusts 120+ km/h	Frequency	Max gust (km/h)	Cause
Toronto Island A	24 years	1	0.04/year	126 (1978/01/26)	Blizzard
Toronto Pearson	53 years	4	0.08/year	135 (1956/07/01)	Thunderstorm related
Trenton	53 years	12	0.23/year	154 (1958/12/22)	Strong warm front
Peterborough	33 years	1	0.04/year	133 (1983/08/08)	Thunderstorm related

In accordance with RD-346 [R-3], “an assessment of the risk of dust and sand storms… made on the basis of historic and recorded data" is required. An exhaustive search through available meteorological information pertaining to Southern Ontario was performed and a lack of historic evidence found. As a result, it is judged highly unlikely that such phenomena will apply to the OPG NND site, and abrasive dust and sand storms were not assessed further.

Tornadoes

The potential for the occurrence of tornadoes in the region of interest was assessed on the basis of detailed historical and instrumentally recorded data for a region of 100,000 km^2 centered at the site. A more detailed investigation was also performed to obtain suitable data for the evaluation of a design basis tornado.

The Fujita scale (F-scale) ranks tornadoes according to estimated wind speeds on a scale of 0 to 5, with an F number of 0 causing light damage and an F number of 5 characterised as being able to cause incredible damage. Since the 100,000 km^2 area evaluated is represented by a circle of radius 180 km centered at the DN site, some study of tornadoes on U.S. soil is necessary.

Relevant and available data concerning tornadoes ranked according to the F-scale are available in Canada from 1918 to 2003 and in the U.S. from 1974 to 2007. The confirmed and probable number of tornado events within 180 km of the DN site for the 30 year period from 1974 to 2003 are presented in **Table 3-6**.

Table 3-6 – Confirmed and Probable Tornado Count within 180 km of the DN site ($100\ 000\ km^2$) from 1974 to 2003[1]

F-Scale	F-Scale wind speeds (km/h)	Canada	USA	Total	Frequency per year per $100\ 000\ km^2$	Proportion
0	64 – 116	108	15	123	4.1	58.9%
1	117 – 180	37	22	59	2.0	28.2%
2	181 – 252	15	4	19	0.6	9.1%
3	253 – 330	5	1	6	0.2	2.9%
4	331 – 417	2	0	2	0.1	1.0%
5	418 – 509	0	0	0	0	0%
All		167	42	209	7.0	100%

Since tornadoes over water or waterspouts leave no trace and are seldom noticed or reported, the annual frequency of tornadoes is likely to be higher than the recorded value of 7.0 tornadoes per year per $100\ 000\ km^2$. However, given the nature of tornado formation in general, it is less likely for tornadoes to form over water than land. A conservative approach would be to calculate a tornado frequency based only on land area, essentially assuming that the formation rate over land and water is the same. This can easily be achieved by counting the same number of tornadoes over $80\ 000\ km^2$ since Lakes Ontario and Erie account for approximately 20% of the original $100\ 000\ km^2$ study area. This method results in a frequency of 8.7 occurrences per year in the $100\ 000\ km^2$ area.

Therefore, with such a frequency, tornadoes can be characterized as a rare, but non-negligible threat and a study of a design basis tornado was required in order to estimate the probability of occurrences on site. This was done by using a representative path length and width for each F-scale level tornado and then generating a large number of random events in a $100\ 000\ km^2$ area. A hit occurs when a tornado path overlapped the $4.85\ km^2$ DN site area. The results of the study are presented in **Table 3-7**.

Table 3-7 – Annual Probability of Tornado Damage to the DN site

F	Hits on the site in $100\ 000\ km^2$ region (10^9 trials)	Number of tornadoes (/30 years)	Probability of F-scale occurrence on site per year	Probability of F or more occurrence per year
0	106711	123	0.04%	0.12%
1	165389	59	0.03%	0.07%
2	283911	19	0.02%	0.04%
3	617673	6	0.01%	0.02%
4	1520464	2	0.01%	0.01%

[1] The tornadoes that struck Woodbridge, Ontario (about 90 km away from the NND site), and Milton, Ontario (about 115 km away from the NND site) on August 20, 2009 were of intensity F2 and F1 respectively, and were within the bounds identified in the *Evaluation of Meteorological Events* report [R-5].

A number of assumptions are made in this exercise. Since this simulation used only the known number of tornadoes in its calculations, a correction for tornadoes over water or waterspouts could not be made in this case. The probabilities might be up to 25% higher if the frequency of tornadoes over Lake Ontario was known. However, the representative path lengths and widths for each F-scale level were determined using their maximum known values, which is a very conservative approach.

Tropical Cyclones

Given the large distance from the Atlantic Ocean, the occurrence of tropical cyclone activity is rare at the DN site, with one storm of tropical origin passing within 400 km of the site every 3 to 4 years. Nonetheless, winds and heavy rains are threats to Southern Ontario, particularly during transition of a tropical to an extratropical cyclone.

The most common fate of a tropical cyclone tracking toward Ontario is for the storm to weaken and undergo extratropical transition. This often leads to moderate to high rainfall and sometimes gusty winds. Good examples are: Gracie (1959), Frederic (1979), Opal (1995), Isabel (2003) and Ike (2008).

The more severe situation for Southern Ontario is when a tropical cyclone undergoes extratropical transition then re-intensifies due to certain temperature conditions. Hazel (1954) is a prime example of this scenario and it was the most destructive system of tropical origin to affect Ontario in recorded history.

Hazel hit Southern Ontario soon after making landfall in the Carolinas. Toronto Pearson reported a little over 150 mm of rain in 2 days, sustained winds of 92 km/h for 2 hours and many hours of winds of 70 km/h or more. Brampton received 203 mm of rain in 48 hours. The strong storm is reported to have generated a surge and a seiche over Lake Ontario; however no historical data were found on the magnitude of the water level changes. By modeling the storm, it was found that a surge and subsequent seiche of the order of 0.75 m is possible at the site.

Due to the rapid decay of wind speed of a purely tropical cyclone as it moves inland, the probability of such a storm retaining hurricane force wind as far inland as the site is minimal. Furthermore, given the low frequency of such storms in Southern Ontario, the probability of an actual hurricane directly impacting the site is extremely low. The probable maximum tropical cyclone then would be a decaying tropical system, with possible winds of tropical storm force, yet unlikely to yield gusts of more than 100 km/h. Hazel was the product of exceptional conditions and is an appropriate approximation of a worst case scenario for systems of tropical origin.

Lightning

Historical lightning strike information was obtained from the Toronto and Trenton MSC sites' reporting of thunderstorm days over a 30 year period between 1971 and 2001. Toronto averaged 27.95 days per year and Trenton averaged 30.27 days per year. Estimates of cloud to ground flashes are obtained assuming 0.1-0.2 cloud to ground flashes per thunderstorm day per square km in accordance with IAEA Guide NS-G-3.4, "*Meteorological Events in Site Evaluation for Nuclear Power Plants*" [R-14]. This results in 2.8 to 5.6 cloud-to-ground flashes (per year per square km) for the Toronto area and 3.0 to 6.1 cloud-to-ground flashes (per year per square km) for the Trenton area.

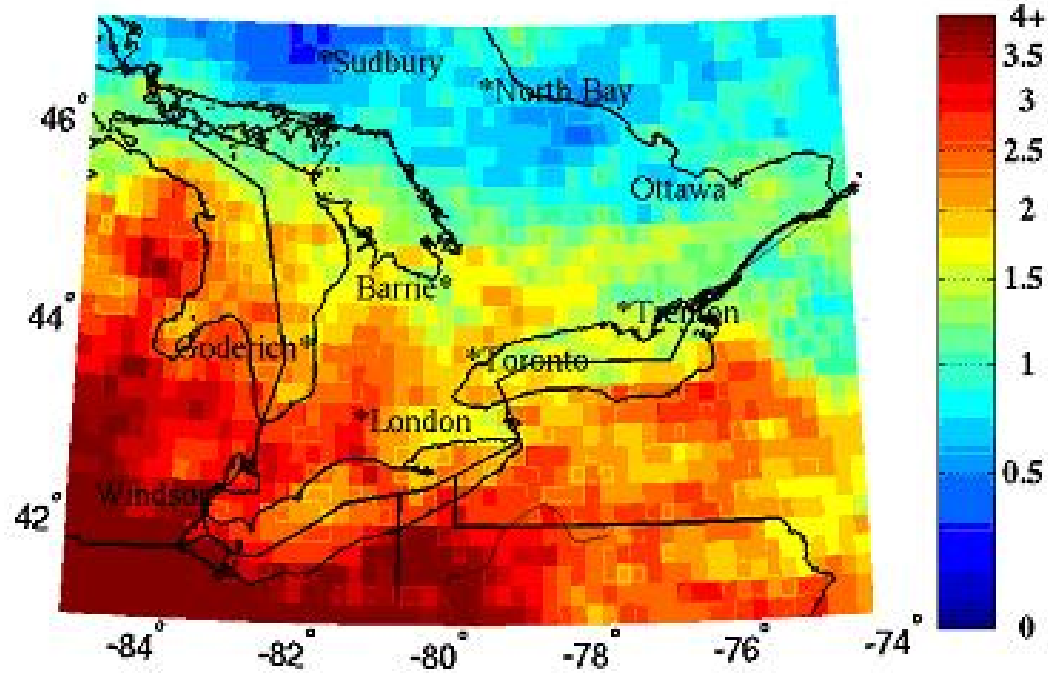

Figure 3-1 – Flash Density (number of flashes/km^2/year) Cloud-to-cloud and cloud-to-ground combined, 1996-2006

Referring to **Figure 3-1**, this seems to be a significant overestimation for Trenton especially considering the fact that the map considers cloud-to-cloud and cloud-to-ground densities combined. However, the DN site appears to be much closer to Toronto in terms of both distance and flash density. Also, considering cloud-to-cloud lightning is detected much less efficiently by the network than cloud-to-ground the lower end of the estimate for Toronto seems reasonable. Given available data, it is estimated that in the vicinity of the site there are 2 to 3 cloud to ground flashes per year per square km.

Freezing Rain

The worst freezing rain event in recorded history over Eastern Ontario is the ice storm of 1998. Over the course of 5 days in January, from 80 -100 mm of freezing rain affected areas from Kingston to Granby, QC.

Toronto Pearson Airport records on average 17.1 hours of freezing rain per year, 8.8 days per year while Trenton airport reports 21.9 hours of freezing rain per year and 11.4 days per year.

Freezing rain totals of 50-75 mm have been reported on a few occasions in Southern Ontario. Near 10 mm of freezing rain is to be expected occasionally. Up to 20 mm of freezing rain is very likely to occur over the time the site will be operational. Historically freezing rain events with more than 50 mm have been observed in the same broad climatological region but are not frequent, with maximal amounts near 100 mm.

3.3 Climate Change

Finally, a study of the potential effects of climate change was required. This section discusses the changes that have taken place in the climate of Southern Ontario over the past century, and what global climate models are projecting will take place over the next 50 to 100 years. This will establish what engineering requirements are needed at the DN site to withstand the impacts of a changing climate.

Extreme wind events that occur with convection such as tornadoes are likewise unable to be modeled by Global Climate Models (GCM). Even tropical cyclones are unlikely to be resolved by GCMs, as the inner core structure of hurricanes needs to be modeled at high resolutions.

Despite the limitations, there is much that can be inferred from GCM predictions of a warming world, as discussed in the *Evaluation of Meteorological Events* report [R-5]. For example, warm Sea-Surface Temperatures (SSTs) are a major driver in hurricanes. Warmer SSTs in a warmer world implies more fuel for hurricanes and therefore stronger or more numerous tropical systems.

A number of studies have examined historical changes in precipitation over Canada. Documenting these changes is difficult, as many observing stations were either unmanned or have unreliable precipitation measurements leading to inconsistent datasets. A study by Zhang et al. (2001) [R-27] found precipitation to have increased by 5-35% from 1900 to 1970, with very little increase after 1970. A report by Stone et al. [R-28] confirms the constant precipitation levels after 1970 while Mekis and Hogg [R-29] even postulate a decrease in heavy precipitation events over Southern Canada. Studies in the U.S. by Karl and Knight [R-30] as well as Knukel and Andsager [R-31] also found some increase in precipitation over the last century.

Over the next hundred years, models such as the Canadian Centre for Climate 2nd generation Global Circulation Model (CCC GCM2) predict almost no appreciable increase in precipitation over Southern Ontario as a result of increased concentrations of greenhouse gases. However some studies including that from Zwiers and Kharin [R-32] predict extreme precipitation events to rise by approximately 14%.

Mean temperatures over the past hundred years were found to have risen by 0.5°C to 1.5°C in a study by Zhang et al. (2000) [R-33]. This increase was found to be due to higher overnight temperatures rather than daytime temperatures. It is commonly accepted that global temperatures, including temperatures in Canada, increased faster than historical norms over the last fifty years.

The study by Zwiers and Kharin [R-32] used a model to study extreme values for maximum temperature in the next 20 years. They found that an increase of approximately 6°C to extreme maxima is possible over Southern Ontario. A more complete study by Environment Canada simulating increased CO_2 concentrations in the Second Generation Coupled Global Climate Model (CGCM2) found similar results. Winter temperatures in the vicinity of the DN site are predicted to rise by 2°C in 2040 and by as much as 5°C in 2100 over the base period of 1971-2000. Similar temperature changes are predicted to occur during the summer months.

Wind Speed

The literature consensus is that global average wind speed will decline due to global warming. Nevertheless, the frequency and intensity of strong wind events such as thunderstorms may very well increase due to the increased transport of moisture from the equator poleward predicted by global climate models. However, this would likely not affect the winter season.

3.4 Flooding Assessments

The flooding assessment was divided into different sections. The main assessments were coastal flooding, which includes flooding by storm surge, seiche and waves, and riverine flooding, which includes overland flooding. A combined flooding assessment was also performed. A description of these assessments is contained in the following sections. For further details relating to flood hazards, see the *Flood Hazard Assessment* report [R-6].

Modification of the flood hazard with time was assessed, which included consideration of:

- Geographical or physical changes to the site and land use;
- Changes to the shoreline and near shore lake bathymetry;
- Climate change for precipitation, air temperature, and wind;
- Future Lake Ontario water level controls.

The flood hazard potential was assessed as unlikely to change with time.

3.4.1 Coastal Flooding

The DN site is located on the north-western shore of Lake Ontario. The control of water levels reduces the range and occurrences of extreme lake levels.

The control of water levels by the International Joint Commission (IJC) will continue in the future and, though the plan for regulation may change, the fundamental function of eliminating extreme lake levels remains. This coastal flood hazard assessment carefully considered the results of the IJC study for management options which included robust modeling of potential future levels under a range of stochastically generated hydrological and meteorological conditions. Based on these results, and comparing with the historical record, the 100-year water level (level that has a 1% chance of being exceeded per year) is 75.6 m and the highest level that resulted from a 500-year water level (0.2% probability per year) is about 76.6 m.

Lake ice coverage and potential for piling and jamming was studied and it was determined that there is no expected flood risk due to these events.

3.4.2 Assessment of Flooding by Storm Surge and Seiche

A numerical model of the hydrodynamics of Lake Ontario was developed to assess the potential for generation of surge and seiche in response to extreme severe weather systems tracking through the region. The model was implemented on a bathymetric grid with 2.7 km resolution. The hydrodynamic model represents the depth-averaged currents and variations in water level that result from wind and atmospheric pressure forcing. Idealized atmospheric pressure and wind fields were applied to represent the main types of severe weather systems that can affect Lake Ontario including extratropical Storms (such as Hurricane Hazel in 1954), Alberta Clippers, Colorado Lows, and Gulf Lows.

The model was run for a large number of combinations of the parameters representing the characteristics of the idealized storms. Analysis of the results provided good insight on the response of Lake Ontario to various weather systems with different characteristics and allows determination of which storms, typical of the region, are the most likely to result in significant surge and possible subsequent seiche.

It was concluded that an extratropical storm, e.g., of Hurricane Hazel type, tracking over the western side of the Lake would build up a surge over the western end with elevated water levels in the Darlington area. Other types of storms tend to build up more modest surges at the western end of the Lake, but often result in a large surge at the eastern end which in turn causes a seiche and subsequently higher levels at the western end than the initial direct response. The highest modeled water level at the DN site resulting from surge or seiche was about 0.75 m. This level can be produced either directly as a surge by a storm of Hazel-type tracking from the south over the western end of the Lake, or indirectly after an Alberta Clipper from the west builds up a large surge at the eastern end of the Lake resulting in a seiche of large amplitude. This is somewhat conservative compared with Ontario Ministry of Natural Resources estimates of storm surge for nearby Cobourg (0.44 m for 100-year return period and 0.47 m for 200-year return period).

3.4.3 Assessment of Flooding by Waves

To describe the flooding potential from waves, a numerical model was used to propagate extreme wave conditions from offshore to the shoreline, followed by application of standard wave uprush and overtopping methods.

A Lake Ontario wind and wave hindcast developed for an IJC water level regulation study by the Wave Information Studies (WIS) of the U.S. Army Corps of Engineers was used to assess wave flooding potential at the DN site. A statistical analysis was performed to determine the estimated 100-year maximum wave heights, which were found to range from 4.5 m to 4.9 m from west to east offshore of the site. A peak wave of 4.7 m with a period of 9.7 s and wave direction from the southwest was selected as the extreme offshore possibility. This value was then input to wave propagation and overtopping prediction software.

The wave propagation model computed the wave field and other wave parameters over a specified range of geographical space, time, wave frequencies and directions. The model inputs included gridded bathymetry and topography, surge levels, and wind and wave hindcast.

Two shoreline armoured structure/revetment scenarios, from the site layout assessment, were considered: a 1V:2H[2] slope structure to be built on the existing shoreline with structure toe located at an estimated 1.2 m depth below the chart datum of 74.2 m (IGLD 1985), and a 1V:2H slope structure assumed to be built on a large infill area into Lake Ontario about 350 m from the existing shoreline with structure toe located at an estimated 4.7 m depth. Together with these two scenarios, two high water level references were considered in applying the results of the extreme wave hindcast analysis for nearshore wave propagation modeling: the 100-year 75.6 m and a ‘100-year plus probable maximum storm surge’ value of 76.35 m. Resultant wave height estimates ranged from 2 m to 2.2 m for the existing shoreline option to 3.5 m to 3.6 m for the infill option, with peak wave periods in both cases equal to 9.7 s.

Several methodologies were applied to predict wave uprush (vertical height at which water may flow up to) and wave overtopping on the NND shoreline structure from the nearshore wave estimates. Calculations were performed by varying the wave height and period, and the structure slope, depth, surface reduction factor, and lake bottom slope for two revetment structures and two high water level scenarios. The wave uprush estimates range from 3.5 m to 11.3 m, and wave overtopping estimates range from 0.015 m^3/s/m to 0.591 m^3/s/m.

The Great Lakes are a geologically stable region where the shorelines are not generally susceptible to shore slope failure or landslide. No tsunamis have been recorded in Lake Ontario thus a tsunami is considered an improbable event and there is no associated flood potential.

[2] Note that slope is defined as the ratio of change in vertical height to change in horizontal distance over a particular bathymetry or shoreline section. A slope of 1V:2H refers to 1 unit vertically to 2 units horizontally (e.g. a 200 m shoreline section that is 100 m higher at one end has a slope of 1V:2H).

A summary of these coastal assessments is presented in **Table 3-8**. The term "probable" in Probable Maximum Storm Surge, Probable Maximum Tsunami and Probable Maximum Seiche of **Table 3-8** refers to a probable theoretical maximum value (height or level) of the event and not to the actual likelihood of the event occurring.

Table 3-8 – Coastal Flood Hazards Assessment Summary

	Flood Potential	Options for Mitigation	Comments
Coastal Flooding			
Probable Maximum Storm Surge	Yes	Yes	An extratropical storm, e.g., of Hurricane Hazel type, tracking over the western side of the Lake builds up a surge over the western end, with elevated water levels in the Darlington area. Other types of storms tend to build up more modest surges at the western end of the Lake, but often result in a large surge at the eastern end which results in a seiche and subsequently higher levels at the western end than the initial direct response. Mitigation can be integrated as part of the design and planning effort.
Probable Maximum Tsunami	No		Tsunamis are rare in Canada. The Great Lakes are a geologically stable region where the shorelines are not generally susceptible to shore slope failure or landslide. No tsunamis have been recorded in Lake Ontario thus a tsunami is considered an improbable event and there is no associated flood hazard potential.
Probable Maximum Seiche	Yes	Yes	See Probable Maximum Storm Surge summary above.
Wind and Wave Effects	Yes	Yes	Wave analysis showed that due to the bathymetry nearshore at the site, the 100-year return offshore wave (4.7 m) breaks at some distance offshore from the proposed armoured structure. Any waves higher than this value would also break. Wave heights are therefore depth-limited and waves that may run up and overtop the structure are similarly reduced in height compared with waves offshore. This is true for both coastal scenarios (existing shoreline and infill) considered. Mitigation can be integrated as part of the design and planning effort.

3.4.4 Assessment of Riverine Flooding

A series of hydrologic models were developed to determine peak flows for key points along Darlington Creek, the site contributing watersheds and for the site specific drainage. Three representative site layouts with various differences in drainage systems and excavations were considered for these assessments. The Probable Maximum Precipitation (PMP) storm event was used as the extreme precipitation event for all hydrologic simulation. The PMP is a theoretical rainfall maximum. It represents the theoretical maximum amount of rainfall that can be produced based on meteorological and orographic parameters related to the area of interest and is not typically a statistical extrapolation of previous rainfall events.

The hydrologic models assumed a fully built-out condition for the Darlington Creek watershed and the site contribution watersheds. For all of the modeled conditions, a 100-year lake level was assumed.

The Probable Maximum Flood (PMF) was also used in this assessment. It is the flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in a particular drainage area and is usually the result of a PMP event.

Subsequent to the development of peak flows, a series of hydraulic models were developed to determine the peak staging associated with these design flows. For the Darlington Creek analysis two potential flooding conditions were assessed. The first was the potential for flood waters to rise and flood the site at the creek floodplain boundary with the proposed site. The second was to assess the potential for flood flows to stage upstream of an existing railroad culvert crossing to a sufficient elevation that a secondary flow path is found for the flood waters to bypass the constriction. It was found that there is no potential for site flooding due to peak flood stages along Darlington Creek for the PMF event as long as the site grading maintains the existing barrier between the proposed build site and the creek. A further model was developed that assumed that the culvert under the railroad was jammed with river ice and debris and that there was no flow through capacity for the culvert. This is also true for the case where the culvert under the railroad jams. Again, there is still no site flood hazard associated with this condition as the elevation necessary to introduce flood flows to the site is much greater than the peak flood stage.

For the site contributing watershed analysis, where these areas already flow through the existing site, the site could be subject to flood flows from these areas. This is known as overland flooding. There is also a flooding potential associated with site specific flooding when the PMP event occurs directly onsite.

A series of hydraulic models were developed to determine if a ditch/berm system could be designed within the realm of common engineering practice, to bypass these flows around the site. It was determined that all of the assessed flood scenarios could indeed be mitigated through some form of conventional engineering design.

After consultation with Central Lake Ontario Conservation Authority and review of aerial mapping and topographic data of the Darlington Creek watershed it was determined that there are no upstream water control structures within the Darlington Creek watershed or local site watersheds. Therefore, there are no flood hazards associated with the failure of man-made water retaining structures. A summary of these riverine assessments is presented in **Table 3-9**.

Table 3-9 – Riverine Flood Hazards Assessment Summary

	Flood Potential	**Options for Mitigation**	**Comments**
Riverine Flooding			
River Flooding PMF	No		There is no potential for site flooding due to peak flood stages along Darlington Creek for the PMF event if the site grading maintains the existing barrier between the proposed site and Darlington Creek.
River Flooding PMF with Debris Jamming	No		There is no potential for site flooding due to peak flood stages along Darlington Creek for the PMF event, with the culvert under the CNR crossing jammed, if the site grading maintains the existing barrier between proposed site and Darlington Creek.
Overland Flooding PMF	Yes	Yes	There is a flood hazard potential for overland flow to impact the proposed site, though the inclusion of a perimeter berm/ditch system can be designed to redirect flow from the site to the Lake.
Site Specific Flooding PMF	Yes	Yes	Mitigation can be integrated as part of the design and planning effort.

3.4.5 Assessment of Combined Flooding

A combined event analysis was conducted to assess the flood hazard potential from a number of concurrent extreme conditions. For the riverine assessment a combined event that included the 100-year storm, occurring on a fully frozen watershed with a 500-year lake level was assessed. It was determined that the flood flows and peak flood stages for this event were much less than those of the PMF event, which itself was not assessed to pose a hazard. Studies of other combinations regarding coastal flooding, such as 100-year lake levels and severe extratropical storms, did lead to some potential flooding scenarios, but none that could not be mitigated through design.

A summary of these combined assessments is presented in **Table 3-10** below.

Table 3-10 – Combined Flood Hazards Assessment Summary

	Flood Potential	Options for Mitigation	Comments
Combined Events Flooding			
Frozen ground (i.e., 100% impervious) 100-year design rainfall 500-year Lake Ontario water level	No		The flood flows and peak flood stages associated with this event were less than those generated by the PMF event. There is no potential for site flooding due to the PMF, given the conditions as shown above, therefore, the same is true for this combined event.
100-year still lake water level with waves of a height equal to the highest wave sustainable at the foot of the armoured infill. No storm surge or seiche added.	Yes	Yes	Mitigation can be integrated as part of the design and planning effort.
100-year still lake water level with waves of a height equal to the highest wave sustainable at the foot of the armoured infill; plus the maximum storm surge / seiche generated by extremely severe post tropical Hazel type storm and an Alberta Clipper.	Yes	Yes	Mitigation can be integrated as part of the design and planning effort.

3.5 Adequacy of Water Supply and Biofouling

The presence of Lake Ontario provides the DN site with a large source of water for condenser cooling and station service water. A study was performed to ensure that any intake structure drawing water from the lake bottom would not be affected by lake level variations. The control of lake levels by the IJC as discussed in Section 3.4.1 facilitates this study in that minimum lake level values can be accurately predicted. As well as a study of lake levels, the effects of seiches, waves and wave backrush were considered and were all determined to not affect the availability of the lake water to an underwater intake structure.

A variety of sources of organisms or organic material that could contribute to biofouling associated with cooling water and service water supply systems originate from the pathway represented by Lake Ontario. As well, the possibility of impact on possible intake structures by the formation of frazil ice was studied. The analysis of water supply conditions, including adequacy of water supply, biofouling and frazil ice are addressed in OPG Report, *"Site Evaluation of the OPG New Nuclear at Darlington - Additional Considerations"* [R-12].

<u>Algae</u>

The Lake Ontario shoreline in the vicinity of the DN site provides a suitable growth environment for *Cladophora* which is a common nuisance algae species.

During mid-summer and fall, *Cladophora* changes state and becomes detached from the substrate and drift in a suspended manner with waves and currents. The loose filaments as well as more substantial clumps of algae have the potential to be entrained at cooling water and service water supply system intakes, resulting in blockage or restriction issues at the inlet as well as further blockage and organic material loading at internal system screens.

Mitigation can be provided by intake designs with screening and filtering capabilities, and structures to minimize intake of water with high algae accumulations.

Other Microorganisms

Biofilms develop on virtually all surfaces immersed in natural aqueous environments, irrespective of whether the surface is biological (aquatic plants and animals) or abiological (stones, particles, metal, and concrete, etc.). Biofilms form particularly rapidly in flowing systems where a regular nutrient supply is provided to the microorganisms.

Thin biological coatings or biofilms associated with microorganisms can reduce the efficiency of heat exchangers and cause microbiologically induced corrosion.

Biofouling control typically involves proper biomonitoring and application of appropriate biocides/antimicrobials specific to the circuits and sensitivity of the system components. The control of the biofilms is a standard operational procedure at facilities supplied by water from Lake Ontario, and accordingly this form of biofouling is considered manageable using available technology.

Macroscopic Plants

Aquatic plants can contribute to floating and suspended plant material that becomes susceptible to entrainment at water intakes. A variety of rooted aquatic plants are common to Lake Ontario.

In addition to contacting screening systems, this plant material can promote colonization facilities with suitable forebay areas.

The design of the intake at depth and the present system of racks and screening applied at DNGS has been effective in accommodating this source of biofouling and similar design features can be incorporated into the detailed design for the NND.

Mollusks

Lake Ontario contains confirmed populations of non-native invasive nuisance mussels including the zebra mussel, *Dreissena polymorpha*, and the quagga mussel, *Dreissena rostriformis bugensis.*

These major biofouling organisms can clog water intake structures, such as pipes and screens and can affect equipment and systems. The establishment and growth of the mussels within water supply/service systems or cooling water systems without mitigative intervention could ultimately restrict or block water flow.

Various anti-fouling strategies are available to address mussel colonization and include mechanical/manual removal by scraping / pressure washing; coatings to inhibit ability to colonize; and oxidizing biocides such as sodium hypochlorite (bleach). Of the systems currently applied at DNGS, mitigation measures have maintained efficient operation of the facility and similar design features can be incorporated into the detailed design for the NND.

Fish

Lake Ontario hosts a diverse local and seasonal population of both warm and coldwater fish species. During impingement investigations at DNGS operations from 1993 to 1995, fish encountered at the mitigation screen system and in sumps included at least 17 species.

Various life stages of fish can be taken into a cooling water system with the cooling water (entrainment), and consequently fish reach screens that protect the cooling water and other water systems (impingement). An excessive load of fish can cause blockage to the screening system and sumps contributing to maintenance requirements.

The intake of the existing DNGS was designed to minimise entrainment of fish through such intake design features as placement of the structure at depth and low intake water velocities typically below the average swimming speed of most fishes, and small intake slot size. Based on effectiveness of this mitigation design during the period through operation, a similar installation would be anticipated to suitably minimize entrainment for the NND.

Frazil Ice

Frazil ice forms in turbulent, supercooled water (water temperatures of -0.01°C to -0.05°C). To generate this environment, hydro-meteorological conditions must be such that there is sufficient heat loss from the water to cause water temperature to decrease to the freezing point. The physical parameters relevant to the formation of frazil ice include water temperature, air temperature, wind speed and humidity.

In lakes, blockages of intakes are associated with open water, low temperatures and clear nights. They are often also associated with strong winds, which increase the rate of heat loss at the water surface and may provide the turbulence that can mix the supercooled water to the depth of the intake. The intake flow can also entrain the supercooled water if it is of sufficient velocity. The depth at which a lake intake will be free from frazil ice impacts is also dependant on other factors, such as lake bottom topography and intake structure dimensions.

Although frazil ice is a potential phenomenon at the DN site, a range of design measures can be implemented for the NND to mitigate potential risk of water intake blockage as has been demonstrated by DNGS and other nuclear power plants on the shores of Lake Ontario.

3.6 Assessment of Seismic Hazards

This section of the report addresses the site seismic parameters and other seismically-induced phenomena related to the site for NND. Assessments have been completed to verify that seismic-related issues at the site for NND have been adequately addressed. Information regarding the analysis of the earthquake ground shaking hazard and other seismic details related to NND are contained in the *Probabilistic Seismic Hazard Assessment* report [R-8].

3.6.1 Data Collection and Investigations

Seismotectonic data on prehistoric, historic, and instrumentally-recorded seismic activity were collected for the region of study. A comprehensive database has been assembled consisting of geological, geophysical, seismological, and geotechnical information relevant to evaluating the ground motion, faulting, and geological properties of the site for NND. Information has been assembled at the regional, near-regional, site vicinity, and site area scales. The site area investigations define the geotechnical data necessary for design of plant foundations, shore protection, structures, and equipment, as well as identification of faults and fault displacements. Near-shore investigation of lakebed is included in the site area investigations. Regional, near-regional, and site investigations are progressively more detailed closer to the site.

The “region” is defined by a nominal 150 km radius around the site per the IAEA Guide NS-G-3.3 [R-16], extended as necessary to include geological structures relevant to seismic characteristics at the site for NND. The seismotectonic properties including evidence of fault movement, amount and nature of displacement, and rates of activity are quantified. Site vicinity studies cover a geographical area of approximately 5 km in radius, and define in greater detail the recent history of faults, especially the potential for surface faulting at the site, and identify conditions of potential geological instability.

The geological, geophysical, and seismological data for the region, near region, and site vicinity of the site for NND is provided by the *Probabilistic Seismic Hazard Assessment* report [R-8]. The approach adopted was to utilize an earlier 1997 study as the starting point, update the database assembled for that study, evaluate the effects of recent regulatory guidelines, and incorporate changes and research findings. The most recent earthquake catalogues were obtained from the Geological Survey of Canada (GSC) and the United States Geological Survey (USGS). These two catalogues were consolidated into a single catalogue for the region covering the time period of 1600 through to 2007.

The regional seismic source zones based on regional geology have been updated. The regional seismic source zones are:

- Iapetan Rifted Margin Source Zone
- Ottawa Graben Source Zone
- Saguenay Graben Source Zone
- St. Lawrence Rift Extension
- Extended Continental Crust Source Zone
- Great Meteor Hotspot Source Zone
- Northern Appalachians Source Zone
- Southern/Northern Grenville Source Zones
- Central Craton Source Zone
- Lineament/Seismicity Composite Zones
- Seismicity-Based Source Zones

Local seismic sources are defined as sources that extend to within a 100 km radius of the site for NND. The local seismic sources assessed include:

- Toronto-Hamilton Seismic Zone
- Niagara-Pickering Linear Zone
- Wilson-Port Hope Magnetic Lineament
- Clarenden-Linden Fault System
- Georgian Bay Linear Zone
- Hamilton-Presqu'ile Fault
- Rouge River Valley Features
- Darlington Fracture Zone

The site for NND lies within the western Lake Ontario region in the tectonically stable interior of the North American continent, which is characterized by low rates of historical seismicity. The region is underlain by middle Proterozoic (greater than 610 million years ago) Grenville basement rock and overlying lower Paleozoic (greater than 290 million years ago) shallow-water sedimentary strata.

3.6.2 Additional Data Collection Outstanding

Preliminary information and existing available geotechnical parameters were gathered and reviewed. During the design phase of the NND, detailed site geotechnical evaluations will be performed to provide definitive dynamic properties of site rock and soil. These additional investigations will include:

- Shear wave velocity: Laboratory tests were conducted to assess the static and dynamic properties of the limestone structures at the DN site as part of a separate investigation as reported in 1979. **Table 3-11** shows the shear wave velocity values determined from a deep borehole (UN-1) in the area for NND. The shear wave velocity values determined in the laboratory tests were consistent with values measured in the Southern Ontario region using shear-wave refraction methodology as reported in 1997. In-situ measurements were not conducted at this stage of the site evaluation but will be completed as part of the detailed design phase for the new nuclear plant.

Table 3-11 – Shear Wave Velocity (Borehole UN-1)

Formation	Approximate Depth (m)	Shear-Wave Velocity (m/s)
Whitby	0 – 2	1,500 (assumed)
Lindsay	2 – 63	2,184
Verulam	63 – 138	1,825
Bobcaygeon	138-157	3,604
Gull River	157 – 184	2,692
Shadow Lake	184 – 192	1,586
Precambrian	> 192	3,007

- Paleoseismology: Identification of potentially liquefiable material has not been completed at this stage of the site evaluation. No known seismically-induced liquefaction features have been previously identified. Fieldwork to confirm existence or non-existence of liquefaction potential will be completed as part of the detailed design phase for the new nuclear plant.

- Seismotectonics and Seismogenic Potential: Deep seismic structure studies using post-1997 data have not been completed at this stage of the site evaluation. These studies can reduce the overall uncertainty in the seismic hazard assessment, and will be completed as part of the detailed design phase for the new nuclear plant.

The above parameters were evaluated to the extent permissible based on currently available data. The overall assessment of seismic hazards was performed in a comprehensive manner, and the conclusions were not affected by these parameters. Further evaluations during detailed design phase will be undertaken to confirm these conclusions.

3.6.3 Seismicity Parameter Characterization and Ground Motion Modeling

The maximum magnitude of earthquakes was assessed using statistical and empirical approaches, and the frequency of occurrence of earthquakes associated with a source was computed from the earthquake catalogue statistics for the source. The assessment of earthquake occurrence rates was based on the observed rate of earthquakes. In order to avoid double counting of earthquakes in the assessments of regional and local sources, the events assigned to the local sources were removed from the catalogue used for calculating the seismicity parameters for the regional sources.

Ground motion models were used to provide estimates of the effects of earthquakes occurring from the seismic sources characterized. Four recently-developed ground motion models were used, and they provide an improved characterization of both the expected ground motions produced by an earthquake and the modeling uncertainty. These models compared well in terms of attenuation of peak ground acceleration (pga) and the predicted response spectra for earthquakes.

The ground motion models provide estimates of peak and spectral acceleration on the surface of generic hard rock consisting of materials with shear wave velocities in excess of 2,700 m/s. The geology of the site for NND consists of approximately 190 m of sedimentary rocks overlying hard basement rocks. The characterization of the dynamic properties of these materials was based on laboratory tests performed on core samples extracted from a deep borehole (UN-1) on site. The effect of this sequence of sedimentary rocks on site ground motions was assessed using site response analysis methods that are recommended for the seismic analysis of nuclear facilities.

3.6.4 Probabilistic Seismic Hazard Analysis (PSHA)

A PSHA has been performed as part of the seismic assessment [R-8] in support of the site evaluation. The standard PSHA calculation procedure considers all earthquakes with intensity above a specified minimum value to be able to generate ground motions that are potentially damaging to well-engineered structures. Typically, the minimum size has been set at magnitude 5. Recently, the Electric Power Research Institute (EPRI) has developed a PSHA methodology that directly addresses the potential for an earthquake of any size to produce damaging ground motions. The parameter used to measure damage potential is the Cumulative Absolute Velocity (CAV) of an acceleration time history produced by an earthquake. The value of CAV measures the overall energy content of the acceleration time history and a value of 0.16 g-seconds is the industry agreed-upon threshold value that an acceleration time history must exceed to be potentially damaging. The EPRI CAV model was employed in the PSHA conducted for the site for NND.

The annual exceedance frequency for ground motion suggested by various guidance and regulations range from 10^{-2} to 10^{-4}. The 10^{-4} value for the site Uniform Hazard Response Spectra (UHRS) has been selected (corresponding to a return period of 10,000 years) as the appropriate level for comparison with the design response spectra for the new nuclear reactor designs under consideration for Ontario.

3.6.5 Seismic Assessment Results

The updated seismic source characterization and ground motion modeling were used to assess the seismic properties of the site for NND. Analysis of the results indicated that both regional and local seismic sources are important contributors to the seismic properties. The ground shaking hazard at the site for NND has been quantified by a PSHA. This PSHA updated a 1997 assessment and included the findings of recent research. These PSHA results were marginally higher than the 1997 DN site PSHA results. The increase in hazard was attributed primarily to higher estimates of earthquake occurrence frequencies based on the updated catalog. Comparisons of the ground motion models used in this study with those used in the 1997 study indicated that they produce similar estimates of ground shaking levels. The use of the EPRI CAV model led to a small reduction in the computed potential seismic hazard.

The UHRS were developed for the annual frequency of 10^{-4} as discussed in the previous section. UHRS were developed for rock outcropping motions at the anticipated level of the foundation of a future nuclear power plant. These UHRS indicate the pga to be less than the 0.3 g spectra as used in the seismic design response of the available vendor designs under consideration for Ontario. Certified seismic design response spectra are based on strong ground motion coincident with the 1 to 10 Hz frequency range of primary interest for nuclear power plant structures and equipment. At high spectral frequencies (above approximately 25 Hz), the mean UHRS were determined to be higher than the vendor presented values of design response spectra (**Figure 3-2**). (The mean UHRS [solid] curve remains below the AP1000 [dotted] curve, the EPR/EUR [dashed] curve, and the ACR-1000 [dashed-dotted] curve except when spectral frequency reaches the range of approximately 25 Hz to 60 Hz). This is a common observation for very stiff sites such as the site for NND, and high spectral frequency exceedance of design response spectra will be mitigated by industry standard engineering design of plant structures and equipment as part of detailed design. As an illustrative example, available literature from Westinghouse and AECL indicated that evaluations have been performed for their standard plant designs using response spectra more representative of very stiff sites. The hard rock site response spectra used by Westinghouse and AECL for these evaluations envelop the NND mean 10^{-4} UHRS (**Figure 3-3**). It is expected that a similar evaluation can be performed for the EPR design to mitigate against the issue of high spectral frequency exceedance of design response spectra.

No seismicity-related issues were identified that would render the site for NND unsuitable for construction of new nuclear facilities.

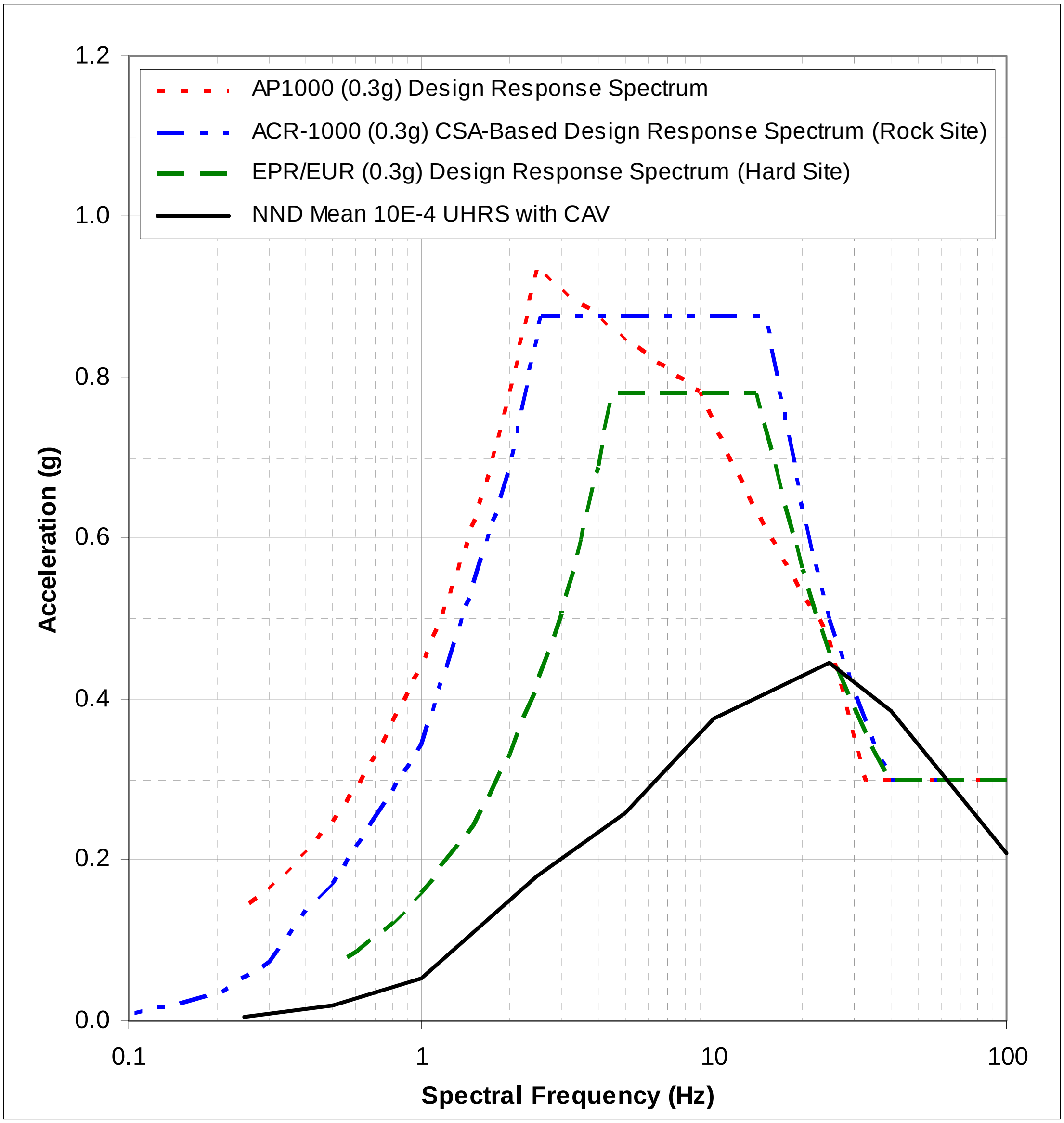

Figure 3-2 – Comparison of Mean 10^{-4} UHRS for NND Site with Vendor Seismic Design Response Spectra

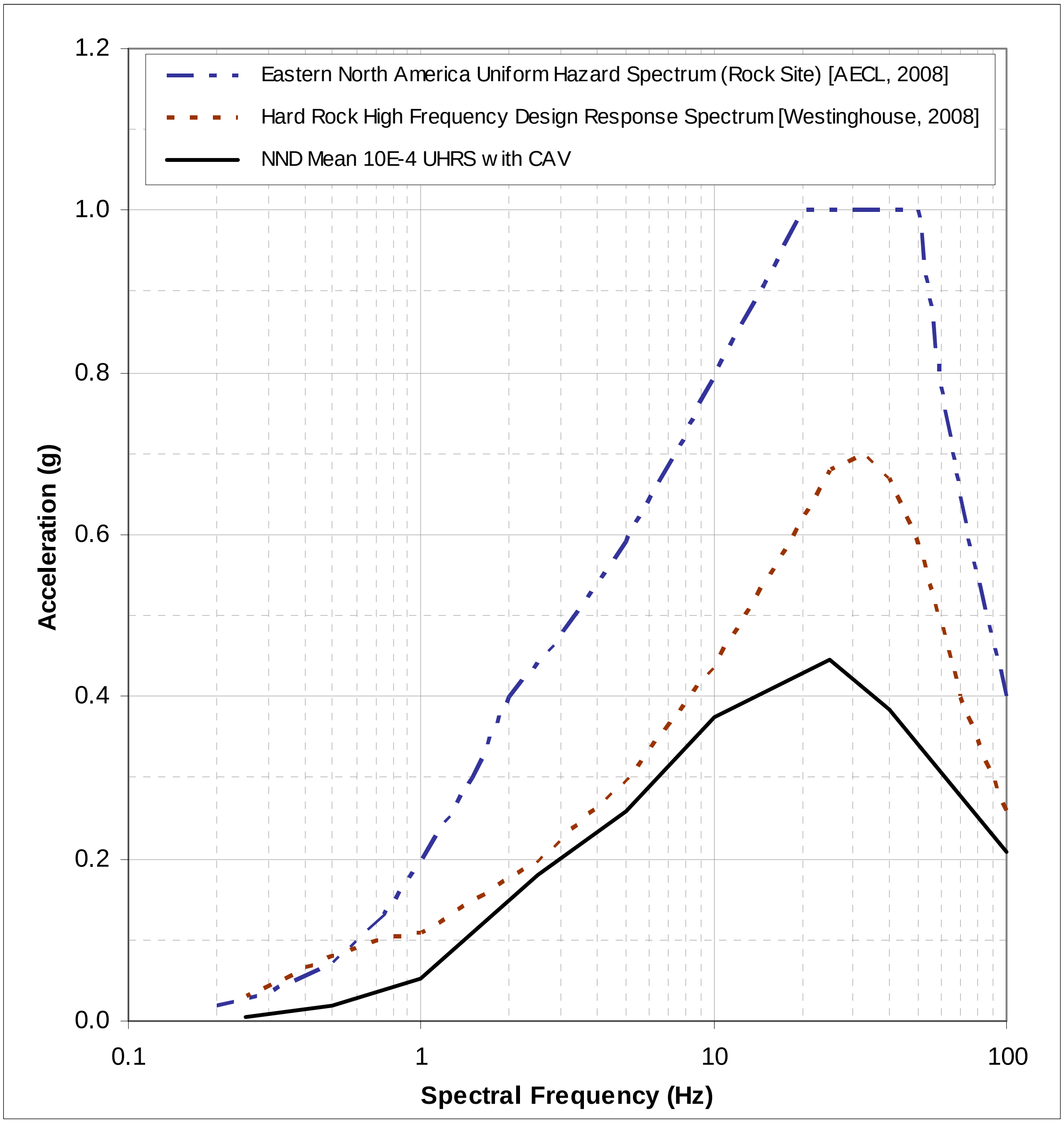

Figure 3-3 – Comparison of Mean 10^{-4} UHRS for NND Site with Spectra Used by Westinghouse and AECL to Assess Plant Response to High Frequency Motions

3.7 Foundation Assessment – Extreme Conditions

The following extreme conditions associated with foundations were analyzed.

- Site seismic hazard,
- Flood from surface water, and
- High waves from Lake Ontario.

Based on the preliminary assessment of the foundations for reactors and other structures under the anticipated extreme conditions, the foundations can be expected to be designed and constructed to withstand the impact of the extreme conditions considered. The foundations for the reactors, mechanical cooling towers and associated structures should be founded on sound bedrock and competent native soils. As such, the soils and the bedrock present at the site for NND together with the planned foundations are expected to be capable of withstanding the impact from the extreme conditions considered.

3.8 Earth Structures Assessment – Extreme Conditions

The extreme conditions considered in the previous section were also analyzed for the following main earth structures as part of the evaluation:

- Natural slopes in the vicinity of the site for NND that will not be altered,
- Cut slopes that will be constructed for the site,
- Fill slopes that will be constructed for the site,
- Dykes that will be constructed along the new shoreline for land reclamation (lake filling), if implemented,
- Retaining walls and/or earth-retaining structures that will be constructed around the reactor foundations,
- Embedded structures,
- Buried pipes and conduits that will be required for services for the site.

From the assessment of the earth structures under extreme conditions, the earth structures should be founded on the competent soils and bedrock present at the site. These structures can be expected to be designed and constructed to withstand the anticipated impacts of the extreme conditions. Required ground improvements to provide suitable foundations for the planned earth structures under extreme conditions are expected to be achieved using conventional construction methods for nuclear power plants.

3.9 Potential for Surface Faulting

The potential for surface faulting is evaluated at the site, site vicinity, and regional levels. Surface faulting at the site has the potential to cause ground motion effects and affect plant structures and buried services. At the site vicinity and regional levels, surface faulting is accounted for in the definition of seismic sources. At the site level, borehole and mapping investigations performed in support of the construction of the DNGS were analyzed.

Interpreting the geological conditions beneath the site for NND is facilitated by available geological information collected at the site during construction of DNGS and exposed soil and bedrock at the St. Marys Cement Plant quarry.

The onshore and offshore boreholes and mapping of the DN excavations did not indicate offsets in the stratigraphic units, shear zones, or deep depressions in the bedrock surface. Hence, no near-surface faulting has occurred in the bedrock at the DN site.

The stratigraphic continuity of the upper Paleozoic bedrock in the site vicinity conformed to the regional dip of approximately 5 m per km to the south. Minor changes in thickness and position of marker units were evident, but the differences were well within the limits of variation expected for sedimentary rock formations in Southern Ontario. No vertical dislocation or displacement was evident in the upper Paleozoic bedrock formations, indicating that faulting has not propagated through the sedimentary rock strata from the basement rock.

Mapping of marker units in the DNGS intake and discharge tunnels that extend over 1 km south of the DNGS site showed continuity consistent with the regional dip. Jointing in the rock was tight and showed no water ingress. The in-situ stress conditions in the bedrock at the DNGS site are also consistent with the stress conditions measures at other locations in the general area in Southern Ontario.

Therefore, it is concluded that the DN site and site vicinity has no evidence of surface faulting in the overburden or bedrock.

3.10 Potential for Volcanism

A methodology for initial investigation of volcanism described in the *Flood Hazard Assessment* report [R-6] suggested evaluating within a 150 km radius of the site.

Although no volcanoes in Canada are active at present, at least three exhibited activities in the last few hundred years and numerous others have the potential to erupt in the near future. The map of “Volcanoes in Canada” available at the Geological Survey of Canada website identifies only British Columbia as having volcanoes of note. The Atlas of Canada indicates that the only active volcanoes in Canada are the Canadian Cordillera (British Columbia and the Yukon Territories). The U.S. Geological Survey Circular 1073 did not indicate any active volcanoes in New York State. Hence, it is concluded that there has been no evidence of recent historic activity within 150 km of the site.

The methodology also stated that if there has been no evidence of Cenozoic era (within the last 65 million years) volcanic rocks or volcanism in the region, then no further investigations are required. Geological maps from Natural Resources Canada did not identify Cenozoic era formations within 150 km of the site for NND. Hence, seismic activity as a result of volcanism has been ruled out as a potential contributor to seismic hazard at the site for NND.

3.11 Conclusions

The PPE [R-4] was developed with inputs from reactor vendor designs in order to create a bounding “envelope” that accounts for the parameters of the three reactor technologies under consideration. Some of these parameters can be compared to the assessments performed in this section.

Meteorology

Meteorological data from the DN site, supplemented by MSC data for the surrounding region, provided sufficient information to evaluate the baseline meteorological conditions in the area as well as to conduct the extreme value analyses for the DN site and locations nearby.

The maximum allowable basic wind speed quoted by the PPE is 232 km/h. With a maximum historical wind gust in the area measured at 154 km/h, wind is not expected to be an issue at this site. As well, an expected and calculated 15 minute average sustained wind speed at a 50 m extreme value of 80 km/h was determined for the DN site. In the case of a tornado, the PPE sets the design basis limit at 368 km/h for maximum wind speed. This corresponds to a tornado of F-level 4, and no F-level 5 tornadoes have been recorded within 180 km of the site from 1974 - 2003. Climate change studies predict a decline in average wind speeds and a possible increase in the frequency and intensity of strong wind events.

The temperature extremes that are not expected to be surpassed in the next 100 years are -31.2°C and 40.9°C. Mitigation will likely be provided by the plant’s heating, ventilation and air conditioning system. Climate change studies show that extreme values may be slightly warmer, but a small rise in average temperature values is the more likely result.

Precipitation levels are bounded by the PPE at 30 mm per 15 minutes, 100 mm per hour and 400 mm per day. From the extreme value analysis, the highest rainfall level is expected to be less than 100 mm per day, which is well within the PPE limits. With little change expected from global warming, even the levels of rain received during the transition of Hurricane Hazel at just over 200 mm in 48 hours do not require special mitigation.

Other meteorological values and phenomena such as snow pack, humidity, atmospheric pressure, lightning and freezing rain show no indications of extreme conditions requiring design mitigation.

Flooding

The results of the flooding study provide information supporting the conclusion that there are no flooding effects so serious that will discount this site from being able to safely support a nuclear power plant.

The flood hazard assessment has indicated that the only two general mechanisms with potential for flooding impacts are associated with extreme coastal processes and direct precipitation on the site. The overall conclusion from this assessment is that the identified potential flood hazards can all be mitigated through conventional engineering means and construction methods.

Adequacy of Water Supply and Biofouling

It was determined to be feasible to place a water intake facility at such a depth as to ensure that Lake Ontario water level variations would not interrupt the supply of water. In addition, by implementing the mitigation measures that have been successfully applied at power generating facilities along the north shore of Lake Ontario, biofouling and frazil ice formation at the site are considered manageable over the lifecycle of the proposed facility. The results of the evaluation confirm reliability and availability of the lake water supply for the NND. Given this water availability, as well as year-round precipitation, droughts at the DN site were not assessed.

Geotechnical Aspects and Seismicity

Based on the results of assessing the soil/rock conditions present at the site for NND and the planned structures, the site can be classified as a “rock and stiff soil site”. The foundations for the reactors can be founded on the sound bedrock located at approximately 64 masl (14 m below the planned ground surface). The perimeter walls of the buildings housing the reactors should be surrounded by compacted engineered fill and competent till deposits. As such, the reactor foundations and the power block structures can be expected to be stable against normal and extreme conditions. Foundations for other structures and earth structures supporting the site can be expected to be stable against normal and extreme conditions provided they are founded on competent soils and/or bedrock.

The ground shaking hazard at the site for NND has been quantified by a PSHA. This PSHA updated a 1997 assessment and included the findings of recent research. These PSHA results were marginally higher than the 1997 DN site PSHA results. The increase in hazard was attributed primarily to higher estimates of earthquake occurrence frequencies based on the updated catalog. Comparisons of the ground motion models used in this study with those used in the 1997 study indicated that they produce similar estimates of ground shaking levels.

Based on an annual frequency of 10^{-4}, the UHRS developed indicate that the pga of the site to be less than the 0.3 g spectra as used in the seismic design response of the available vendor designs. At high spectral frequencies (between approximately 25 and 65 Hz), however, it was noted that the response spectrum for the site exceeded the vendor presented 0.3 g design response spectra. This is a common observation for very stiff sites such as the site for NND, and industry standard engineering design of plant structures and equipment will be incorporated as part of detailed design to mitigate against the observed exceedance of design response spectra at high spectral frequency. Westinghouse and AECL have performed evaluations of their standard plant designs using response spectra more typical for very stiff sites and have reported acceptable plant performance. It is expected that a similar evaluation can be performed for the EPR design to mitigate against the issue of high spectral frequency exceedance of design response spectra.

The DN site and site vicinity shows no evidence of surface faulting in the overburden or bedrock. Seismic activity as a result of volcanism has been ruled out as a potential contributor to seismic hazard at the site. No seismicity-related issues were identified that would render the site for NND unsuitable for construction of new nuclear facilities.

4.0 ASSESSMENT OF POTENTIAL EXTERNAL HUMAN-INDUCED EVENTS

To confirm the suitability of the DN site for the proposed plant, it must be demonstrated that the risk of external human-induced events that have the potential to jeopardize the safety of the proposed plant at the site is either negligible or can otherwise be mitigated.

Potential sources of external human-induced events applicable to the DN site were identified and the severity of the associated hazard phenomena were evaluated. For the events that pose non-negligible incremental risk to the proposed plant, requirements for mitigation through engineering solutions were identified.

The assessment of external human-induced events for NND is documented in detail in a separate confidential report, which will be provided to the CNSC. In order to address security concerns and confidentiality agreements that prevent the release of specific data used in the assessment, the detailed report is classified as confidential. The results of the assessment have been summarized in a proprietary technical report, NK054-REP-01210-00010, "*Summary Report: Site Evaluation for Nuclear Installations at Darlington Site: Evaluation of External Human Induced Events*" [R-10].

4.1 Methodology

The approach used in this assessment to screen and evaluate the identified external human-induced events was based on the methodology described in IAEA Guide NS-G-3.1 [R-18].

4.1.1 Screening

The potential sources of external human-induced events were screened according to distance from the proposed location of the new NPP, and then the associated events were screened according to probability of occurrence.

A Screening Distance Value (SDV) was defined for each hazard to represent the distance beyond which the hazard source would be considered too far away to have impact on the proposed plant. Only the external human-induced events whose sources were located within the SDV were considered further.

The events whose sources were located within the SDV were then screened according to event probability. The Screening Probability Level (SPL) is defined as the annual probability of occurrence of an event and is typically expressed as a frequency. The SPL value chosen for this assessment is 1 x 10^{-8} occurrences per year. The basis for this number is that no single event should contribute greater than 1% of the RD-337, "*Design of New Nuclear Plants*" [R-34] Large Release Frequency (LRF) target. An overall event frequency (F_{HES}) was conservatively estimated for each potential hazard associated with an external human-induced event. Only the external human-induced events that were estimated to occur more frequently than the SPL were evaluated further.

4.1.2 Detailed Evaluation

The extent of the potential risk to nuclear safety was then evaluated for the events that passed through the screening described in Section 4.1.1.

For each event assessed in the detailed evaluation, the likelihood that the event would lead to a radiological release was estimated and assigned as the Conditional Probability Value (CPV). Without detailed reactor design information available at the time of the evaluation, the CPVs were conservatively estimated based on the use of quantitative descriptors from OPG station risk assessments and guidance provided by the IAEA Guide NS-G-3.1 [R-18].

The annual probability of an event escalating to a radiological release could therefore be estimated as the product of the event frequency, F_{HES}, and the CPV. F_{HES} was then compared to the Design Basis Probability Value (DBPV) – a limiting design frequency defined as the ratio of the SPL to the CPV as shown below:

$$F_{HES} \times CPV > SPL$$

$$F_{HES} > \frac{SPL}{CPV} = DBPV \rightarrow$$ Event requires hazard mitigation, control or prevention via design basis of plant[3]

Any event in which F_{HES} was estimated to be less than the DBPV was considered to pose negligible incremental risk to the proposed plant. Any event for which F_{HES} was found to exceed the DBPV was identified to require mitigation, control, or prevention.[4]

[3] Note that events may be considered and analyzed as beyond design basis events based on calculated probability values per RD-337 [R-34] requirements.

[4] To account for uncertainties in the estimation of event frequency and to address any possible future increase in risk, events for which F_{HES} exceeded 30-percent of the DBPV were also considered for mitigation, control, or prevention.

4.2 Identification of External Human-induced Events

In order to perform a comprehensive assessment, both stationary and mobile potential sources were considered. Based on the guidance provided by RD-346 [R-3] and NS-G-3.1 [R-18], the following types of external human-induced events were identified for consideration in this assessment:

- Aircraft crashes,
- Ship accidents,
- Detonation explosions,
- Release of hazardous fluids,
- Fires,
- Radiological releases from DNGS,
- Electromagnetic interference, and
- Blasting at the St. Marys Cement Plant quarry.

Hazards associated with the following were not considered in this assessment:

- Malevolent, willful actions: RD-346 [R-3] refers to the evaluation of non-malevolent events only.
- Future connections to the grid: Consideration of future connections to the grid is the responsibility of the Ontario Power Authority.

4.3 Aircraft Crash Events

Aircraft crashes that are of concern for the site can arise due to in-flight reliability failures involving aircraft en-route, whose flight path intersects the vicinity of the site, or from aircraft movements at airports near the site.

Based on data available on aircraft movement statistics in Canada, the following aircraft categories were considered in the estimation of the aircraft crash risk:

- Light aircraft,
- Small transport aircraft,
- Large transport aircraft,
- Helicopters, and
- Military combat and jet trainers.

Information on the distance between the site and nearby airports, and the types and frequency of aircraft movements was collected and considered in defining an appropriate SDV.

Additionally, specific consideration was given to the following types of events that are known to contribute to the overall aircraft crash risk:

- Background crash – occurs at the site deriving from general air traffic in the region
- Airfield crash – occurs at the site deriving from a takeoff or landing operation at a nearby airport
- Airway crash – occurs at the site due to air traffic in the main civil and military air traffic corridors.

Because there are no designated air traffic corridors in Canada, the concept of an SDV was applicable only to airfield crash events. Using a conservative SDV, airports in the near vicinity of the site including the proposed future Pickering airport, expected to be in operation by the year 2032, were considered in this evaluation.

The annual probabilities of aircraft crashes having impact on the proposed plant were estimated for the current year, for the first year of operation of the proposed Pickering airport, and for the year of the expected end of life of the proposed plant. The detailed evaluation determined that the current and projected risk of aircraft crashes would require mitigation and specific consideration in the proposed plant design.

4.4 Ship Accidents

The annual probability of a ship accident affecting the intake or discharge channels and impairing water flow (as a result of mechanical damage to the structures or blockage via the spillage of loads or waterborne debris) was estimated. Based on the results of screening by probability, the risk of ship accidents was assessed further. However, the detailed evaluation determined that the likelihood of a ship accident leading to a radiological release would be very low, and therefore, the risk of ship accidents would not require mitigation.

4.5 Detonation Explosions

There are two different forms of explosions: detonations and deflagrations. Detonations, which are discussed in this section, generate higher near field pressures than deflagrations. Deflagrations, which include Vapour Cloud Explosions (VCEs) and Boiling Liquid Evaporating Vapour Explosions (BLEVEs), are addressed in Section 4.6.2.

For all assessments involving explosion hazards, a conservative approach based on the engineering relationship between Trinitrotoluene (TNT) equivalent mass and distance was used to estimate the SDV in accordance with the IAEA Guide NS-G-3.1 [R-18].

The annual probability of a detonation significant enough to reach the site was estimated for the current situation and for the year of the expected end of life of the proposed plant. The results of the evaluation indicated that, due to the frequency of occurrence, detonation explosions do not require mitigation. However, mitigation should be considered as a conservative measure to account for a possible future increase in risk.

4.6 Release of Hazardous Fluids

This section covers the risks associated with the following:

- Toxic gas clouds from the release of toxic gases,
- Deflagrations (explosions) from the release of Liquefied Petroleum Gases and Transportation of Dangerous Goods (TDG) Class 2.1 flammable pressure liquefied gases,
- Explosions from the release of flammable fluids in confined areas, and
- Fires from the release of flammable fluids.

RD-346 [R-3] also identifies the inclusion of substances such as radioactive fluids and asphyxiants in the assessment. The risk of radioactive releases is specifically addressed in Section 4.8. The risk of asphyxiants was not evaluated because asphyxiants are conventional hazards, which present only localized effects. The concentration of asphyxiants required to reach harmful levels is 3-4 orders of magnitude greater than that of toxic gases. By the time an asphyxiant reaches the OPG NND air intake on the station roof for any release scenario, it will be diluted to safe levels. Therefore, asphyxiants were deemed to have no impact on nuclear safety.

To identify all possible sources of hazardous fluids, transport routes, industrial plants, and pipelines located in the vicinity of the site were considered in this assessment.

4.6.1 Toxic Gas Clouds

In non-fire scenarios, toxic fluids which can become airborne, disperse toward the plant, and infiltrate the plant through ventilation intakes pose a toxicity hazard to plant personnel including main control room operators. These fluids are referred to as “cold” toxic gases.

Additionally, some fluids which are flammable, combustible, or which decompose under intense heat, can generate toxic combustion products. Such flammable fluids containing chlorine, nitrogen, or sulphur yield combustion/decomposition products, which are highly toxic. These fluids are referred to as “hot” toxic gases.

Toxic gas clouds reaching the main control room at high enough concentrations could impair an individual’s abilities to take protective action. The annual probability of such an occurrence was estimated for the current situation and for the year of the expected end of life of the proposed plant. The results of the detailed evaluation indicated that the risk of toxic gas clouds to the site would require mitigation and specific consideration in the design basis of the proposed plant.

4.6.2 Deflagration Explosions

Flammable fluids such as propane that have high vapour pressures and are transported in bulk as Liquefied Petroleum Gases can produce two types of deflagratory explosions:

- VCE:

  With VCEs, the ignition of the vapour cloud is delayed until after the cloud has begun to disperse and become mixed with air. Blast waves due to VCEs can damage buildings and equipment.

- BLEVE:

  Blast waves arising from BLEVEs can be accompanied by missiles and fireballs. Because the magnitude of the hazard of a BLEVE blast wave alone is bounded by that associated with a VCE blast wave, only hazards associated with the BLEVE missile and the BLEVE fireball were evaluated further.

Although the risk of BLEVE missiles are discussed here, the risk of BLEVE fireballs is discussed in Section 4.6.4.

The VCE hazard is associated with Liquefied Petroleum Gases, which readily become airborne and disperse downwind. Because a blast wave only results from a VCE when there is sufficient turbulence created by nearby buildings or structures to accelerate the flame velocity of the cloud, it was conservatively assumed that such structures would be present in the final design of the site for the purposes of this assessment. The detailed evaluation determined that VCE blast waves posed negligible incremental risk to the plant, and therefore, would not require mitigation.

The most prominent example of a BLEVE missile hazard is that caused by the failure and then rocketing of a tank containing Liquefied Petroleum Gas (e.g., propane, butane, etc.). When traveling at high velocity, a BLEVE missile can damage outdoor equipment and indoor equipment if the missile were to fall onto the powerhouse roof. For BLEVEs, the frequency is estimated to exceed the DBPV due to projected increase in traffic over the life of the plant.

The overpressure effects on the building must be mitigated. Mitigation may require the use of an appropriate physical barrier or physical separation of important safety equipment / systems. Mitigation requirements for this hazard may be considered in more detail during the detailed design phase of the project.

4.6.3 Confined Explosions

Confined explosions (deflagrations), can occur by way of ignition of a flammable airborne mixture in a building or in the vapour space of a storage tank containing a flammable fluid such as diesel fuel or fuel oil. The blast waves that result from confined explosions are localized.

The results of screening by distance identified that confined explosions pose negligible incremental risk to the site as there are no substantial, external sources located close enough to the site.

4.6.4 Fires (Release of Flammable Fluids)

Flammable or combustible fluids can produce fires and thereby generate thermal radiation that can impact personnel and equipment.

The types of thermal radiation hazards of concern are:

- Pool fire (e.g., over an oil storage tank dike),
- Jet fire from a natural gas pipeline failure, and
- BLEVE with accompanying fireball (e.g., from liquefied petroleum gas).

With the exception of the BLEVE fireball, thermal radiation effects are localized and do not carry over large distances. In the case of the new nuclear plant, these impacts concern only the outdoor equipment (e.g., fire in fuel oil storage tank dike). Hydrocarbon fires were also considered in this assessment, for which the concern is not with respect to thermal radiation but with the generation of carbon monoxide that is toxic at high concentrations.

The assessment determined that fires from the release of flammable fluids pose negligible incremental risk to the site because there are no substantial sources located close enough to the proposed NPP.

4.7 Forest Fires

A forest fire, like a hydrocarbon fire, will produce soot, carbon dioxide and carbon monoxide. The primary concern is with respect to carbon monoxide, as it is toxic, but only at high concentrations. A total woodland area of 23 hectares is located within 1 km north of the site. As with any other forested area in the province, it is susceptible to forest fire.

This assessment determined that the risk of forest fires at the site would not require mitigation because the consequences of the carbon monoxide hazard posed to the main control room operating staff were assessed to be insignificant. Although the impact has been determined to be negligible, manual activation of the toxic gas mitigation system will also safeguard against this hazard.

4.8 Radiological Releases from Nuclear Events at DNGS

Potential radiological hazards in the region that could affect the safe operation of the nuclear plant were evaluated.

Nuclear events at the DNGS considered in this assessment were as follows:

- Tritium Removal Facility accidents leading to a release of tritium,
- In-plant fire near a storage area of active liquid waste,
- Used fuel accident,
- Design basis reactor accidents, and
- Beyond design basis reactor accidents which include severe accidents that have the potential for a significant offsite release.

These events do not pose a concern to equipment but have the potential to impact the operating staff and in particular, main control room operators of the proposed plant.

Regulatory dose limits at the site boundary apply to all the nuclear events listed above with the exception of Beyond Design Basis Accidents. Therefore, only Beyond Design Basis Accidents were considered further in this assessment.

An upper bound frequency for the occurrence of a Beyond Design Basis Accident from the four-unit DNGS was estimated by using the OPG large off-site release limit [R-36] as the surrogate annual probability per unit for all significant radiological releases attributable to Beyond Design Basis Accidents and by applying conservative assumptions on wind direction toward the new NPP. A detailed evaluation determined that nuclear events including Beyond Design Basis Accidents at DNGS posed negligible incremental risk to the proposed plant, and therefore, would not require additional mitigation.

4.9 Electromagnetic Interference

Electromagnetic interference can affect the functionality of electronic instrumentation and control equipment and can be initiated by both on-site sources such as high voltage switchgear and off-site sources such as telephone networks.

External sources of electromagnetic interference including high-voltage transmission lines at DNGS and telecommunications towers were identified for consideration in the assessment.

Because the effects from the electromagnetic interference sources are continuously present, the risk of electromagnetic interference at the site must be addressed in the design basis of the proposed plant.

4.10 Blasting at the St. Marys Cement Plant Quarry

There are two effects to be considered in relation to blasting at the St. Marys Cement Plant quarry. One effect is the blast wave associated with the detonation. This was assessed and deemed not to require mitigation.

The second effect concerns the seismic impact of the quarry operation. As indicated in the *Evaluation of Geotechnical Aspects* report [R-9], the effects of blasting have been monitored by Natural Resources Canada at two monitoring stations located at the east and west sides of the DN site. In a one year period the highest peak ground velocity recorded was 1.57 mm/sec [R-7]. This is in the range between “noticeable to persons” and “troublesome to persons”, but is much less than the “damage to walls” threshold level. The seismic effects of St. Marys’ blasting occurring nearer to the DN site should be accounted for in the plant design.

4.11 Conclusions

Of the external human-induced events evaluated, the following events were identified to warrant mitigation through consideration in the design basis of the proposed plant:

- Aircraft crashes,
- Release of hazardous fluids (specifically toxic gases),
- BLEVE missiles
- Overpressure caused by deflagration explosions
- Electromagnetic interference, and
- Blasting at the St. Marys Cement Plant quarry.

Additionally, as a conservative measure, mitigation of the risk of explosions such as detonations originating from mobile sources should be considered to account for a possible future increase in risk.

The assessment concluded that engineering solutions can be implemented for the proposed plant to mitigate the risks associated with the external, human-induced events identified above. All other events considered were determined to pose negligible incremental risk to the new NPP. It was determined that the emergency response to these events could be effectively handled by execution of the site emergency plans. This information supports the conclusion that there are no external, human-induced events that would prevent the site from hosting the proposed plant.

5.0 EVALUATION AGAINST SAFETY GOALS

The reactor designs that are under consideration for the proposed site were evaluated against applicable safety goals, taking into account the characteristics of the site, and the impact of potential radiological releases from the NPP on effective dose to members of the public and emergency planning.

5.1 Applicable Safety Goals

The acceptability of the radiological consequences of discharges during normal operation and potential accidental releases of radioactive materials from the proposed nuclear plant is determined by demonstrating compliance with applicable safety goals.

With respect to radiological releases under normal plant operations, the proposed plant must adhere to the *Radiation Protection Regulations* (SOR/2000-203) [R-35] enabled by the *Nuclear Safety and Control Act* which specify an effective dose limit of 1 mSv per year for persons who are not nuclear energy workers.

For radiological releases resulting from Beyond Design Basis Accidents, the following quantitative safety goals are defined in RD-337 [R-34]:

> *Small Release Frequency (SRF)*
> *The sum of frequencies of all event sequences that can lead to a release to the environment of more than 10^{15} becquerel of iodine-131 is less than 10^{-5} per reactor year. A greater release may require temporary evacuation of the local population.*
>
> *Large Release Frequency (LRF)*
> *The sum of frequencies of all event sequences that can lead to a release to the environment of more than 10^{14} becquerel of cesium-137 is less than 10^{-6} per reactor year. A greater release may require long term relocation of the local population.*

Only preliminary safety analyses were available for the plant designs at the time of this assessment. Therefore, the evaluation against the RD-337 [R-34] safety goals was limited to an assessment to demonstrate that the reactor designs under consideration meet the intent of the RD-337 [R-34] safety goals with respect to the impact of protective measures (e.g., temporary evacuation, long term relocation) on the local population. The feasibility of implementation of these emergency measures at the proposed site was also evaluated.

5.2 Dispersion Modeling

Because the atmosphere and the hydrosphere are the major exposure pathways by which radioactive materials released from a nuclear power plant could be dispersed in the environment and transported to locations where they may reach the public, radioactive releases to both air and water were evaluated in this assessment. Detailed information pertaining to dispersion modeling, dose consequences and impact on emergency planning can be found in the *Dispersion of Radioactive Materials in Air and Water* report [R-11].

Sufficient baseline data for the following site-specific characteristics have been gathered to support dispersion modeling:

- meteorological variables (for dispersion in air),
- surface water and groundwater hydrology (for dispersion in water),
- population distribution in the region, and
- use of land and water in the region.

These site-specific characteristics are discussed in Section 2.0.

5.2.1 Dispersion of Radioactive Materials for Normal Operations

In addition to the site-specific characteristics listed previously, the following information was used to determine the dose consequences of airborne and waterborne emissions from normal operations:

- source term for the discharge of radioactive material to the environment,
- human exposure pathways,
- identification of potential critical groups, and
- physical characteristics governing the transport and diffusion of radioactive materials.

<u>Radiological Source Terms</u>

For each of the plant designs, the source terms associated with the estimated maximum airborne and waterborne emissions under normal operations are provided in the PPE [R-4]. These were used to calculate the bounding doses for normal operation [R-11].

<u>Human Exposure Pathways</u>

For the assessment of the dispersion of radioactive materials for normal operations, the generalized environmental pathway model from CSA N288.1 "*Guidelines for Calculating Derived Release Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities*" [R-37] was used. This model, as shown in **Figure 5-1** [R-11], covers all potential exposure and release scenarios including atmospheric and aquatic pathways.

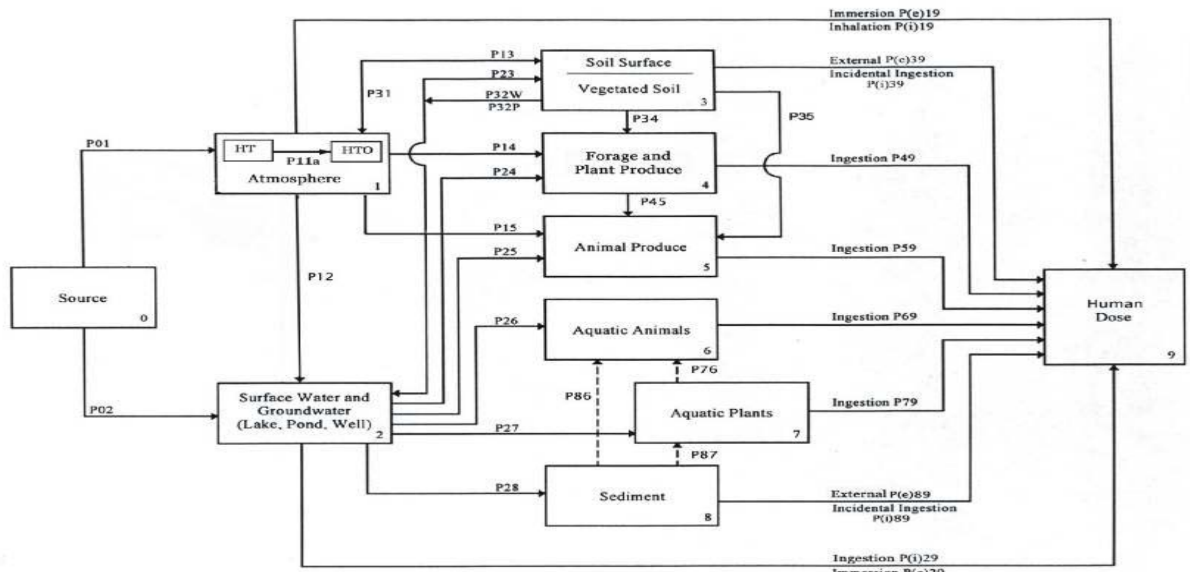

Figure 5-1 – Environmental Transfer Model

This pathway model is representative of the 'box type' model described in the IAEA Guide NS-G-3.2 [R-19], in which the atmosphere and bodies of water, or sections thereof, are modeled as homogeneous compartments. In this model, average concentrations are computed for each compartment and transfer constants are defined to relate the variables for one compartment to those in adjacent compartments.

This model was programmed in a code known as Integrated Model for Probabilistic Assessment of Contaminant Transport (IMPACT) which allows the user to assess the transport and fate of contaminants through a user-specified environment. The most recent version of the IMPACT code (version 5.2.2) was used for this assessment. This code embodies CSA N288.1 [R-37] to reflect updates in scientific developments related to the understanding of environmental transport models and human dosimetry.

Identification of Potential Critical Groups

Doses received by individual members of the public as a result of a given radionuclide release will vary depending on factors such as proximity to the release, dietary and behavioural habits, age and metabolism, and variations in the environment. The critical group represents members of the public who, by virtue of location, characteristics or habits, may receive the highest dose for a particular age class or radionuclide group.

As shown in **Table 5-1**, eleven potential critical groups were identified for the purposes of this assessment. The representative locations of these potential critical groups are identified in **Figure 5-2** [R-11].

Table 5-1 – Summary of Potential Critical Groups

Potential critical group	Type of Resident	Wind sector (direction to)	Distance from NND site (km)
Farm	Permanent	WNW	2.8
Dairy farm	Permanent	N	2.3
Rural residents	Permanent	NE	1.8
West East Beach residents	Permanent	ENE	2.2
Bowmanville residents	Permanent	NE	3.1
Oshawa residents	Permanent	WNW	7.3
New resident	Permanent	NNW	3.0
Industrial (St. Marys Cement)	Temporary	NE	0.8
New industrial	Temporary	NW	3.6
Fisher[5]	Temporary	E	1.1
Camper	Temporary	W	5.2

[5] For this assessment, the representative location for the "Fisher" potential critical group was amended from that used in the Darlington Radiological Environmental Monitoring Program [R-23] to an area, which is close to the NND site.

For the purposes of completeness in this assessment, the two potential critical groups identified as "New resident" and "New industrial" in **Table 5-1** were added to the nine previously defined critical groups used in the Darlington Radiological Environmental Monitoring Program [R-23]. The new groups were introduced to represent the future locations of urban residents and industrial sites that would be closest to the new NPP according to "*Growing Durham Study, Scenario Evaluation and Recommended Preferred Growth Scenario Working Paper and Addendum*" [R-38].

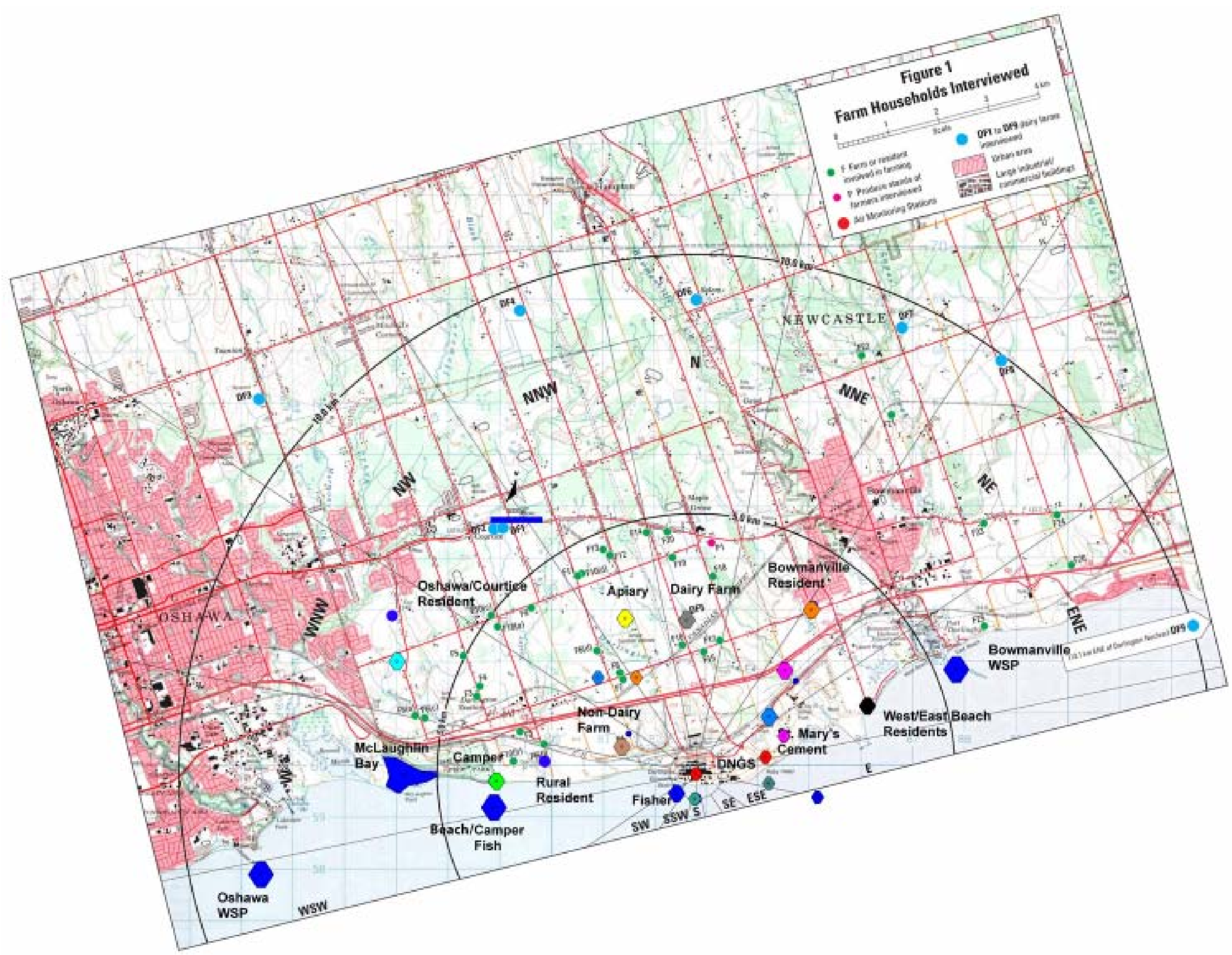

Figure 5-2 – Locations of Potential Critical Groups

The present population consists of both permanent and temporary residents. The permanent population is represented by the Farm and Resident groups, which are assumed to reside at their representative locations for 100-percent of the time. The short-term transient population is represented by the Fisher and Camper groups and the long-term transient population is represented by Industrial groups. Members of the Fisher, Industrial, and Camper groups are assumed to reside at their locations for 1, 23, 50 percent of the time respectively.

The following assumptions regarding the dietary habits of the population were applied to this assessment [R-11]:

- The fraction of local food intake is as determined by the DN site specific survey [R-26].
- No local grain products are consumed by humans.
- Local cow's milk is ingested only by dairy farm residents.
- Drinking water is consumed from local sources as determined by the DN site specific survey [R-26].
- Darlington Provincial Park was the location for beach recreational activities for all potential critical groups except for the Industrial and Fisher groups.

In order to account for the different habits, intake rates, and dose coefficients attributable to different age classes, each of the potential critical groups were refined into three age classes as follows:

- One year old infant,
- Ten year old child, and
- Adult.

Additional details of the characteristics of the potential critical groups, including local water and food usage and food and water intake rate, are provided in the *Dispersion of Radioactive Materials in Air and Water* report [R-11] and the Radiological Environmental Monitoring Program [R-23].

<u>Characteristics Governing Transport / Diffusion</u>

For airborne emissions, all the plant designs considered for the proposed site will have provisions for monitoring and filtration of the gases, vapour, and airborne particulate generated during normal operations before release to the environment via a common exhaust stack. The release point elevation, release temperature, volumetric flow rate of release, and building height (to the top of the tallest power block structure) for each plant design were obtained directly from the PPE [R-4].

For waterborne emissions, all the plant designs considered for the proposed site will have provisions for the collection and treatment of liquid effluents prior to discharge to the lake. Additionally, there is no direct discharge of liquid radioactive materials to groundwater. For this assessment, the effluent discharge rates to the lake were obtained directly from the PPE [R-4] and the water plume parameters such as effluent recirculation factors and plume velocities were estimated.

A conservatively high ambient air temperature of 20°C, which is the highest daily mean temperature recorded at the DN site, was assumed.

5.2.2 Dispersion of Radioactive Materials for Accidental Releases

Radiological Source Terms

In the absence of detailed accident source term information for each of the plant designs, an assessment [R-11] was performed to evaluate scenarios corresponding to the RD-337 [R-34] safety goal release thresholds to assess the potential impact of such release in terms of radiation dose to the public. These are not design basis cases and are intended to be indicative only, to show that the intent of RD-337 [R-34] with respect to the impact of protective measures on the public can be met. Two RD-337 [R-34] Safety Goal Based (SGB) releases to the environment were developed as approximations of severe accident releases that would require the implementation of either short-term or long-term emergency response measures – one release representing the “SGB Small Release” and the other representing the “SGB Large Release”.

To establish the radionuclide mix for the full release, a representative core radionuclide inventory was selected from the reactor technologies based on considerations for reactor core size, fuel burnup rate, and fuel enrichment. Release fractions for a severe accident release category were obtained from the available safety analyses for the reactor technologies. These release fractions provided the basis for development of the source terms for the SGB releases. For the “SGB Small Release”, these release fractions were normalized to yield a release of 10^{15} Becquerel (Bq) of Iodine-131 to the environment. For the “SGB Large Release”, these release fractions were normalized to yield a release of 10^{14} Bq of Caesium-137 to the environment.

It must be noted that these “stylized” SGB releases do not represent real accident events applicable to any of the plant designs being considered as not all reactor-specific design elements, which would allow for mitigation of such releases, were credited in this assessment.

For NND, it is assumed that surface water runoff from the NPP buildings will be collected in storm water management ponds and then discharged to an existing drainage course or Lake Ontario. Furthermore, accidental releases to groundwater would be mitigated through standard engineering practices for detecting and containing leaks to meet requirements. Therefore, direct accidental releases to water would only be expected to result from accidental airborne releases and the associated fallout to Lake Ontario. By accounting for the dose consequences from the ingestion of both food and water, the assessment of the SGB atmospheric releases inherently addresses the dose consequences of both accidental airborne and waterborne releases.

Human Exposure Pathways

For this assessment, the exposure pathways were assumed to be cloudshine, groundshine, inhalation, and resuspension inhalation. The long-term exposure pathways also included ingestion of contaminated food or drinking water.

Characteristics Governing Transport / Diffusion

Each SGB release was conservatively represented as a cold ground-level release and modeled as a continuous plume released into the environment over 3 days (72 hours). The radionuclides were assumed to be retained within containment for a period of 24 hours before any releases to the environment.

To account for building wake effects, the nearest building downstream of the release was assumed to be the existing DNGS-A. Regarding surface roughness, the immediate surrounding area was assumed to be low density residential land and farmland.

5.3 Dose Consequences

5.3.1 Results for Normal Operations

For each of the reactor designs, doses resulting from the estimated maximum airborne and waterborne emissions were calculated for each age class within the eleven potential critical groups described in Section 5.2.1.

For each plant design, two cooling options (once-through cooling, and cooling tower) were considered.

Once-through cooling option

From all the reactor designs, the maximum calculated total dose due to airborne and waterborne emissions was approximately 5 μSv per year which is well below the *Radiation Protection Regulations* (SOR/2000-203) [R-35] limit of 1 mSv per year. As shown in **Table 5-2**, the bounding dose is attributed to the “Dairy Farm” critical group and is primarily due to airborne emissions.

Cooling tower option

From all the reactor designs, the maximum calculated total dose due to airborne and waterborne emissions was approximately 5 μSv per year which is well below the *Radiation Protection Regulations* (SOR/2000-203) [R-35] limit of 1 mSv per year. As shown in **Table 5-2**, the bounding dose is attributed to the “Dairy Farm” critical group and is primarily due to airborne emissions.

Table 5-2 – Summary of Maximum Doses for Releases During Normal Operations

	Maximum Total Dose (μSv/y)	Dose Contribution by Pathway (μSv/y)		Receptor	
				Critical Group	Age Class
Once-through cooling	4.90	Airborne	4.90	Dairy Farm	1-yr old infant
		Waterborne	3.48E-04		
Cooling tower	4.90	Airborne	4.90	Dairy Farm	1-yr old infant
		Waterborne	3.11E-03		

It should be noted that the bounding doses from this assessment were not attributed to the two new potential critical groups (“New resident”, “New industrial”) that were introduced for completeness in this assessment.

The sensitivity of the results to changes to the following factors was assessed:

- Ambient air temperature,
- Lake current flow rate,
- Location of critical groups.

An increase in air temperature (up to 25°C) and an increase in lake current flow rate (by a factor of 2) each resulted in slight increases to the projected annual doses. However, the doses remained well below the *Radiation Protection Regulations* (SOR/2000-203) [R-35] limit of 1 mSv per year.

To address potential changes in critical group locations, hypothetical groups were introduced at a location closest to the point of emission beyond the St. Marys Cement plant and along the predominant wind direction. Using conservative assumptions, it was demonstrated that even with these hypothetical groups, the individual doses to the public due to normal operations of the proposed plant would be well below the *Radiation Protection Regulations* (SOR/2000-203) [R-35] limit of 1 mSv per year.

5.3.2 Results for SGB Releases

For the “SGB Small Release” and “SGB Large Release”, the dose to a member of the most critical group was determined as a function of distance over different time periods.

Specific time periods were defined to distinguish between the initial days of the release (Early Phase) and the subsequent long-term period (Late Phase) following the release. The doses acquired during the Early Phase and the Late Phase are typically used to determine the short-term emergency response and the long-term emergency planning respectively. These time periods are illustrated in relation to the progression of the SGB release in **Figure 5-3**.

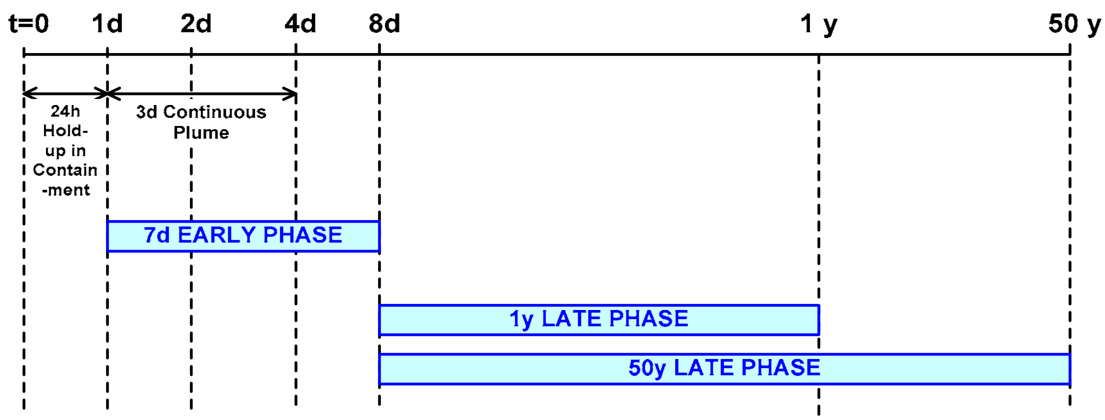

Figure 5-3 – Timeframes for SGB Releases

RD-337 [R-34] identifies that a release to the environment of more than 10^{15} Bq of Iodine-131 (i.e., "Small Release") may require temporary evacuation of the local population. Therefore, for the "SGB Small Release", the assessment was focused on the projected dose for the Early Phase and the short-term emergency response. The results are shown in **Figure 5-4** and **Figure 5-5**.

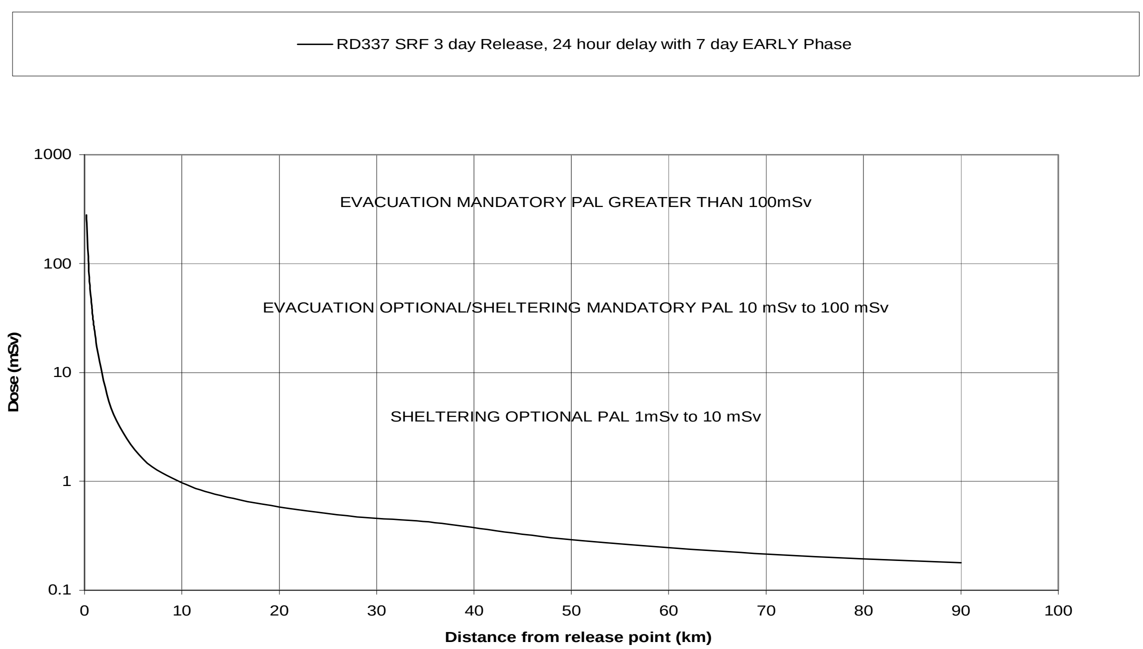

Figure 5-4 – "SGB Small Release": Variation of Committed Effective Dose with Distance for the SGB SRF Release – 7 Day EARLY Phase

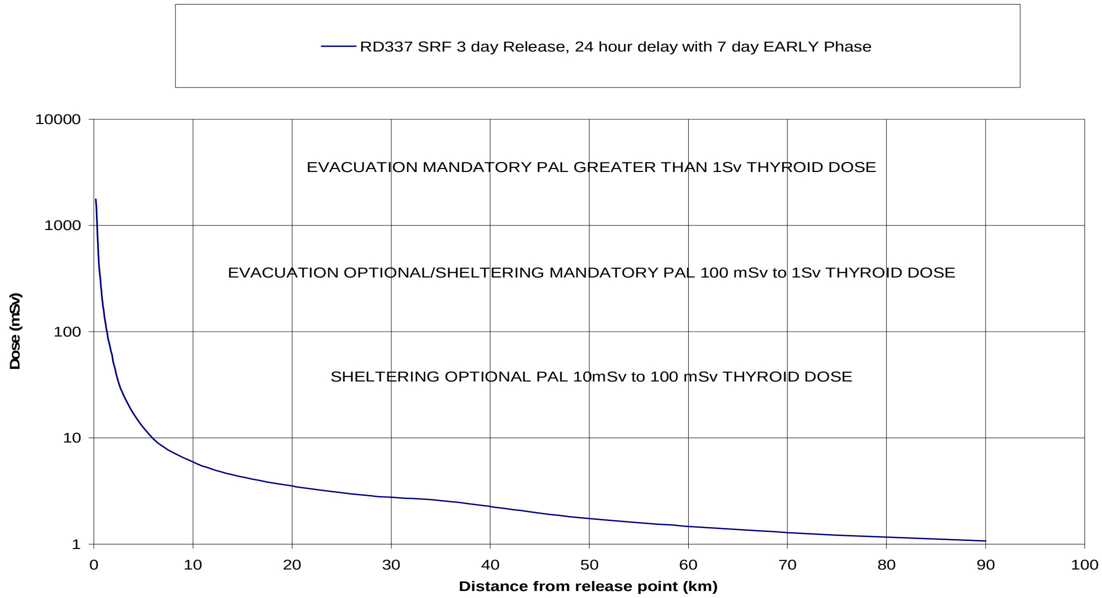

Figure 5-5 – "SGB Small Release": Dose to Thyroid with Distance for the SGB SRF Release – 7 Day EARLY Phase

The 1999 Provincial Nuclear Emergency Plan (PNEP) [R-39] specifies overall principles, policies, basic concepts, organizational structures and responsibilities. It has been revised and is now called the Provincial Nuclear Emergency Response Plan (PNERP) [R-40]. The PNERP [R-40] received Cabinet approval at the end of January 2009 and was issued by an Order of Council on February 11, 2009. OPG is working with the province on implementation of the PNERP [R-40]. The information used in the present report is not affected by the revision. The 1999 PNEP [R-39] provides Protective Action Levels (PALs), expressed in terms of projected radiation doses, that serve as aids in planning and decision-making during an emergency. When the projected radiation doses for the "SGB Small Release" are assessed against the PALs, the results indicate that exposure control measures including temporary evacuation of the local population would be required within the vicinity of the new NPP. The impacts to emergency planning are discussed further in Section 5.4.

The population density in the immediate proximity to the DN site is currently low which supports the unimpeded implementation of the current PNERP [R-40]. Available population growth projections also support the unimpeded implementation of the PNERP [R-40]. The assessment is provided in NK054-REP-03490-00001 "*Emergency Preparedness Site Evaluation for OPG New Nuclear at Darlington*" [R-41].

RD-337 [R-34] identifies that a release to the environment of more than 10^{14} Bq of Caesium-137 (i.e., a Large Release) may require long-term relocation of the local population. Therefore, for the "SGB Large Release", the assessment was focused on the projected dose for the Late Phase and the long-term emergency planning requirements. The results are shown in **Figure 5-6** below.

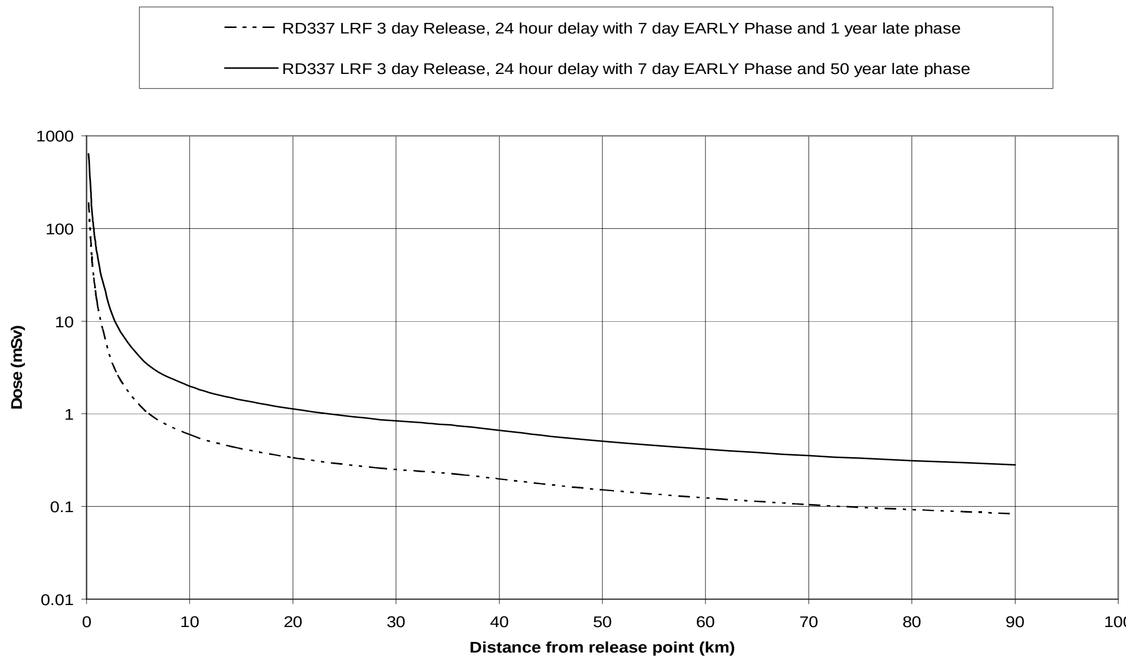

Figure 5-6 – "SGB Large Release": Variation of Committed Effective Dose with Distance for the SGB LRF Release – LATE Phase

The 1999 PNEP [R-39] specifies that evacuees should be permitted to return to the evacuated areas when the projected dose from external exposure and inhalation over the next year is assessed to be under 20 mSv. Therefore, if the estimated dose accumulated over a year were to exceed 20 mSv, then long-term relocation should be considered. When the projected doses for the "SGB Large Release" are assessed against this dose intervention level of 20 mSv per year, the results indicate that long-term relocation of the local population would be required within the vicinity of the proposed plant. The impacts to emergency planning are discussed further in Section 5.4.

5.4 Impact on Emergency Planning

The area around the boundary of a nuclear station for which a nuclear emergency plan is made is divided into zones. The zones closest to the station are areas in which detailed planning and preparedness is carried out for measures against exposure to radioactive emissions. First priority for provincially directed actions is assigned to the Contiguous Zone (area within a 3 km radius of the station) and second priority is assigned to the Primary Zone (area within a 10 km radius of the station).

For the “SGB Small Release”, the areas in which exposure control measures would potentially be required in accordance with the PALs is shown in **Table 5-3**.

Table 5-3 – Exposure Control Measures for the “SGB Small Release”

	1999 PNEP [R-39] PAL		Radius of Affected Area from New NPP
Sheltering	Whole-body dose	1-10 mSv	Within 10 km
	Thyroid dose	10-100 mSv	
Evacuation	Whole-body dose	10-100 mSv	Within 2 km
	Thyroid dose	100-1000 mSv	

For the “SGB Large Release”, the area in which relocation of the local population would potentially be required in accordance with the 1999 PNEP [R-39] dose intervention level for the return of evacuees is shown in **Table 5-4**.

Table 5-4 – Relocation for the “SGB Large Release”

	1999 PNEP [R-39] Dose Intervention Level		Radius of Affected Area from New NPP
Relocation	Whole-body dose	20 mSv / year	Within 1 km

The results indicate that temporary evacuation of the local population in the vicinity of the plant may be required in the case of the “SGB Small Release” and long-term relocation of the local population in the vicinity of the plant may be required for the “SGB Large Release”. The affected areas represent those areas closest to the station in which detailed planning and preparedness for exposure control measures would be expected to be conducted.

5.5 Conclusions

Doses due to radiological emissions during normal operations of the new NPP are expected to be well within regulatory annual dose limits.

For assessment purposes, “stylized” SGB releases were derived based on a representative core isotopic inventory and a severe accident isotopic release mix from the available safety analyses for the reactor technologies being considered for the NND site. It must be noted that these “stylized” SGB releases do not represent real accident events applicable to any of the plant designs being considered as not all reactor-specific design elements, which would allow for mitigation of such releases, were credited in this assessment.

The results from the assessment of these SGB releases demonstrate conformance with the intent of the RD-337 [R-34] safety goals. That is, temporary evacuation of the local population in the vicinity of the plant may be required in the case of the “SGB Small Release” and long-term relocation of the local population in the vicinity of the plant may be required for the “SGB Large Release”. The affected areas represent those areas closest to the station in which detailed planning and preparedness for exposure control measures would be expected to be conducted. It must be noted that these results were based on preliminary safety analyses available for the reactor designs at the time of this assessment.

The current population and future population (based on population growth projections available at this time) are not expected to affect the feasibility of implementing the PNERP [R-40] at the NND site.

6.0 CONCLUSION

In order to evaluate the suitability of the NND site for the new NPP, OPG has initiated a series of independent technical reviews in accordance with RD-346 [R-3], RD-337 [R-34], and NS-R-3 [R-13] (and associated guides). The technical reviews are aimed to provide a technical basis in support of the licensing process.

All areas of potential hazards, identified in the original application for LTPS [R-1] as:

- Meteorological events,
- Flooding hazards,
- Seismic hazards,
- Geotechnical hazards,
- External, human induced hazards,
- Hazards related to site characteristics and its influence on potential dispersion of radioactive materials,

were assessed and the specific risks to the public and the environment, associated with these hazards, that would be posed by the new NPP on the NND site were evaluated. The evaluations were performed, wherever possible, by comparing the values of assessed parameters with the corresponding values in the PPE [R-4] and the evaluation therefore applies to reactor designs within this envelope.

In Section 2.0, the DN site’s current baseline conditions are described in terms of geography, hydrology, seismology, meteorology, geology, geotechnical conditions and hydrogeology. The baseline conditions considered include its current state at the DN site, as well as predicted changes during the projected life of the new NPP. These conditions, in conjunction with the hazards identified serve as inputs for the assessment of risks and consequences the new NPP on the DN site would pose to the public and environment.

Section 3.0 presents the results of assessment of naturally occurring hazards and potential impact they may have on the new NPP during its lifetime.

- The assessment of meteorological phenomena, including rare and extreme weather and projected climate change impact, concluded that there are no meteorological hazards that make the DN site unsuitable for a new NPP. Furthermore, it can be concluded that no measures beyond conventional mitigation against meteorological phenomena are required for NND.
- The flooding hazards assessment identified extreme coastal processes and extreme precipitation at the DN site as two potential flooding hazards. The overall conclusion from this assessment is that the identified flooding hazards can be mitigated through conventional engineering means and construction methods.
- It was determined to be feasible to place a water intake facility at such a depth which will ensure that Lake Ontario water level variations would not interrupt the supply of water. In addition, by implementing the mitigation measures that have been successfully applied at power generating facilities along the north shore of Lake Ontario, biofouling and frazil ice formation at the site are considered manageable over the lifecycle of the proposed facility. The results of the evaluation confirm reliability and availability of the lake water supply for NND.
- The response of the NND site to potential seismic events was assessed by means of a PSHA. The PPE [R-4] identified the limit of the peak ground acceleration to be 0.3g. In the seismic assessment, the NND site UHRS indicated the peak ground acceleration to be less than the 0.3 g spectra used in the seismic design response of the available vendor designs. For the high frequency range of between approximately 25 and 60 Hz, the NND UHRS exceeded the vendor design response spectra. Westinghouse and AECL have performed evaluations of their standard plant designs using response spectra more typical for very stiff sites and have reported acceptable plant performance. It is expected that a similar evaluation can be performed for the EPR design to mitigate against the issue of high spectral frequency exceedance of design response spectra. This issue will be addressed through detailed engineering design and is not considered restrictive in the site evaluation process.
- The assessment of geotechnical conditions at the NND site did not reveal any inherent problems that would render the NND site unsuitable for the new NPP. The assessment concluded with the recommendation that the foundations of the NPP should be placed on sound limestone bedrock at approximately 64 masl, which is 14 m below the planned ground surface level.

Section 4.0 presents the results of the assessment of external, human-induced events applicable to the new NPP. Potentially hazardous events were identified and conservatively classified into those that are deemed to pose negligible incremental risk to the new NPP, and those which would require mitigation through engineering solutions. The conclusion of this assessment is that there are no external, human-induced events, which would render the site unsuitable for the new NPP.

Section 5.0 presents the results of the assessment of the dispersion of radioactive materials at the NND site. The assessment confirmed that the new NPP would be expected to meet regulatory annual dose limits [R-35] for normal operations. For assessment purposes, "stylized" SGB releases were derived based on a representative core isotopic inventory and a severe accident isotopic release mix from the available safety analyses for the reactor technologies being considered for the NND site. It must be noted that these "stylized" SGB releases do not represent real accident events applicable to any of the plant designs being considered as not all reactor-specific design elements, which would allow for mitigation of such releases, were credited in this assessment. The results from the assessment of these SGB releases demonstrated that, in conformance with the intent of the RD-337 [R-34] safety goals, temporary evacuation of the local population in the vicinity of the plant is expected to be required in the case of the "SGB Small Release". Furthermore, long-term relocation of the local population in the vicinity of the plant is expected to be required for the "SGB Large Release". The current population and future population (based on available population growth projections) are not expected to affect the feasibility of implementing the PNERP [R-40] at the proposed site.

The overall conclusion is that the NND site is suitable for the new NPP. The new NPP at the NND site would not pose any unreasonable risk to the public or the environment.

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8.0 GLOSSARY

ACR-1000	Advanced CANDU Reactor
AP1000	Advanced Passive Reactor
BLEVE	Boiling Liquid Expanding Vapour Explosion
Bq	Becquerel
CAV	Cumulative Absolute Velocity
CCC GCM2	Canadian Centre for Climate 2nd generation Global Circulation Model
CEAA	Canadian Environmental Assessment Act
CGCM2	Coupled Global Climate Model (Second Version)
CNR	Canadian National Railway
CNSC	Canadian Nuclear Safety Commission
CPR	Canadian Pacific Railway
CPV	Conditional Probability Value
CSA	Canadian Standards Association
DBPV	Design Basis Probability Value
DN	Darlington Nuclear
DNGS	Darlington Nuclear Generating Station
EPR	Areva US EPR
EPRI	Electric Power Research Institute
EUR	European Utility Requirements
F_{HES}	Event frequency
F-Scale	Fujita Scale
GCM	Global Climate Model
GSC	Geological Survey of Canada
IAEA	International Atomic Energy Agency
IGLD	International Great Lakes Datum
IJC	International Joint Commission
IMPACT	Integrated Model for Probabilistic Assessment of Contaminant Transport
LRF	Large Release Frequency
LTPS	Licence to Prepare the Site
MACCS	MELCOR accident consequence code system
masl	metres above sea level
MSC	Meteorological Service of Canada
NND	New Nuclear at Darlington
NPP	Nuclear Power Plant
OPG	Ontario Power Generation
PAL	Protective Action Level
pga	Peak Ground Acceleration
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PNEP	Provincial Nuclear Emergency Plan
PNERP	Provincial Nuclear Emergency Response Plan
PPE	Plant Parameters Envelope
PSHA	Probabilistic Seismic Hazard Analysis
QA	Quality Assurance

SDV	Screening Distance Value
SGB	RD-337 Safety Goal Based
SPL	Screening Probability Level
SRF	Small Release Frequency
SSTs	Sea-Surface Temperatures
TDG	Transportation of Dangerous Goods
TNT	Trinitrotoluene
UHRS	Uniform Hazard Response Spectra
USGS	United States Geological Survey
VCE	Vapour Cloud Explosion
WIS	Wave Information Studies
WPCP	Water Pollution Control Plant