NEW NUCLEAR GENERATION

Project Description for the

Site Preparation, Construction and Operation of the Darlington B Nuclear Generating Station

Environmental Assessment

Submitted to
The Canadian Nuclear Safety Commission

April 12, 2007

ONTARIO POWER GENERATION

PROJECT DESCRIPTION

for the

SITE PREPARATION, CONSTRUCTION, AND OPERATION OF THE DARLINGTON B NUCLEAR GENERATING STATION

ENVIRONMENTAL ASSESSMENT

Attachment to CD# N-CORR-00531-05863

Submitted to
The CANADIAN NUCLEAR SAFETY COMMISSION

April 12, 2007

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1.0 INTRODUCTION AND BACKGROUND

1.1 BACKGROUND

Ontario Power Generation Inc. (OPG) is the proponent for this Project. OPG is a corporation incorporated pursuant to the *Ontario Business Corporations Act*, whose shares are wholly owned by the Province of Ontario.

OPG is one of the successor corporations to the former Ontario Hydro. In addition to hydroelectric and fossil-fuelled power generating stations, OPG operates the Pickering A, Pickering B, and Darlington Nuclear Generating Stations, and the Pickering and Western Waste Management Facilities. The Darlington Waste Management Facility is currently under construction. OPG is also the owner of the nuclear generating stations located in Ontario's Bruce County that are operated by Bruce Power.

OPG's management systems have been certified as meeting the ISO 14001 standard for environmental management systems at the Darlington nuclear site. OPG has also been the recipient of certification by the Wildlife Habitat Council for the environmental stewardship and biodiversity programs it has established at its Darlington nuclear generating facilities.

On September 21, 2006, OPG submitted to the Canadian Nuclear Safety Commission (CNSC), an "Application for Approval to Prepare a Site for the Future Construction of a Nuclear Power Generating Facility in the Province of Ontario, Regional Municipality of Durham, Municipality of Clarington" (the Application).

On November 22, 2006, the CNSC acknowledged receipt of the application and informed OPG that "Staff has also determined that the application is for a Project of a type for which an Environmental Assessment (EA) will be required pursuant to the Canadian Environmental Assessment Act and related regulations before any licence may be granted".

1.2 NEED FOR THE PROJECT

On June 13, 2006, the Province of Ontario issued a Supply Mix Directive (SMD) to the Ontario Power Authority (OPA) that included the requirement to "plan for nuclear capacity to meet base-load electricity requirements but limit the installed in-service capacity of nuclear power over the life of the plan to 14,000 MW." At the same time, OPG was directed "to begin a feasibility study on the refurbishment of its existing facilities to review the economic, technological and environmental aspects of refurbishment", and "to begin the work needed to enter into an approvals process, including an environmental assessment for new units to be built at an existing facility". This Project fulfills the "new unit" component of that directive.

At this time, the OPA is developing an Integrated Power System Plan (IPSP) for Ontario. Through the IPSP, the OPA forecasts the expected demand for electricity and seeks to ensure that there is adequate generation and transmission to meet the demand. The OPA has received public input in the development of the IPSP, and intends to file the IPSP with the Ontario Energy Board (OEB) in 2007.

The OEB will hold public hearings on the IPSP. In those hearings, the OPA needs to demonstrate how the IPSP implements the SMD, including the 14,000 MW of baseload nuclear capacity.

To address this, the OPA is required to provide:

i. an assessment of the level of base-load generation required over the forecast period, and the gap between that forecast and existing resources available to serve base-load;
ii. an economic assessment of the feasible refurbishment or additions of new nuclear power capacity up to the 14,000 MW ceiling; and
iii. an assessment of the economic and financial risks associated with life extension options for existing nuclear facilities and for new nuclear facilities.

The current expectation is that the OEB decision will be issued in 2008.

1.3 NATURE OF THE PROPOSED PROJECT

The purpose of the proposed Project is to produce up to 4800 megawatts (MWe) of baseload electricity from up to four additional nuclear generating stations, to meet the requirements of the Province of Ontario. The exact amount of new nuclear generation required is not known at this time. The 4800 MWe was selected as an appropriate upper boundary for the purpose of the assessment on the basis of the reactor technologies available and the potential amount of additional nuclear baseload generation which may be required to provide 14,000 MW of installed in-service nuclear capacity. To accomplish this task the proposed Project involves:

- Preparation of the Darlington Nuclear Site for construction;
- Construction of the Darlington B nuclear reactors and associated facilities;
- Construction of the appropriate nuclear waste management facilities for storage and volume reduction of waste;
- Operation and maintenance of the Darlington B nuclear reactors and associated facilities for approximately 60 years of full power production;
- Operation of the appropriate nuclear waste management facilities; and
- Development planning for decommissioning of the nuclear reactors and associated facilities, and eventual turn over of the site to other uses.

For EA planning purposes, the following preliminary schedule for the four phases of the Darlington B nuclear generating stations has been proposed. The dates provided are overlapping to address uncertainties in scheduling and the range of potential start and finish dates for the total of four units. For EA planning purposes, it is assumed that one or two reactors will be initially constructed, potentially followed by a further two or three reactors. The EA Phase is anticipated to take three to five years; Site Preparation and Construction Phase approximately sixteen years assuming two phased developments of six to eight years each; Operation Phase for approximately sixty years for each unit at full power equal to seventy years; and Decommissioning leading to eventual abandonment of the site license, approximately 40 years once the last unit has reached its end of operating life. Preparation for Decommissioning will commence approximately three to four years prior to the last unit shutdown. Dates are rounded for later-phased activities.

Table 1.3-1: Preliminary Schedule for each Project Phase for EA Purposes

Phase	Bounding Start - End Dates
EA Phase	2006 to 2011
Site Preparation and Construction Phase	2010 to 2026
Operations Phase	2016 to 2100
Decommissioning Preparation, Decommissioning and Abandonment	2090 to 2140

1.4 PURPOSE AND CONTENT OF THIS DOCUMENT

The purpose of this document is to:

- Respond to the CNSC requirement to submit a Project Description to enable CNSC staff to evaluate the scope of the Project and the required Environmental Assessment,

- Provide a basis for other federal departments and agencies, pursuant to the *Federal Coordination Regulations*, to identify whether they are likely to exercise a power in respect of the Project, or be in possession of specialist or expert information or knowledge that is necessary to conduct the Environmental Assessment.

- Assist in the early identification of potential environmental effects that should be included in the scope of the Environmental Assessment.

This Project Description includes the following information:

- This introduction, providing the background and purpose of this document, (Section 1);

- A summary description of the Project including the facilities to be sited, constructed, operated, and decommissioned and the activities associated with site preparation, construction, operation, and decommissioning, (Section 2);

- The location of the Project and a description of the surrounding area, (Section 3) including an overview description of the physical and biological environments within the areas potentially affected by the Project; and

- A summary of the consultation that has occurred to date respecting this Project Description and the mailing address and phone number of a contact person who can provide additional information about the Project (Section 4).

2.0 SUMMARY DESCRIPTION OF THE PROJECT

2.1 LOCATION OF THE PROJECT

The Darlington Nuclear Site (DNS) is approximately 480 hectares in size, located in the Municipality of Clarington, in the Regional Municipality of Durham (Durham Region), Ontario. The DNS is located on the north shore of Lake Ontario, about 70 km east of Toronto, about 5 km south west of the community of Bowmanville, and about 10 km east south east of the City of Oshawa. The general location of the DNS is shown in Figures 2.1.

The southern boundary of the DNS is Lake Ontario. The northern boundary is the South Service road immediately south of Highway 401. To the east of the site, is the large industrial complex associated with St. Marys Cement limestone quarry and processing plant. To the west of the site, is the Darlington Provincial Park, agricultural and commercial lands and the Courtice Water Pollution Control Plant, being constructed to serve the growing needs of this portion of Durham Region. The DNS Site environs are shown in Figure 2.2.

The DNS is serviced by a transportation network of provincial and municipal roads. Personnel travelling to the station via provincial Highway 401 have ready access to the station via the Courtice Road, Holt Road or Waverly Road interchanges. The southern terminus of Holt Road is the main entry gate to the DNS. There is a secondary entry gate (Park Road) on the South Service Road west of Holt Road.

The existing generating station is generally located in the southwest quadrant of the site. Clustered around the four reactor buildings are the security, engineering and related operational support service buildings. North of the CN rail line is the soil stockpile and construction landfill created at the time of original construction and the Hydro One switchyard linking the power plant to the bulk transmission system.

The DNS has been selected for this project for many reasons. The site is large enough to accommodate up to four additional reactors. There is good access to a major load centre to the west, via the existing switching station sized to connect the second four units to the bulk transmission system. OPG has extensive operating experience to draw on at the DNS, having begun studying the site, the surrounding lands and waters in the 1970s, documenting the effects of the construction of the first four units, and then monitoring the operation of the plant since 1991. OPG also has a highly skilled workforce, with a track record of safe and reliable performance protecting the environment, workers and members of the public. OPG has developed and maintained a good working relationship with our neighbours and the municipal and regional governments.

Darlington B, the new generating station, is proposed to be located in the east half of the DNS, with the reactor buildings and other related structures located south of the CN rail line. More details of the site layout and land use is provided in Section 3 following.

2.2 PREVIOUS ENVIRONMENTAL STUDIES

Since the 1970s, OPG (formerly Ontario Hydro) has been engaged in extensive data collection and analysis documenting the original baseline conditions of the site, the effects of construction of the DNGS, and the effects of safe operation over the past 30 years. In keeping with the various licences that it has received and maintains, OPG performs ongoing environmental effects monitoring at the DNS. The emissions and effluent from the DNGS are monitored on an ongoing basis, and the radiological and conventional effects are evaluated and reported to the CNSC, and other federal and provincial departments and ministries. The CNSC considers the monitoring data provided for the purpose of the ongoing licensing of the station and the determination that OPG is making “adequate provision for the protection of the environment.” (NSCA, s. 24(4))

In 2001, the Darlington Nuclear Generating Station Ecological Effects Review (DNEER) was completed. The purpose of the DNEER was to evaluate and predict any potentially significant adverse ecological effects from operation of Darlington NGS and provide follow-up recommendations for monitoring or mitigation.

One of the design improvements made at Darlington NGS was the lake bottom intake structure and the lake bottom diffuser. For a period of 26 years, (1970 to 1996) OPG studied the nearshore aquatic environment associated with the nearshore environment. Since operations began, studies of the effects arising from the intake tunnel and diffuser have concluded that the offshore lake bottom diffuser is effective at dissipating heat to minimize thermal ecological effects. Similarly, the lake bottom intake structure is effective at reducing the quantity of fish entrained. Construction and use of similar structures may be recommended in this Project.

In 2003, an EA was completed and approved by the CNSC for site preparation, construction and operation of the Darlington Used Fuel Dry Storage facility (DUFDS-EA) (OPG 2003). This EA determined the location and size of the used fuel dry storage facility, now in the final stages of construction. The used fuel dry storage facility, now known as the Darlington Waste Management Facility (DWMF), is located centrally on the site south of Holt Road. The DWMF includes a processing building and three used fuel dry storage buildings with sufficient capacity to store all the used fuel from the operation of the existing DNGS to its end of service life.

Figure 2.1: General Location of the Darlington Nuclear Site

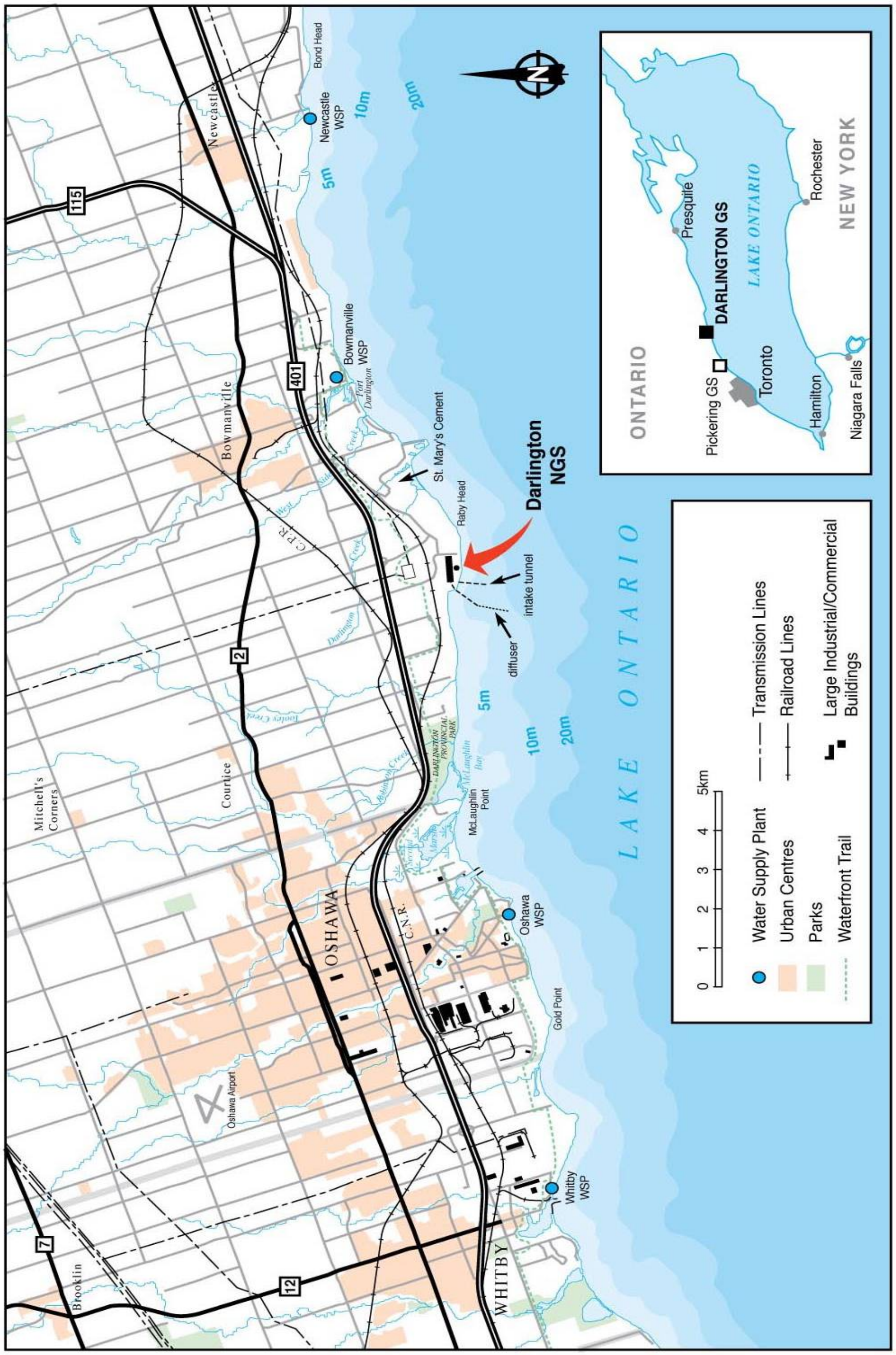
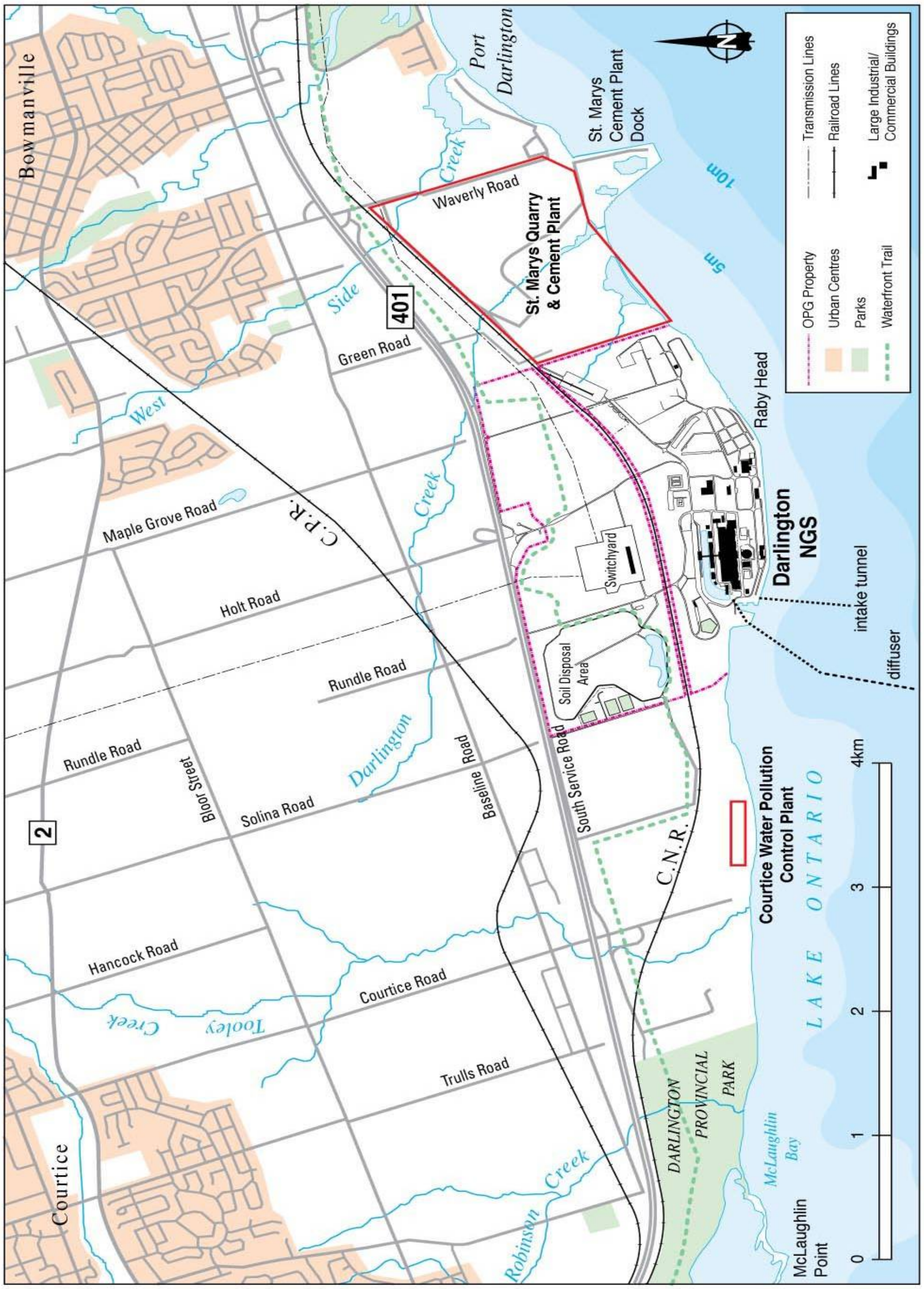


Figure 2.2: Darlington Nuclear Site Environs



2.3 LEGISLATION, REGULATIONS AND POTENTIAL AUTHORIZATIONS REQUIRED

2.3.1 Federal Authorizations

Pursuant to the *Nuclear Safety and Control Act*, licenses must be obtained from the Canadian Nuclear Safety Commission (CNSC) in order to prepare the site for construction, operation, or decommissioning of a Class I Nuclear Facility. Class I Nuclear facilities include the reactors, and the used fuel dry storage facilities. The Class I Nuclear facilities also include all necessary systems and structures that are directly related to the operation of the facilities such as security access control structures, on-site stand-by and emergency power generating systems, water treatment systems, effluent and emission treatment systems, and cooling structures.

Facilities that are part of the Project but that are not directly related to the operation of the nuclear power generating stations are approved for location at the site by the CNSC. The approval granted by the CNSC is required due to the emergency preparedness requirements applicable to the facilities. Further, the production, use and application of nuclear energy has been determined by the Supreme Court of Canada to be a matter of national concern within the exclusive jurisdiction of the federal government.

The anticipated construction and operation of the potential structures that may be located in Lake Ontario, such as the intake structure, outfall structure, land reclamation along the shoreline, and the possible construction of a wharf at which large components can be delivered to the site may require approval or a determination under the *Navigable Waters Protection Act.* The construction of the structures to be located in Lake Ontario may also require authorization under the *Fisheries Act*.

Excavation and blasting may require a license from Natural Resources Canada under the *Explosives Act*. Excavation, earth moving and vegetation removal as required may also effect wildlife habitat and species. The *Species at Risk Act* and the *Migratory Birds Convention Act* may also apply to the conduct of, and the effects of the project.

A new crossing over the rail line that runs through the property may be constructed, or the existing crossings may be enhanced. A new siding may also be constructed. Approvals for the crossing and siding would be required under the *Railway Safety Act*.

OPG has not identified any federal government department or agency that is, or may be, providing land or financial support to the Project.

Other federal authorizations that may be required for the Project will be identified with further definition of the Project activities and through the review of this Project by the federal authorities.

2.3.2 Provincial Authorizations

Pursuant to section 71 of the *Nuclear Safety and Control Act*, any work or undertaking constructed for the development, production or use of nuclear energy is declared to be a work or undertaking for the general advantage of Canada. As such, provincial laws apply to the facility only to the extent determined as appropriate by the CNSC. Pursuant to subsection 44(6) of the *Nuclear Safety and Control Act*, the CNSC may incorporate a provincial Act and the regulations made there under, through a regulation, or pursuant to section 21 the CNSC may enter into arrangements with the province with respect to the application of its laws to the nuclear facility. Finally the CNSC may, through its license conditions, require the licensee to comply with any international, national, or provincial code or standard. For example, the CNSC may require OPG to obtain a permit from the Central Lake Ontario Conservation Authority for a modification to the shoreline. An archaeological assessment of the Project lands may be required by the CNSC, compliant with the *Ontario Heritage Act* and its regulations.

Historically, Nuclear Power Generating Stations in Ontario have obtained Certificates of Approval from the Ontario Ministry of the Environment for the emissions and effluents that arise from the operation of the facility. Additionally, Nuclear Power Stations in Ontario have obtained Certificates of Approval for on-site conventional waste handling. Elevating devices and pressure vessels used within the facilities have been registered with the provincial Technical Standards and Safety Authority pursuant to the applicable Acts and Regulations.

The ability to connect the station electrically with the electricity transmission grid will require the approval of the Ontario Energy Board.

2.3.3 Provincial Environmental Assessment

This Project is expressly excluded from a provincial environmental assessment as it is not a designated undertaking pursuant to the Ontario *Electricity Projects Regulations*. This regulation identifies the electricity projects that require a provincial environmental assessment under the Ontario *Environmental Assessment Act*. In any event, the construction and operation of the nuclear facilities are outside the jurisdiction of the Province.

2.4 ALTERNATIVE MEANS OF CARRYING OUT THE PROJECT

There are a number of alternative means that are being considered within the EA for carrying out the Project. These include:

- The reactor designs, which will be assessed on the basis of the type of technology used by the designs;
- Site location options including the potential location and orientation of the reactors on the site, and the potential number of reactors;
- Condenser cooling systems, including lake based cooling, and atmospheric cooling towers;
- Nuclear waste management systems to be used on site.

The Project will consider the technical feasibility of these alternatives, and comparison of their potential environmental effects. The comparison will contribute to the actual alternatives selected for implementation. The selection of the actual means of carrying out the Project will also be based on other factors that are external to the environmental assessment, such as financing, schedule, availability, and Canadian content. All site location options will be assessed in the EA with respect to the international site location criteria specified in the IAEA guide NS-R-3 as specified by the CNSC.

2.5 PRINCIPAL BUILDINGS, STRUCTURES, AND SYSTEMS

A nuclear power generating station is composed of several buildings, structures and systems. The following provides a summary of the principal buildings, structures and systems that would be constructed and operated at the DNS.

The main structures of the proposed facility which will house the systems and infrastructure of the power plant include the following:

2.5.1 Reactor

The reactor is the portion of the facility in which energy from the fuel is converted into heat, which is used to make steam. Major components include the reactor vessel, the fuel handling system, the heat transport system, a moderator, reactivity control mechanisms, shut down systems, and containment.

The type of reactors to be constructed and operated as part of Darlington B has not been selected. OPG intends to use a Multiple Technology approach and consider four different types of reactors. The reactor types that OPG will consider are:

- Pressurized Heavy Water Reactors (PHWRs) with designs such as the Enhanced CANDU-6 (EC6);
- Pressurized Water Reactors (PWRs), with designs such as the EPR, AP1000, APWR, OPR 1000 and APR 1400;
- Boiling Water Reactors (BWRs), with designs such as the ABWR and the ESBWR; and
- Pressurized Hybrid light/heavy water Reactors (PHRs), with designs such as the ACR-1000.

Available designs within each type will be evaluated to establish bounding assessment values that provide a conservative indication of the effects operation of a reactor of that type will have on the environment. To ensure that the environmental assessment thoroughly covers the potential impacts of any design OPG ultimately selects, OPG anticipates including all these reactor types in the EA process, following which OPG will make a business decision on the preferred reactor. This business decision will be made near the completion of the EA Study Report preparation or after the EA study has been completed. Should the business decision on reactor technology be made prior to the EA completion, that technology will be adopted as the preferred technology and the others will be carried forward in the EA study as alternative methods. The Plant Parameter Envelope (PPE) proposed to be used for EA purposes, and a generic description of each reactor type is provided in Appendix A of this document.

As has been noted above, for EA planning purposes four nuclear units with a total capacity of up to 4800 MWe has been selected as a maximum bounding scenario for the EA studies. The actual number of units constructed and the installed capacity will vary and not exceed this limit. In some designs, fewer than four reactors may be required to meet this assumed output, while in the case of other designs, the cumulative output of four reactors will not reach this assumed maximum output.

Licensing the construction and operation of a nuclear reactor is an intensive process that requires careful and thoughtful consideration by OPG and the CNSC. It is anticipated that such licensing will take several years to achieve.

Table 2.5.1 – Overview of Reactor Classes

	Pressurized Heavy Water Reactors (PHWR)	**Pressurized light Water Reactors (PWR)**	**Boiling Water Reactors (BWR)**	**Pressurized Hybrid heavy and light Water Reactors (PHR)**
Vendors	• Atomic Energy of Canada Ltd.	• Westinghouse • Korea Hydro and Nuclear Power • Areva • Mitsubishi	• General Electric	• Atomic Energy of Canada Ltd.
Designs	• Enhanced CANDU 6	• AP 1000 • OPR 1000 • APR 1400 • EPR • APWR	• ESBWR • ABWR	• ACR 1000
MWe (range)	750	1000 – 1650	1350 - 1500	1200
Fuel Used	Natural Uranium (0.7% U235)/Slightly Enriched (<2% U235)	Enriched (4 - 5% U235)	Enriched (4 – 5% U235)	Slightly Enriched (<2% U235)
Reactor	• Calandria containing horizontal fuel channels	• Reactor vessel containing vertically arranged fuel assemblies	• Reactor vessel containing vertically arranged fuel assemblies	• Calandria containing horizontal fuel channels
Heat Transport System	• Heavy Water • Steam Generators • Horizontal flow through fuel channels via feeders • Pressurized	• Light Water • Steam Generators • Vertical flow through the reactor • Pressurized	• Light Water • Vertical flow through the reactor	• Light Water • Steam Generators • Horizontal flow through fuel channels via feeders • Pressurized
Safety Systems	• Neutron Absorbing Rods • Neutron Absorbing Liquid Injection • Containment • Active Core Cooling Systems	• Neutron Absorbing Liquid Injection • Containment • Active Core Cooling Systems • Passive Core Cooling Systems	• Neutron Absorbing Liquid Injection • Active Core Cooling Systems • Passive Core Cooling Systems • Containment	• Passive Core Cooling Systems • Containment • Neutron Absorbing Rods • Neutron Absorbing Liquid Injection

2.5.2 Turbine Generator

The Turbine Generator Powerhouse will contain the more conventional systems of the power plant that convert the steam from the operation of the reactor into electrical energy. The turbines and generators and related systems and structures will be located within the Turbine Generator Power House or adjacent structures. Once electricity is produced, it will be transmitted from the Power House to the Hydro One switchyard located on site for distribution through their bulk transmission system.

Figure 2.4 illustrates two alternative site layouts for up to four reactors and associated powerhouse.

a) East - West Orientation

b) North – South Orientation

2.5.3 Condenser Cooling

To condense the steam used to produce electricity, the excess heat is removed by condenser cooling systems and structures. Two alternative means of cooling are being considered within the EA: lake-water cooling or atmospheric cooling. Two alternative means of atmospheric cooling will be described: natural draft cooling towers, or mechanical draft cooling towers. Each of these options will be assessed as an alternative means of cooling to the preferred option of lake-water cooling.

Cooling towers are an alternative means of cooling the steam used to power the turbines to produce electricity, by transfer of the heat to the atmosphere. Natural draft cooling towers are larger and may be 120 metres in height. Mechanical draft cooling towers are smaller in size and use top mounted fans to draw air up through the tower to produce draft. The fans consume approximately three percent of the power produced by the generating station. Potential cooling tower layouts should they be selected are shown in green in Figures 2.4 a and b.

For EA planning purposes, OPG has assumed that lake-water cooling will be the preferred method of cooling, based on the current performance of the DNGS. Lake water cooling involves bringing large volumes of lake water into the plant through a lake bottom intake tunnel located 700 meters offshore at a depth of 10 metres. The DNGS intake structure is designed to minimize their effects on fish and other organisms that might otherwise get entrained by the high volume (150 cubic meters per second) and flow rate of the intake. The lake water is screened to remove debris, algae, and other materials before use in cooling systems within the plant. Once used, the warmed water is returned to the lake through an offset diffuser pipe running 1800 metres offshore, to minimize the heat impact on the lake and the potential for recirculation of heated water. The diffuser design limits the temperature plume to 2 degrees celsius within the 50 hectare area surrounding each discharge jet. This minor temperature differential does not have a significant effect on local fish species. A similarly designed intake and outfall with equal or better performance will be considered for Darlington B is illustrated in Figures 2.5.3a and b.

Figure 2.4a: Darlington Nuclear Site Illustrative Layout - East – West Orientation

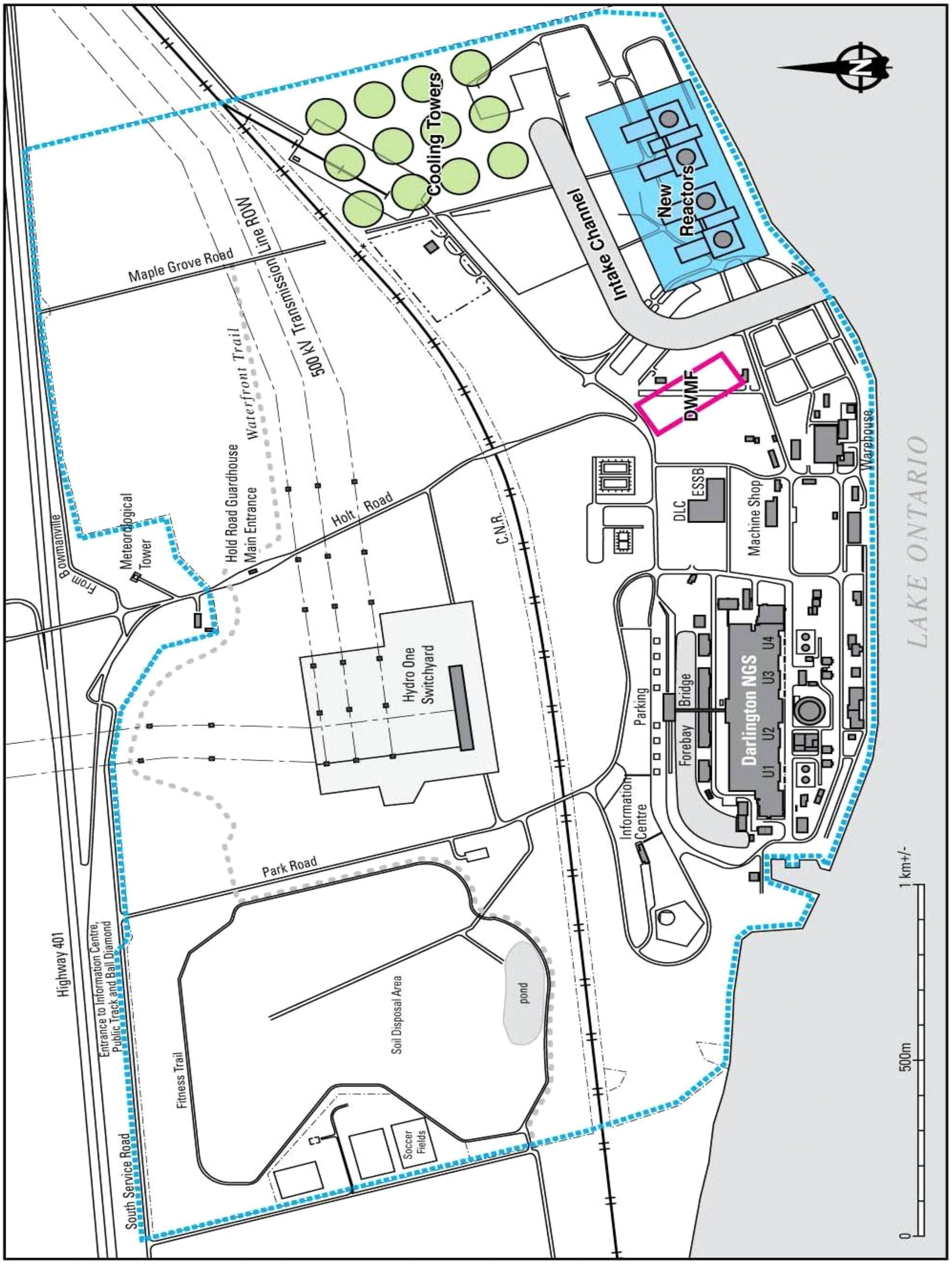


Figure 2.4b: Darlington Nuclear Site Illustrative Layout - North – South Orientation

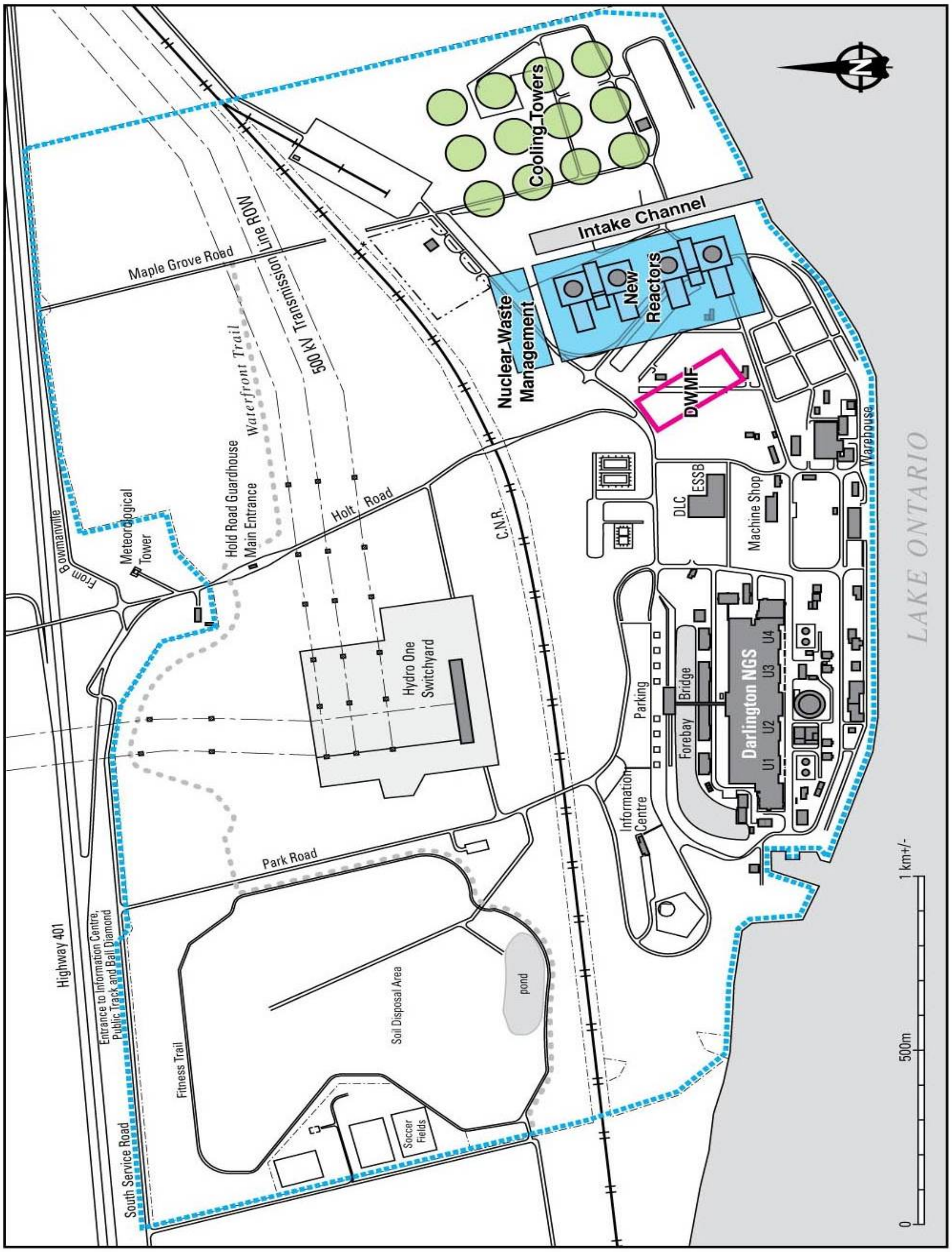


Figure 2.5.3a: Darlington NGS Cooling Water Intake

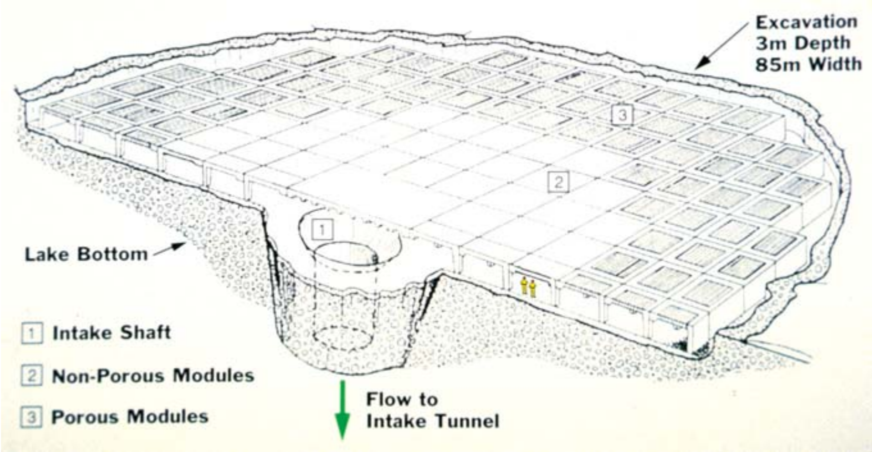
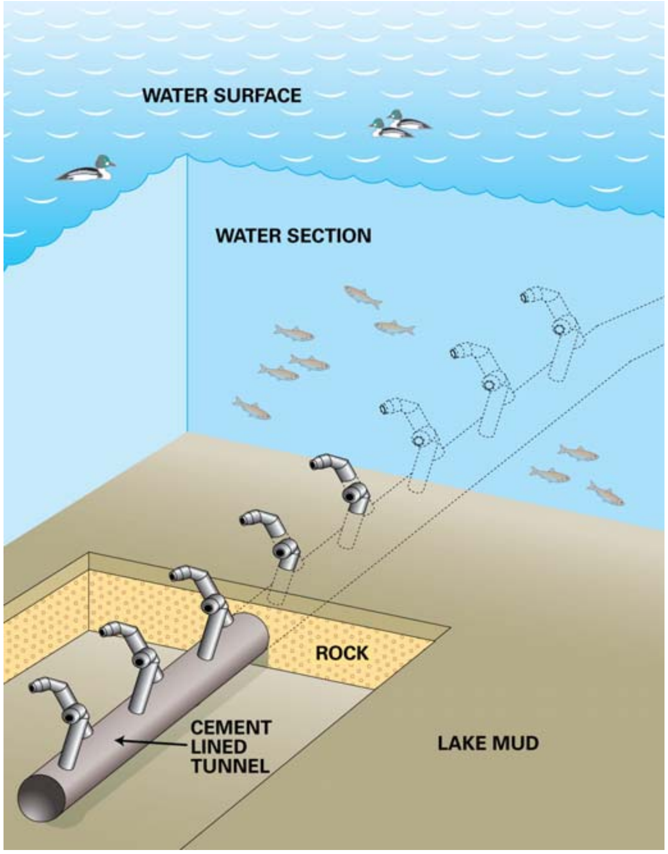


Figure 2.5.3b: Darlington NGS Water Discharge Diffuser



2.5.4 Nuclear Waste Management

2.5.4.1 Low and Intermediate Level Waste Management

The radioactive low and intermediate level waste (L&ILW) produced during the day-to-day operation and maintenance of the reactors will be handled in a manner that attempts to minimize the volume of waste produced. Typical examples of L&ILW include ion exchange resins, filters, rags, mops, floor sweepings, tools and clothing that become contaminated as part of operation and maintenance activities. L&ILW will be managed in a similar manner regardless of the reactor selected. For EA purposes, two alternative means of managing L&ILW are proposed: the L&ILW will be managed on the Darlington Nuclear Site in a low and intermediate level waste management facility; or transported off-site to be managed at an appropriately licensed facility. The specific types, volumes and characteristics of low and intermediate level waste produced during the life of the facility will be described for each reactor class as part of the PPE process.

2.5.4.2 Used Fuel Management

On-site used nuclear fuel storage facilities will be part of each of the reactor designs considered. In every case, the storage facility is composed of transfer systems that carry the used fuel from the reactor to a used-fuel storage pool in which the used fuel is stored and cooled. The used fuel will be stored in an irradiated used fuel storage bay until it has cooled sufficiently for storage using an alternative means. This wet storage system within the reactor facility must allow for acceptably aged fuel and operating margin of at least one year.

After the used fuel has cooled, it may be safely stored in dry-storage containers. The Project will include two on-site storage options, including the expansion of the current DWMF, or the construction of a separate used fuel dry storage facility specifically for the Darlington B generating station. For EA planning purposes, the volumes and characteristics of used fuel waste arising from the operation of each reactor will vary depending on the reactor technology. The technologies being considered include not only the natural uranium fuel used today in the DNGS reactors, but also fuel that is somewhat enriched.

For EA planning purposes, it is also assumed that the used fuel will continue to be stored at site until the federally regulated Nuclear Waste Management Organization (NWMO) takes responsibility for the long-term management of the used fuel as directed by the federal government, and that the NWMO long-term management facility will be available within the operating lifespan of the Darlington B reactors. The site study, construction, and operation of this long-term used fuel management facility will be the subject of its own separate environmental assessment process.

2.6 DESCRIPTION OF PROJECT WORKS AND ACTIVITIES

The environmental assessment addresses site preparation, construction, and operation. Decommissioning is assessed only in a preliminary manner and it is expected to be subject to its own environmental assessment when approval to decommission is sought. It is anticipated that the activities will overlap to some extent, for example, construction may commence on some buildings prior to all of the site preparation activities being completed.

2.6.1 Site Preparation & Construction Phase

The Site Preparation and Construction includes all general activities needed to prepare the site for construction and then to construct the nuclear reactors and associated buildings, structures, and systems such as the powerhouse and condenser cooling system. Site preparation and construction activities may involve:

- Construction and enhancing roads to provide access to the site, potentially including the access to Provincial Highway 401;
- Re-establishment of a rail line spur if required;
- Construction of a wharf if required;
- Construction of parking lots and laydown areas;
- Construction site fencing;
- Removal of existing trees and vegetation if necessary;
- Shoreline stabilization and lake infilling, coffer dam construction;
- Realigning intermittent stream channels and draining some wet areas across site;
- Earthmoving activities including cutting, filling, grading construction areas, creating berms and stockpiles;
- Installation of necessary infrastructure such as power, water main, sewage systems, surface water drainage, storm water sewers;
- Bedrock excavation for foundations, installation of bedrock piles;
- Expansion of the switchyard;
- Receipt and management of materials and components for installation;
- Installation of the intake and outfall to Lake Ontario;
- Construction of cooling towers if required;
- Construction of the reactors, power house buildings, structures, and systems;
- Removal of construction debris to a licensed facility, including any hazardous waste created during construction;
- Testing and commissioning of systems and structures;
- Landscaping;
- Final site fencing and security system installation.

Site Preparation and Construction activities will vary dependent on the reactor design selected. Most of the designs that are currently available are constructed on a modular basis, which involves manufacture and assembly of systems and components in controlled separate facilities, followed by transportation to the DNS for installation. The reactors may be constructed one or two at a time, with sequencing and schedules dependent on the type and size of the reactor technology selected. As noted above, for EA planning purposes it is assumed that the reactors will be constructed in two phases of six to eight years each.

2.6.2 Operation Phase

The Project includes all of the works and activities that occur on-site during routine operation and maintenance of the Darlington B nuclear reactors and associated buildings, structures, and systems.

For some reactor designs, operation will include refurbishment of reactor components after approximately 30 years of full power operation. Total operation is assumed to be approximately

60 years of full power operation per reactor.

Operation includes the interim storage of all used fuel on site produced during the operating life of the reactors, and the appropriate low and intermediate level waste management.

The processing and handling of non-radioactive waste on the site, including hazardous waste and the preparation for shipping off-site to an appropriate licensed facility, is part of normal operations.

2.6.3 Decommissioning Phase

The Project includes the preliminary plan covering the major activities associated with decommissioning, leading to eventually making the site available for other uses. Decommissioning is anticipated to commence no sooner than the end of operation of the last Darlington B reactor. Decommissioning may commence with approximately 30 years of safe storage activities to allow the radioactivity of reactor components to naturally decay prior to dismantling. Dismantling may last for an additional five to ten years. Site monitoring for an additional ten years once decommissioning activities have been completed is anticipated before the release of the site for other uses. Decommissioning requires its own detailed environmental assessment to be performed as an early step in the decommissioning licensing process.

2.7 POTENTIAL ACTIVITIES AND ASSOCIATED ENVIRONMENTAL INTERACTIONS

The Project works and activities described above will, to a greater or lesser extent, lead to interactions with the existing environment in and around the DNS. The following project – environment interactions matrix provides an initial overview of the potential interactions that may occur. Table 2.7.1 describes the potential interaction during site preparation and construction and operation of the Project. The table includes the major components of the environment to be described in the environmental assessment in the first column. These are further subdivided into environmental aspects that may be expected to change as a result of some Project work or activity.

The potential interactions identified in the table associated with the Darlington B project reflect effects that have been identified in other large nuclear projects undertaken in Ontario. The interactions matrix was prepared by judging the potential effects of this Project on the DNS site as it is currently understood by OPG technical specialists. The table is organized to list the highest potential interactions first, followed by medium and low. The potential interactions identified may be negative or positive, although the negative effects are emphasized. In assessing the potential for interaction, applicable mitigation measures are assumed.

2.7.1 Potential Site Preparation and Construction Interactions

The interactions matrix indicates the greatest potential for changes to terrestrial environments, cultural heritage (archaeological sites), principally as a result of the excavation necessary to prepare the site for the main structures associated with the new power plant and the soil stockpiling on site. Also related to construction, are the many moderate shorter-term changes that are typical of large construction projects, such as dust and sediment generation, local increases in noise and reduced air quality during construction. Construction best practices, such as storm water management systems and waste management programs, will be implemented to minimize these effects. Any hazardous wastes generated during construction will be managed in accordance with applicable requirements. During Site Preparation and Construction, environmental effects associated with the use of heavy equipment, the presence of a large number of construction personnel, and the by-products of construction are expected. Many of the activities associated with construction will lead to increased employment, infrastructure development, and increased municipal revenue.

2.7.2 Potential Interactions during Operations

During operations, the interactions are more limited and associated with the very small ongoing exposure of workers, the environment around the plant, and to members of the public to radiation. Radiological accidents and malfunctions are also identified as a potential source of releases. Conventional effects are also identified, associated with potential use of cooling tower technology, the changes to lake water temperature, runoff from surface water, and the interactions with the lake fish and other aquatic organisms. Chemical discharges to both air and water are associated with the protection of the boilers during Operations.

Throughout the operations phase, local and regional purchasing and employment will contribute to increased municipal revenue and the maintenance of community infrastructure.

Mitigating actions, many of which are well established in nuclear plants throughout the world, will be identified to off-set or minimize the potential harm to the environment associated with Operation of the facilities. The designs for the buildings, structures, and systems will include features that address the risks that arise during operation of the reactor and other systems. Programs similar to those currently used by OPG to ensure the safe and secure operation of its nuclear power generating stations will also be used.

Table 2.7.1: Potential Project-Environment Interactions

Component	Aspect	Potential Interaction Construction	Operation
Socio-economic Conditions	Community services, infrastructure improvements Municipal finance Employment opportunities Competition for workers affecting pay scales and shortages	High	Moderate
Terrestrial Environment	Wildlife habitat and corridor modification Removal of terrestrial species of significance	High	Low
Hydrology & Water Quality	Surface water relocation and drainage Surface water runnoff water quality Lake circulation, thermal plume, lake water quality	Moderate	Moderate
Aquatic	Shoreline infilling and modification Instalation of intake and outfall structures Aquatic species and vegetation entrainment and impingement	Moderate	Low
Geology and Hydrogeology	Lowering groundwater table locally Soil and rock excavation, Landfill and berm creation	Moderate	Low
Land Use and Transportation	Road access to site Rail and dock construction if required Increased road traffic and accident frequency Conventional waste volume to sanitary landfill	Moderate	Low
Atmosphere	Air quality, dust and noise during construction Cooling tower operation if required Noise and gasous emissions during operation	Moderate	Low
Physical & Cultural Heritage	Cultural heritage sites identified and archaeological excavation prior to construction earthworks Visual change to landscape	Moderate	Low
Radiation and Radioactivity	Exposure to workers, the public and environment during operation of the reactors and nuclear waste management facilities Accidents and malfunctions during operation	Low	Moderate
Aboriginal Interests	Aboriginal or treaty rights Cultural sites and traditional harvesting activities	Low	Low

3.0 EXISTING SITE ENVIRONMENT CONDITIONS

3.1 DARLINGTON NUCLEAR SITE LAND USE

The DNS site is large, approximately 480 hectares, and has a frontage on the north shore of Lake Ontario of about 3160 metres The DNS layout is shown in Figure 3.1. The site is roughly divided into north and south portions by the Canadian National (CN) rail line that transects the property. The main features of each portion of the site are

- South-West – The existing Darlington NGS (DNGS) is located on this portion of the property. Included in this area are the four nuclear units, the powerhouse, standby generators, Vacuum Building and many support structures located within the operating island. Surrounding this are most of the related support facilities, ranging from the Engineering Support Services Building to the Hazardous Materials Storage Building, the Sewage Treatment Plant, and parking areas. The Nuclear Waste Management Facility for interim dry storage of used fuel is being constructed within this portion.

- South-East - The south-east side of the site is an area that was used during the original construction of Darlington NGS for equipment and material laydown yards and temporary facilities. The area remains accessible by a network of rough roads. The south-east portion of the property is the area under consideration as the site for the new nuclear reactors.

- North-West – The construction soil disposal pile and construction landfill sits in the north-west portion of the property. The landfill is now used for recreational purposes - playing fields, naturalized areas, and walking trails.

- North-Central – On this portion of the property is the 500 kV switchyard operated by Hydro One.

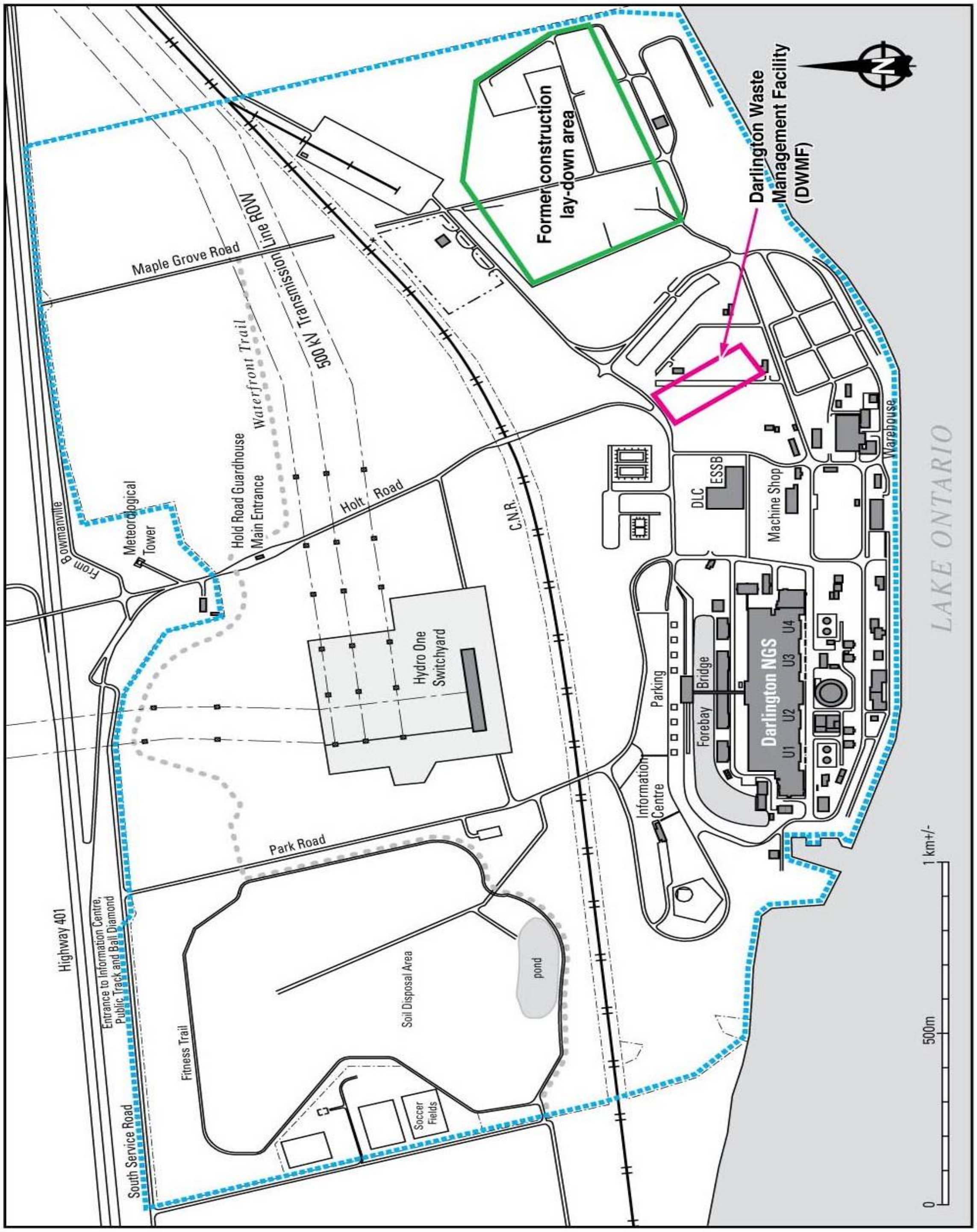
- North-East – The main feature in the north-east portion of the property is the 500 kV transmission line. This portion of the property remains largely in agricultural land use, woodlots and ponds. The recreational walking trails have been extended into this portion of the site.

3.2 LOCAL MUNICIPALITIES AND SURROUNDING AREA

Durham Region includes the City of Pickering, the City of Oshawa, the Towns of Ajax and Whitby, and the Townships of Brock, Scugog and Uxbridge, and Clarington. As of May 2006, the estimated population of Durham Region is about 590,000. Durham Region includes both urban and rural uses. In general, the urban uses parallel the shoreline of Lake Ontario in the communities of Pickering, Ajax, Whitby, Oshawa and Clarington. The rural uses generally occur in the northern communities of Brock, Scugog and Uxbridge.

Clarington includes several small urban centres - Bowmanville, Courtice, Newcastle Village, and Orono - and more than a dozen rural settlements and hamlets. The estimated population of Clarington is 80,000, as of May 2006. Clarington also has both urban and rural land uses. The

Figure 3.1 Darlington Site Layout



urban land uses, including residential, commercial, and industrial, are generally located south of the 3rd Concession and along Lake Ontario. The rural land uses, including agricultural uses and rural hamlets, are generally located north of the 3rd Concession. The land uses abutting the DNS north of Highway 401 are predominantly agricultural, rural residential or light industrial and commercial.

The lands to the immediate east and west of the DNS are mainly zoned for a variety of industrial uses, of note being the St. Marys cement plant and quarry. The Courtice Water Pollution Control Plant is currently under construction to the west of the DNS. An energy park industrial subdivision is also being discussed for the area west of the DNS.

3.3 ABORIGINAL COMMUNITIES & INTERESTS

There are eight First Nation communities that may have an interest in the Project. Six of these are located within 80 km of the site and these First Nation communities all have a historical relationship with the lands along the north shore of Lake Ontario (from Toronto east to the Bay of Quinte), and north to Lake Simcoe and Rice Lake through Treaties. A seventh First Nation located in Brant County also has a Treaty relationship with lands to the east of DNS. An eighth community, the Huron-Wendat has an interest in cultural heritage sites in Durham Region. There are also several Métis organizations, which represent Métis people that reside within Durham Region, which may have an interest in the Project.

The First Nations are listed below:

Respective communities	**Approximate location**
Mississaugas of Alderville First Nation	20 km southeast of Peterborough on south side of Rice Lake
Curve Lake First Nation	15 km northeast of Peterborough on Buckhorn Lake
Hiawatha First Nation	15 km southeast of Peterborough on north side of Rice Lake
Mississaugas of Scugog Island First Nation	35 km north of Oshawa on Scugog Island in Lake Scugog
Chippewas of Georgina Island First Nation	Southern end of Lake Simcoe near Sutton West
Kawartha Nishinabe First Nation	Buckhorn area – no Reserve lands to date
Mississaugas of the New Credit	15 km south of Brantford, adjacent to the Six Nations
Huron–Wendat Nation	Near Quebec City, Quebec

3.4 CULTURAL HERITAGE

There are several registered archaeological sites within a 10 km radius of DNS. Two such sites are located to the east of the DNS. The first site, located on Lot 20 corner of the south end of Maple Grove Road, is evidenced by the discovery of projectile points and ground stone artefacts which may date to the Archaic period circa 1,000 to 6,000 BC; and the second, located on Lot 21, may be of a similar age to the first, with a ground stone axe and projectile points being reported.

In addition, the Ministry of Culture considers many lands within Durham Region to have high archaeological potential for prehistoric and historic archaeological sites of significance. The criteria for identifying these areas includes proximity to lake shorelines, watercourses, springs or wetlands, relict shoreline feature, or know historic land uses and sites.

The first European settlement of the DNS was in 1794. A family cemetery is present on the western part of the DNS (on Lot 24 on the east side of Solina Road). This cemetery is well-removed from the Project site. Preliminary research has also indicated that the remnants of two homesteads, “Raby Cottage” (Lot 19, just west of the southern end of Maple Grove Road) and William Pooley’s 19th-century house (on Lot 18) may occur within the general vicinities of the Project site.

3.5 BIO-PHYSICAL ENVIRONMENT

3.5.1 Geology, Hydrogeology and Seismicity

The geology of the DNS is composed of glacial, glacio-lacustrine, and glaciofluvial deposits. The upper bedrock is Ordovician, composed of the Lindsay and Verulam Formations, which are characteristically 120 metres of fine grained argeillaceous to shaly limestones, buried beneath up to 10 metres till at the lakeshore. This is underlain by the Bobcaygeon and Gull River limestones which are an additional 75 metres thick, sitting on top of the crystalline gneissic rocks of the Precambrian basement. Testing of these limestone rock structures has generally indicated a very low permeability stratigraphy.

A sand, gravel, and cobble beach exists at the base of the steep shoreline cliffs that are found to the east and west of the site. The north shore of Lake Ontario was originally a steep to near vertical shore cliff rising 12 to 30 m above the lake water level. The construction of the Darlington NGS reclaimed 10 hectares of land from the lake, levelled the bluffs and placed erosion protection along most of the site shoreline. Lake filling required approximately 2 km of new shoreline to be reinforced with armourstone.

Groundwater movement below DNS is from north to south toward Lake Ontario. Perched water table conditions occur locally in small, poorly drained areas. Groundwater in the bedrock occurs in fissures, joints, and bedding planes that generally occur in the fractured upper surface. The extensive soil and bedrock excavation during the DNGS construction affected groundwater flow across the site. Groundwater discharge has been noted in the south west corner of the property in two small ravine features.

The region lies within the tectonically stable interior of North America, which is characterized by low rates of seismicity. The DNS is considered stable, with only minor tremors recorded. The seismic zoning map for the area classifies both the region and the site as only having minor earthquake damage probability. Seismicity of the site, for the purposes of planning new structures, is summarized in the National Building Code of Canada, 2005. The National Building Code of Canada, 2005 provides parameters for 5%-damped horizontal spectral acceleration values for 0.2, 0.5, 1.0, and 2.0 second periods, and the horizontal Peak Ground Acceleration value that has a 2% probability of being exceeded in 50 years. The closest location in the National Building Code of Canada, 2005 to the DNS is Newcastle (Bowmanville).

The values provided in the National Building Code of Canada 2005, which comprise the most recent and reliable data are:

Seismic Data				
$S_a(0.2)$	$S_a(0.5)$	$S_a(1.0)$	$S_a(2.0)$	PGA
0.22	0.12	0.061	0.016	0.12

3.5.2 Hydrology and Water Quality

Surface water drainage in the region consists of several generally parallel watercourses flowing southward to Lake Ontario. Water quality in these streams is typical of urban/rural watersheds in southern Ontario.

The major streams in the local regional drainage basin are offsite to the east (Darlington Creek) and west (Tooley Creek). Darlington Creek traverses the northeast corner of the DNS and discharges to Lake Ontario.

There is a single permanent stream discharging to a ravine on the west side of the site. The ravine is south of the man-made landfill pond, Coot's Pond, which is the largest pond on the property. It was created immediately south of the landfill and west of Park Road at the time of the Darlington NGS construction. Surface water drainage from the landfill goes to the landfill pond, before discharging to Lake Ontario via the stream. Surface water drainage from the north east portion of the site drains off-site to both the north and the east. Treefrog, Polliwog, and Dragonfly ponds are three smaller ponds, located north of the CNR tracks, west of Maple Grove Road, south of the South Service Road, and east of Holt Road. It is anticipated that construction activities will interfere with these ponds and the associated wildlife that inhabit the area in and around the ponds.

Water samples collected from drainage areas on the DNS have been found to have water quality conditions typical of industrial sites in southern Ontario.

3.5.2.1 Lake Ontario

The DNS is located on the northern shoreline of Lake Ontario. Lake currents are predominantly along shore. During the spring-summer-fall period, along-shore currents are biased to the west. During the winter period, along-shore movement tends to be more evenly divided between the west and the east.

The area around DNS is in a zone of active sediment movement, rather than one of net sediment accumulation.

Thermal plume studies were conducted between 1990 and1995, during warm and cold weather conditions. The thermal effect caused by operation of DNGS was considered moderate (≤ 2°C) and localized (detectable within 7 km). The size of the plume varied dependent on the weather conditions, with the plume being slightly larger in warm weather conditions.

The quality of the water in Lake Ontario varies dependent on the proximity of the facility to large urban centres. In general, lake water quality in the vicinity of the DNS has remained consistently good over the life of the facility.

3.5.3 Aquatic Environment

3.5.3.1 Aquatic Species

The fish community in Lake Ontario adjacent to the DNS includes over 25 fish species, mainly alewife, lake whitefish, round whitefish, rainbow trout smelt, white sucker, three spine stickleback, emerald and spot tail shiners.

An electrofishing assessment was performed in September 1998 and April 1999 in Darlington Creek, which cuts across the northeast corner of the site. This study classified this section of the creek as a typical warm water fish community. Typical warm water stream fish species were found with the ephemeral pools associated with the stream (Gartner Lee Limited, 1999). No significant or rare species were noted. Spawning rainbow trout and white sucker were observed in the spring survey just downstream from the site boundary. Species found in the four refuge pools included: brook stickleback, fathead minnow, creek chub, common white sucker, long nose dace, black nose dace, and blunt nose minnow.

Commercial fishing is not a significant industry in the area.

Large numbers of zebra mussels occur in nearshore waters at DNS, which is consistent with the Lake Ontario environment. Due to the rocky lakebottom habitats scoured by wave and current action, the density and diversity of benthic invertebrate organisms are limited in the vicinity of the DNS. The species that are commonly found are those that can tolerate the generally hostile environment along the shorelines.

3.5.3.2 Aquatic Vegetation

Since 2000, lake clarity has changed due to zebra mussels. The result is an increase in algae growth, and the presence of algae in deeper water. Filamentous attached algae grow in great abundance on rocks and other hard surfaces at the Lake Ontario shoreline and on rocky substrates on the bottom of the lake.

The Lake Ontario shoreline in the vicinity of the DNS provides a good growth environment for filamentous attached algae. It is a south-facing shoreline and thus receives greater insolation than a north-facing shoreline. There is also a considerable area of solid substrate on the lake bottom in the vicinity of the DNS, particularly to the east, upon which filamentous attached algae can grow.

3.5.4 Atmospheric Environment

3.5.4.1 Meteorological Conditions

The area in which the DNS is located has warm summers and cold winters. The mean annual temperatures are about 7 to 8 °C. Mean daily temperatures fall below freezing in December through March. The coldest recorded hourly temperature measurement was -30.5°C, and the warmest recorded hourly temperature measurement was 31.5°C.

Precipitation is quite uniformly distributed throughout the year with a slight maximum in the fall season. Total annual precipitation averages about 800 mm (water equivalent) of which about one-fifth occurs as snowfall.

Based on data collected from the DNS Meteorological Tower, at the 10 m elevation, the prevailing winds near DNS are generally blowing from the west, northwest or southwest directions over 50% of the time. Also, there is a high frequency (48%) of light winds (<10 km/hr). Winds are lightest in the summer and strongest in the winter and spring.

National Building Code of Canada, 2005 provides values for design temperatures, precipitation, snow load, and hourly wind pressures. The reliable and up-to-date values provided in the National Building Code of Canada, 2005 are:

Design Temperature				**15 Min. Rain, mm**	**One day Rain. 1/50, mm**	**Ann. Rain, mm**	**Ann. Tot. Ppn., mm**	**Snow Load, kPa, 1/50**		**Hourly Wind Pressures, kPa**	
January		**July 2.5%**									
2.5% °C	1% °C	Dry °C	Wet °C					S_s	S_r	1/10	1/50
-20	-22	30	23	23	86	760	830	1.4	0.4	0.46	0.60

3.5.4.2 Air Quality and Noise

Air quality in the vicinity of the DNS is typical of the general air quality in southern Ontario throughout the Quebec–Windsor corridor and the Greater Toronto Area. In general, the substances that combine to produce smog or acid rain dominate air quality effects: carbon monoxide (CO), nitrogen oxides (NOx), volatile organic compounds (VOCs), sulphur dioxide (SO2), and particulate matter (PM).

The current non-radiological emissions from Darlington NGS include periodic release of steam generator water treatment chemicals associated with steam venting (e.g., hydrazine, ammonia) and combustion gas releases from the testing of stand-by generators and emergency power generators.

Existing noise conditions at the DNS are influenced by several sources: Darlington NGS activities, on- and off-site road traffic, railway traffic on the CNR line, industrial noise from the neighbouring St. Mary's Cement plant, and Lake Ontario shore winds and waves.

3.5.5 Terrestrial Environment

The core off-site natural areas that may interact with the DNS via naturalized connecting linkages include a complex to the west consisting of the provincially significant Oshawa Second Marsh (approximately 9 km westerly), the McLaughlin Bay Wildlife Reserve (approximately 8 km westerly), and Darlington Provincial Park (approximately 7 km westerly), and the provincially significant Westside Marsh approximately 2 km to the east.

Wildlife habitat is associated with the natural areas, vegetation communities and cultural developed sites (buildings and other structures). Six broad vegetation community types exist: shrub bluff, cultural meadow, cultural thicket, cultural woodland, deciduous forest, and wetland.

The DNS provides habitat for breeding and migrant bird species and provides breeding and foraging habitat for a variety of herpetofauna and mammals. The wildlife habitats generally correspond to the vegetation communities described previously. Since 1997, annual breeding bird and amphibian studies have been conducted at the DNS. Over 70 species of breeding birds have been identified. Amphibians that currently breed at the four ponds on the site are American Toad, Northern Leopard Frog, Green Frog, and Gray Treefrog.

The site supports a population of white-tailed deer concentrated in the area immediately east of the landfill. Other mammals reported include a number of small and medium-sized mammal species such as white-footed-mouse, meadow vole, eastern chipmunk, masked shrew, deer mouse, groundhog, and eastern cottontail (2005, Brian Henshaw). American beaver, muskrat, and big brown bats have been reported in the area of Coot's Pond (landfill pond). Predators include the short-tailed weasel, red fox, and coyote.

At least 28 butterfly species, 208 moth species, and 39 species of dragonflies and damselflies have been recorded.

Only one reptile, the garter snake, has been found on the property. Numerous Midland painted turtles have been observed at Coot's Pond since 1997.

Two nationally and provincially rare plant species are present on the Darlington site: the cup plant and sundrop.

No species at risk or endangered species are known to be directly affected by the proposed Project. Thirty-seven acres of woodlot, three ponds, and associated wildlife could potentially be affected by the Project. The shoreline cliffs on the east end of the property may need to be graded due to the construction of DNGS B. These cliffs provide habitat to an unknown number of breeding bank swallows.

3.5.6 Radiation and Radioactivity

OPG conducts environmental radiological monitoring programs in the vicinity of its nuclear generating stations, the results of which are reported on an annual basis to the CNSC. OPG routinely measures the concentration of selected radionuclides in the atmospheric, aquatic, terrestrial, and geophysical environments.

3.5.6.1 Natural Background Radiation

Regardless of where people live or work, they are exposed to baseline sources of radiation from naturally occurring radiation and radioactivity, and anthropogenic sources. OPG's annual report on environmental radiological data summarizes the magnitude and sources of radiation around the DNS, including assessment of background radiation, mainly attributable to ionizing radiation from cosmic rays: naturally occurring radionuclides in air, water, and foo, and gamma radiation from radioactive material in the soil, rocks and building materials used in homes. Natural background radiation accounts for 96.1% of the annual dose estimate to members of the public around Darlington. In addition, people are exposed to anthropogenic sources of background radiation from medical and dental procedures, and from commercial / industrial processes, accounting for 3.8% of the total annual background dose estimate.

3.5.6.2 Workers and Public Dose Management

Regulatory limits on radiation doses to Nuclear Energy Workers (NEWs) and other members of the public off-site, and most visitors (non-NEWs), are specified in regulations under the Nuclear Safety and Control Act. Regulatory limits on radiation doses to NEWs and non-NEWs apply to the sum of doses received via all exposure pathways: airborne, waterborne and direct radiation from licensed nuclear activities. They specifically exclude doses from natural background radiation, and medical and dental procedures.

OPG uses targets and Action Levels for the control and monitoring of radiation doses and radioactivity releases, as components of its As Low As Reasonably Achievable (ALARA) program. OPG has set Exposure Control Levels (ECLs) and targets on radiation doses to NEWs and non-NEWs for activities licensed by the CNSC as described below.

The annual radiation dose to NEWs is subject to an ECL of < 10 mSv per calendar year to prevent workers from approaching regulatory dose limits, set at 50 mSv in any year or 100 mSv over a five year period, and 4 mSv for a pregnant worker over the balance of the pregnancy. In addition, all radioactive work is planned and documented in advance, which can include taking into account anticipated hazards, survey requirements, dosimetry, personal protection equipment, contamination control measures, backout conditions and contingency plans.

To facilitate the control and limitation of radioactivity releases to air and water, OPG has calculated Derived Release Limits (DRLs) (OPG 1999b) based on a methodology approved by the CNSC. A DRL is the release rate for a radionuclide or a group of radionuclides that would result in the average member of the critical group (most exposed group of members of the public) receiving an annual dose of 1 mSv, the regulatory limit for a member of the public other than an NEW. For members of the public, OPG has a dose rate target at the exclusion zone boundary of less than or equal to $\leq$10 μSv/y (less than 1 % of the public dose limit). Operational targets for radionuclide releases are set at a small fraction of the DRL to avoid the possibility that the dose limit could be exceeded.

OPG maintains the worker doses as ALARA through a number of policies, practices and procedures (OPG 2003a) including:

- Shielding;
- Radioactive work planning;
- Control of access to areas of high activity or possible contamination;
- Protective clothing;
- Respiratory Protection;
- Alarming dosimetry control devices;
- Fixed alarming instruments; and
- Decontamination practices.

Furthermore, OPG maintains minimal exposures to the surrounding populations by operating well within the regulatory dose limits. In addition to operating within the regulatory limits, OPG uses the DRLs, and monitoring to confirm that emissions/doses are below target levels as part of their ALARA program. ALARA activities include:

- Monitoring and controlling the routine releases of radioactive material to the environment;
- Prohibiting any permanent habitation within the DNS;
- Excluding all unauthorized persons from the DNS;
- Maintaining dose rates at the boundary fences within the dose rate targets for DNS operations as described in the Safety Report(s);

OPG uses the results from these monitoring programs and procedures to calculate the effect on the population based on the highest dose to any of the Critical Groups around the DNS. The assessment completed in 2005 demonstrated that the maximum dose due to the operation of DNGS was 0.9 μSv. This is 0.09 % of the annual legal limit of 1,000 μSv or 1 mSv, and 0.05 % of the annual average Canadian background radiation dose of 1,840 μSv.

4.0 Consultations Held on the Project

4.1 CONSULTATIONS TO DATE ON THE PROJECT

On September 21, 2006 OPG announced that it had begun the federal approvals process for new nuclear generation at the Darlington site. Since then OPG has undertaken a number of communications and consultation activities with respect to the Project. These are described in the following sections.

4.1.1 Notifications and Announcements

OPG issued a media release on September 22, 2006, notifying the public in general that it had submitted an application for a site preparation licence. The following publications ran articles in response to the release.

Table 4.1: Summary of Media Coverage of Site Preparation Application

Paper	Date	Article Title
The Globe and Mail	September 23, 2006	Ontario Power sees new reactor at Darlington; utility files site preparation licence to expand province's nuclear capability
The Toronto Star	September 23, 2006	OPG seeks okay for 2 new reactors
The National Post	September 23, 2006	Darlington eyed for nuclear expansion
Clarington This Week	September 24, 2006	OPG begins approvals process for new build at Darlington
Clarington This Week Whitby This Week Oshawa This Week	September 27, 2006	They Like Us, They Really Like Us! (editorial)
The Globe and Mail	September 27, 2006	OPG not ready to say 'I do' to AECL's Candu; Will keep options open on technology
Clarington This Week Whitby This Week Oshawa This Week	September 28 , 2006	Darlington ideal for new nukes (editorial)

4.1.2 Notification Letters

In November 2006, OPG distributed a letter announcing the commencement of the site preparation licensing activity and inviting respondents to attend community information sessions. The letter was distributed to approximately 150 local stakeholders (including local elected officials, federal, provincial and municipal agencies and authorities, community groups and organizations, Aboriginal organizations and First Nations, and others who have attended Darlington Nuclear licensing activities).

4.1.3 Newspaper & Radio Advertising

OPG ran advertisements in local newspapers during the week of September 25, 2006 informing the community that it had submitted an application for a site preparation licence. The advertisements noted that OPG would hold community information sessions in the upcoming months.

OPG ran advertisements inviting the public to attend community information sessions during the last weeks of November 2006 in the newspapers listed below on the dates indicated. The total circulation of these four papers is approximately 121, 000.

Paper	**Run Dates**
The Canadian Statesman	November 15th, 22nd
The Orono Times	November 15th, 22nd
Oshawa This Week	November 17th, 19th, 24th, 26th
Clarington This Week	November 17th, 19th, 24th, 26th

A radio advertisement inviting the public to attend the community information sessions ran for six days, three times a day on three radio stations throughout Clarington and Oshawa. The radio stations and advertisement run dates are indicated below.

Radio Station	**Dates**
KX96 FM - New Country	November 15 – 21, 2006
CKGE FM - New & Classic Rock	November 15 – 21, 2006
CKDO AM - Golden Oldies	November 15 – 21, 2006

4.1.4 Web Site

A Project Web site was established on September 22, 2006. The Web site serves as a vehicle to provide access to information, as well as a mechanism to receive input from interested persons as an enhancement of the public consultation program. Automated features include feedback forms and forms to request briefings or presentations.

To date, OPG has received a number of inquiries through the Web site, mainly with respect to the project timeline and the Environmental Assessment (EA). Since its inception, the Project Web site has had an average of 3,000 visitors to the home page per month.

4.1.5 Information Line

A 1-800 information line was established in September 2006. It is answered in person during regular business hours. When not answered in person, the dedicated line informs callers how to obtain details and/or more information about the project. Messages are checked and responded to within 48 hours and all comments are incorporated into the stakeholder comment database with any follow-up required.

To date, OPG has received a number of inquires through the information line, largely with respect to the Community Information Sessions, which took place in November 2006.

4.1.6 Public Information Materials

In November 2006, OPG published a new public information brochure on new nuclear generation at the Darlington site. It is available on the Project Web site and at all OPG Nuclear Information Centres. In addition, OPG has provided to the public:

- Copies of Powerpoint presentations and panels used in the community information sessions (see section below)
- Copies of the CNSC Licensing Guide to new Nuclear Power Plants
- Copies of the Site Preparation Application.

4.1.7 Stakeholder Briefings and Interviews

OPG briefed the Municipality of Clarington, the Darlington Site Planning Committee and the Durham Nuclear Health Committee on the initiation of the project and associated licensing activities.

In February and March of 2007, OPG also sought the views of key stakeholders, including federal authorities, provincial, regional and municipal governments, Aboriginal groups, and repesentatives of civil society (including labour, education, business, energy and environmental interests). Approximately eighty stakeholders were invited to attend one of a number of briefings on the Project. The purpose was to share information and to obtain feedback on the proposed nature of the project and related works and activities, including the approach to consideration of alternative means, and preliminary identification of potential project – environment interactions.

Feedback in these sessions has primarily been in the following areas:

- **Environmental Assessment (EA) requirements and process:**
  - Does the technology decision impact the bounding dates for the EA?
  - Would the reactor design need to be confirmed before the EA process can proceed? If not what are the risks?
  - Does the EA look at the full life-cycle of the station?

- **Reactor technology selection and capacity:**
  - What range of technologies is being considered?
  - Who is making the technology decision?
  - Are there significant environmental differences between the different reactor technologies?
  - How many megawatts is OPG planning for? The Project Description is for four reactors but the plan is for two. How will this work?

- **Site development considerations:**
  - What is the rationale for the selection of Darlington?
  - Has the Province decided that this is the location for new nuclear generation?
  - Be clear as to whether alternative sites are limited to the property at Darlington or if other property owned by OPG will be considered.
  - What will be the size of the units?
  - With such long timeframes, how do you respond in the long term to changes to the environment?

- **Nuclear waste management:**
  - The challenge of nuclear waste is the most significant issue.
  - Will waste be contained at the site? How long will used fuel be at the site?
  - Over what time frame do you need to consider waste management at site? I.e. how far into the future do you plan for?

- **Public communications and consultation:**
  - Try and set some context around the use of the term abandonment. If it is strictly a licensing usage that should be made clear, otherwise it may suggest a “walk away” attitude.
  - Have there been any public notices yet? What issues have been identified by the public?

4.1.8 Community Information Sessions

OPG held a series of five Community Information sessions during the month of November 2006, to share information, describe key activities and communicate progress. Approximately 200 people attended these sessions. Four areas of discussion emerged throughout the sessions that pertain directly to new nuclear generation. They include the following:

- There is interest in the matters that will be considered when choosing a reactor technology and vendor, specifically:
  - What type of fuel would be used, and whether the use of enriched fuels would be considered;
  - Whether AECL and CANDU technology would be used, and if not, what other vendors and technologies exist;
  - Cost, waste and environmental considerations of each reactor type; and
  - Who will decide – government or OPG?

- There is interest in the timelines to bring new generation into service, particularly in the length of time required to complete all the approvals:
  - Why would it take 9 – 12 years to bring new nuclear generation into service at an existing site with an existing nuclear power plant; and
  - How this timeline benchmarks with other countries.

- There is interest in how nuclear waste is to be managed, and concern that long-term plans are not in place for waste management. Specifically there is interest in:
  - Whether and what type of nuclear waste would be stored at the site; and
  - The status (or lack) of a program for long-term management of the waste streams, particularly used fuel.

- There is interest in the matters that were considered in selecting the Darlington site, specifically:
  - How that was done and whether other sites (such as Wesleyville) were considered;
  - Whether the proximity to St. Mary’s Cement poses a problem;
  - How many reactors will be built and how much land will be needed; and
  - How the determination of a willing host will be made.

A range of other matters were raised in the sessions including questions pertaining to the licensing and environmental assessment process and economic and employment considerations. A report of these Community Information Sessions is available at www.opg.com/newbuild.

4.1.9 Community Outreach

OPG has also attended at a number of community events to provide information on the proposed Project to residents and the general public, and to answer questions and receive their comments. These events have included:

- Whitby Rotary Club (January 30 2007)
- Pickering-Ajax-Uxbridge Energy Forum (February 24, 2007)
- Canadian Nuclear Association Winter Seminar (February 28 – March 1, 2007)
- Oshawa Spring Home and Garden Show (March 16 – 18, 2007)

Through participation in these types of community events, OPG has engaged approximately 500 people directly in discussions about the Project. Feedback has been largely to obtain clarification of the nature of the Project and approvals process, including

- Clarification of the types of reactor technologies being considered,
- Questions about the length of time it takes to conduct an environmental assessment;
- Inquiries about the nature and timing of employment opportunities;
- Questions and concerns about long-term nuclear waste management; and
- Questions about energy supply in the near term (i.e. next 8 – 10 years).

4.1.10 OPG Employee Consultation Activities

OPG has held three employee information sessions on the Project, sessions in which project related information is available for staff to review, and Project staff are on hand to respond to any questions employees may have. It has also included articles in the following employee newsletters:

- OPG Today
- OPG Power News
- Darlington On Site

4.2 PROJECT DESCRIPTION DISTRIBUTION LIST

Government agencies that may have an interest in the proposed Project, and thus may wish to be included in the distribution list for this Project Description document, are as follows:

- Environment Canada (EC);
- Natural Resources Canada (NRCan);
- Health Canada (HC);
- Department of Fisheries and Oceans (DFO);
- Department of Indian Affairs and Northern Development (DIAND);
- Transport Canada (TC);

- Ontario Ministry of the Environment (MOE);
- Ontario Ministry of Culture and Heritage (MCH);
- Ontario Ministry of Natural Resources (MNR), including Central Lake Ontario Conservation Authority (CLOCA);
- Ontario Ministry of the Solicitor General, specifically Emergency Management Ontario;
- Regional Municipality of Durham;
- Municipality of Clarington;
- Durham Regional Health Department.

4.3 OPG CONTACT PERSON

The contact person for additional information on the Project Description is:

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ABBREVIATIONS AND ACRONYMS

BWR	Boiling Water Reactor
^{o}C	Degrees Celsius
CLOCA	Central Lake Ontario Conservation Authority
CN	Canadian National
CNSC	Canadian Nuclear Safety Commission
CO	Carbox Monoixide
DFO	Department of Fisheries and Oceans
DIAND	Department of Indian Affairs and Northern Development
DNEER	Darlington Nuclear Ecological Effects Review
DNGS	Darlington Nuclear Generating Station
DNS	Darlington Nuclear Site
DUFDS	Darlington Used Fuel Dry Storage
DWMF	Darlington Waste Management Facility
EA	Environmental Assessment
EC	Environment Canada
Ha	Hectare
HC	Health Canada
IPSP	Integrated Power System Plan
ISO	International Standards Association
Km	Kilometre
km /h	Kilometres per Hour
kPa	Kilo Pascals
kV	Kilo volt
L & ILW	Low and Intermediate level waste
M	Meters
MCH	Ontario Ministry of Culture and Heritage
Mm	Milimeters
MNR	Ontario Ministry of Natural Resources
MOE	Ontario Ministry of the Environment
MW(e)	Megawatts
NEW	Nuclear Energy Worker
NGS	Nuclear Generating Station
NOx	Nitrogen Oxides
NRCan	Natural Resources Canada
NSCA	Nuclear Safety and Control Act
NWMO	Nuclear Waste Management Organization
OEB	Ontario Energy Board
OPA	Ontario Power Authority
OPG	Ontario Power Generation Inc.
PGA	Peak ground acceleration
PHR	Pressurized Hybrid light and heavy water Reactor
PHWR	Pressurized Heavy Water Reactor
PM	Particulate Matter
PPE	Plant Parameter Envelope
PPN	Precipitatioin
PWR	Pressurized light Water Reactor

S_a	Spectral Acceleration
SMD	Supply Mix Directive
SO2	Sulphur Dioxide
TC	Transport Canada
μSv	Micro Sievert
VOCs	Volatile Organic Compounds

APPENDIX A:

Plant Parameter Envelope Description

&

Reactor Technology Descriptions

1.0 INTRODUCTION

The purpose of Attachment A to the Project Description for the Site Preparation, Construction, and Operation of a new Nuclear Power Generation Station at the Darlington Nuclear Site (DNS) is to provide information on:

- The Plant Parameter Envelopes that will be developed for the purpose of evaluating the safety and potential environmental effects of the multiple reactor designs, and
- The multiple reactor technologies that are being considered for the site.

2.0 PLANT PARAMETER ENVELOPE

Plant Parameter Envelopes (PPE) is a concept that was developed in the United States of America for use in the Early Site Permitting (ESP) process for new nuclear power generating stations. The PPE concept creates a bounding envelope that is used to assess the potential safety and environmental effects of a nuclear generating station at a particular site when a design has not been selected. Prior to obtaining permission to construct a new facility, the actual design selected would be reviewed to ensure that the design fits within the bounding envelope.

The PPE approach has been incorporated into three of the four applications to the United States Nuclear Regulatory Commission (USNRC) for ESPs. PPEs used in these applications were subjected to public reviews and comments in the environmental assessment process applied by the USNRC, and have been accepted by the USNRC.

<u>Use of the PPE Concept for the Darlington Nuclear Site</u>

OPG is considering several types of reactor designs for the potential new nuclear power generating station at the Darlington Nuclear Site (DNS). Therefore, OPG has decided to use the PPE approach.

The PPEs will be developed to describe a range of different nuclear plant designs by using the limiting value (the value that has the greatest potential to result in an adverse environmental effect) from the different nuclear plant designs under consideration for each parameter in the PPE. The following types of information regarding the interfaces between the proposed site and nuclear plant will be included in the PPEs:

- site characteristics that are required to support the safe operation of a nuclear plant (e.g., cooling water, ambient air temperature, etc.);
- the capability of the nuclear plant to withstand the natural and man-made environmental hazards associated with the site (e.g., earthquake, tornado, potential floods from nearby dams, snow load, rainfall, etc.); and
- the impact of the nuclear plant on the site's natural and environmental resources (e.g., potential increases in water and air temperatures, gaseous and liquid releases of radioactive material).

The PPEs will group the reactor designs into classifications based on technological similarities, i.e., Pressurized Heavy Water Reactors, Pressurized Water Reactors, Boiling Water Reactors, and Pressurized Hybrid light and heavy water Reactors. The most limiting values for the reactors that are considered in each classification will ensure that the PPEs are conservative.

The level of conservatism associated with the PPEs, in turn, ensures that the site is acceptable for a specific reactor design that falls within the bounds of the PPE features / values.

As part of the PPEs, OPG will provide information on the radiological impacts on members of the public from gaseous and liquid effluents that would occur during normal operation of the nuclear power plants. Estimates of the maximum normal operation doses to the public for each reactor class considered will be based on a composite of the bounding available data on liquid and gaseous radiological effluents for the vendor-specific reactor designs being considered in that class.

Further, as part of the PPEs for the Darlington site, OPG will provide information on doses to the public due to design basis accidents for the nuclear power plants being considered in all reactor classes. Estimates of the maximum accident doses to the public will be based on the analysis of a selection of credible design basis accidents for the different reactor designs considered within each classification.

Margins may be added to the normal operations and accident doses to the public cited in the EA to allow for greater conservatism in the range of vendor-specific designs considered in the PPEs.

The PPEs will also provide:

- A means of comparing several nuclear reactor class options, and
- A clear summary of the limiting values of relevant parameters for those classes of reactor design that would be addressed in the comprehensive study.

Therefore, the PPEs will support the consideration of "alternative means of carrying out the project that are technically and economically feasible and the environmental effects of any such alternative means" (clause 16(2)(b) of the Canadian Environmental Assessment Act).

3.0 REACTOR TECHNOLOGIES

OPG is considering several types of nuclear reactors for potential construction and operation at the Darlington Nuclear Site. The reactor technologies under consideration have been grouped, based on key environmental characteristics, such as the emissions from normal operations and from potential accidents and malfunctions, into the following classes:

- Pressurized Heavy Water Reactors (PHWRs), with designs such as the Enhanced CANDU-6 (EC6);
- Pressurized Water Reactors (PWRs), with designs such as the EPR, AP1000, APWR, OPR 1000, and APR 1400;
- Boiling Water Reactors (BWRs), with designs such as the ABWR and the ESBWR; and
- Pressurized Hybrid light/heavy water Reactors (PHRs), with designs such as the ACR-1000.

All of the reactor designs use uranium dioxide (UO2), clad in zirconium alloy tubing, to form fuel rods that range in diameter and length. These fuel rods are arranged into bundles or assemblies of various dimensions and complexity, depending on the reactor design. The fuel used by the reactor designs differ in the percentage of the fuel that is U235.

The nuclear fuel in the reactor core provides heat to the reactor coolant, which is then used to generate steam, which in turn is used to drive turbines for electricity production. Most reactor designs (e.g., PHWR, PWR and PHR) utilize steam generators and an independent secondary cooling system (i.e., separated from the primary reactor coolant by the steam generators) to generate steam to drive the turbines. BWRs do not have a separate secondary cooling system; therefore, the steam used to drive the turbines comes directly from the reactor core (i.e., referred to as direct cycle). As a result, the turbines in a BWR plant must be appropriately shielded.

All of the previously mentioned reactor designs are equipped with special safety systems or features that mitigate the consequences of postulated accidents. Reactor control and shutdown systems are available to shut the reactor down rapidly. Emergency core cooling systems are available to rapidly provide alternate cooling to the reactor core. Low leakage rate containment buildings are built around the reactor to retain radioactive fission products should they be released from the reactor core during an accident. In recent reactor designs, more passive safety systems have been introduced (i.e., those that don't rely on active components, such as timely valve and/or pump operation, to perform their safety function).

The following sections, prepared using publicly available information, contain brief summaries of the reactor technologies.

3.1 Pressurized Heavy Water Reactor (PHWR)

<u>Introduction</u>

PHWRs use natural uranium as fuel and heavy water (i.e., deuterium) as the moderator and heat transport fluid. All of the power reactors operating in Canada are PHWRs. The Enhanced CANDU 6 reactor developed by Atomic Energy of Canada Ltd. (AECL) is the currently available PHWR reactor design. The Enhanced CANDU 6 (EC6) reactor design is based on the CANDU 6 design built in Qinshan, China. As the features of the EC6 have many key features in common with the CANDU 6 reactor, the latter is used in this discussion. The CANDU 6 produces a gross output of 728 MWe with 1336 MWth of waste heat to the condensers. The global CANDU 6 fleet has an average lifetime capacity factor of 88% (up to 2004), although the Korean CANDU 6 fleet has a lifetime capacity factor of 92.2%.

<u>Normal Operation</u>

The Heat Transport System (HTS), which provides core cooling during normal operation contains 4 steam generators and 4 pumps arranged into two "figure of eight" cooling loops (refer to Figure 3.1.1).

A "figure of eight" loop is shown schematically in Figure 3.1.2. Coolant picks up heat from the fuel in the fuel channels (described in next subsection) and then travels via the outlet feeders into an outlet header. Coolant from a number of channels (i.e., usually either a quarter or a half of all the fuel channels in the core) mixes in the outlet header before passing to a steam generator where heat is exchanged to generate steam to drive the turbines via a secondary cooling system. The cooled primary side coolant from the steam generator outlet then moves on to a pump that drives the coolant into an inlet header, which supplies the coolant to the inlet feeders connected to the fuel channels that comprise the reactor core. The figure of eight loop is completed by an identical, reversed circulation sequence on the opposite side of the core.

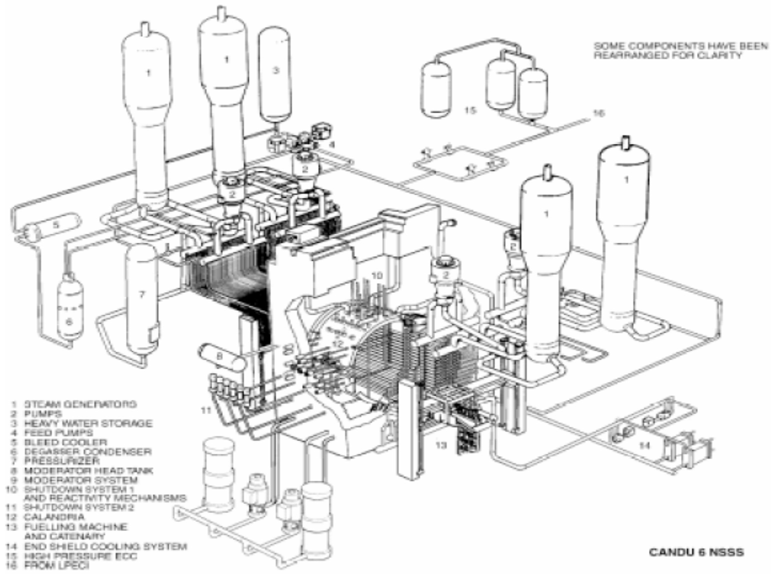

Figure 3.1.1

The HTS pressure is controlled with a pressurizer and a 'feed and bleed' storage/condenser system. There is also a shutdown cooling system to handle decay heat under shutdown conditions. The steam generator design includes preheaters to improve plant efficiency.

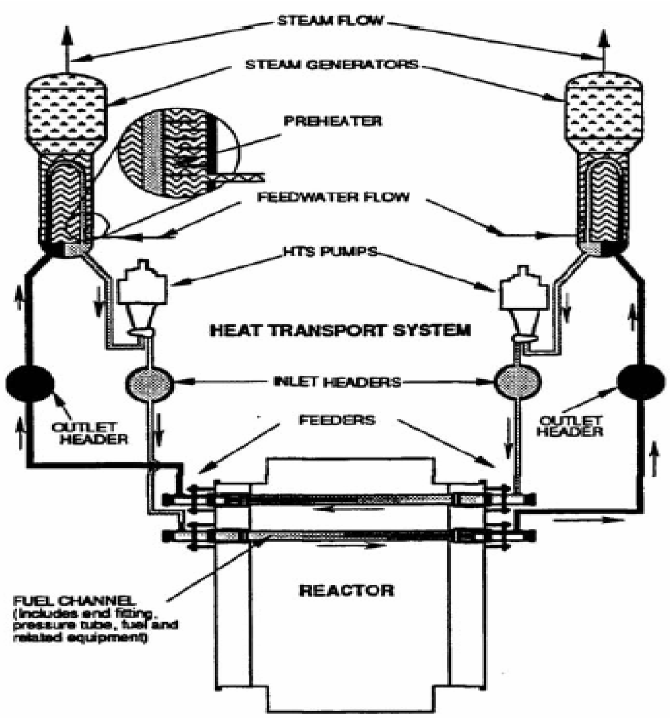

Figure 3.1. 2

Reactor Core

The CANDU 6 reactor core (refer to Figure 3.1.3) has 380 fuel channels filled with fuel bundles, horizontally arranged within a cylindrical vessel called a calandria, which is otherwise filled with heavy water moderator at slightly above atmospheric pressure and at a temperature of 70-80°C. The moderator is cooled by an independent heat exchanger and circulation system and also acts as a passive heat sink under accident conditions.

Horizontal and vertical reactivity control devices pass through the moderator between the fuel channels. Vertical reactivity absorber rods provide power maneuvering capabilities for large power changes, reactor startup and reactor shutdown. They also assist in flattening of the core power distribution in conjunction with the fuelling scheme. Long-term control of the power distribution and reactivity in a CANDU 6 reactor is achieved mainly through on-power fuelling. Short-term reactor control is performed by the Reactor Regulating System (RRS), which includes a set of in-core self-powered flux detectors, and a digital control system for vertical, refillable tubes containing light water called Liquid Zone Controllers. Gadolinium and boron can also be added to or removed from the heavy water moderator, for long-term reactivity adjustment.

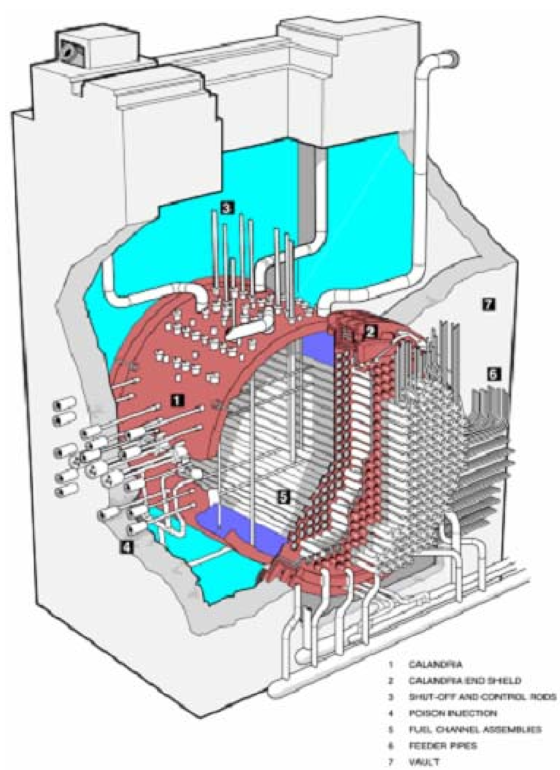

Figure 3.1.3

The calandria is enclosed by end shields (refer to Figure 3.1.4), which typically contain light water and carbon-steel balls. The end shields support the fuel channels and provide shielding of the reactor vault to limit activation during operation, and to permit access for maintenance during plant shutdown. The end shields are embedded within the walls of a concrete reactor vault. The space between the cylindrical exterior of the calandria and the flat interior walls of the vault is filled with light water and is called a shield tank. The shield tank provides shielding of the reactor vault from neutrons and gamma rays.

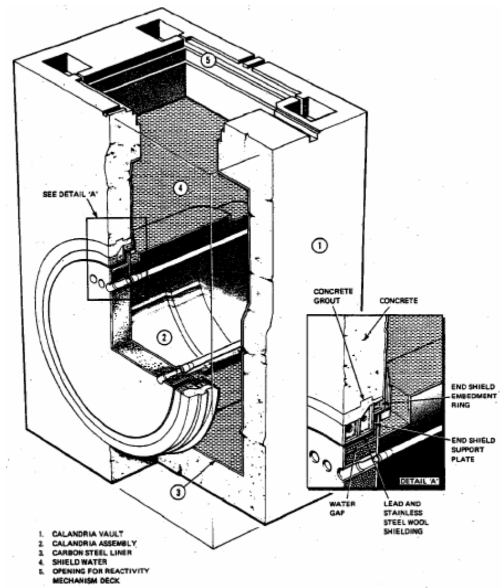

Figure 3.1 4

Each fuel channel is comprised of a thicker walled zirconium alloy Pressure Tube (PT) inside a concentric Calandria Tube (CT), two endfittings, two closure plugs and 12 fuel bundles (refer to Figure 3.1.5). The PT, CT and the annulus between the PT and the CT separate the cool, low-pressure moderator from the hot, pressurized coolant. The annulus between the PT and CT contains a gas, which can be tested for moisture to detect leaks. The end-fittings include closure plugs, which are accessible by robotic fuelling machines, and this allows for on-power fuelling. This feature eliminates the need for outages to replace fuel and helps increase the overall capacity factor of the CANDU 6 design.

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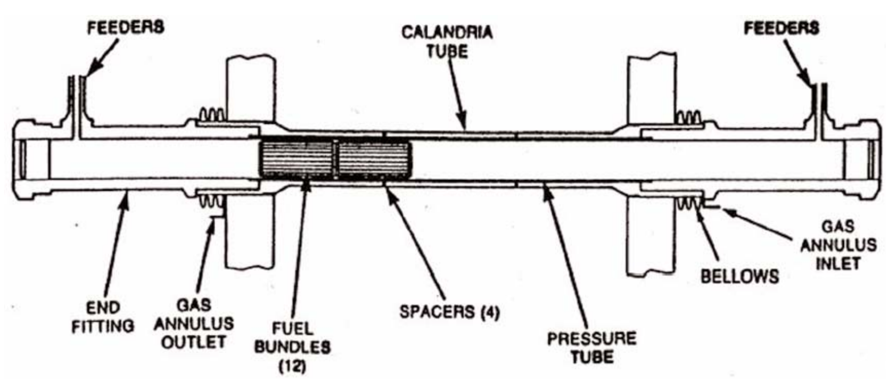

Figure 3.1.5

Fuel Design

CANDU 6 fuel consists of compressed and sintered pellets of natural uranium dioxide (0.72 % U-235 in total U) clad in Zircaloy tubes to form elements. These elements are then assembled into fuel bundles about a half meter long by welding the elements onto circular end plates (refer to Figure 3.1.6). Current CANDU-6 reactor fuel designs have 37 elements.

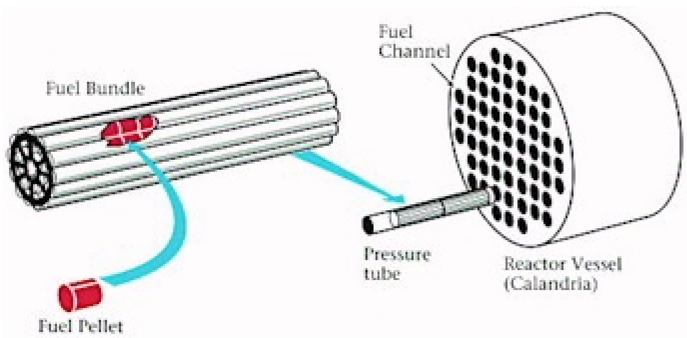

Figure 3.1.6

Special Safety Systems

The CANDU 6 has four special safety systems: Shutdown System 1 (SDS1), Shutdown System 2 (SDS2), the Emergency Core Cooling System (ECCS), and the Containment System.

The two safety shutdown systems are physically and functionally separate from each other and from the RRS. Each SDS is independently capable of shutting down the reactor and is passively driven once tripped. SDS1 consists of mechanical shutoff rods that drop vertically into the core by gravity with a spring assist. SDS2 uses pressurized tanks to inject concentrated gadolinium nitrate solution into the moderator through nozzles, which horizontally span the calandria.

The ECCS provides fuel cooling in the event of a loss of coolant accident (LOCA). The ECCS incorporates three stages: high-pressure injection, medium-pressure injection, and low-pressure recirculation. The high-pressure injection stage uses pressurized tanks to inject water into the HTS for rapid makeup of coolant water. The medium-pressure stage supplies water by pump from a storage tank. The low-pressure recirculation stage recovers water that has been collected at the sump in the basement of the reactor building and pumps it back into the HTS via heat exchangers, for long-term cooling.

The function of the containment system is to provide a post-accident environmental barrier. The containment system includes the containment building and the containment heat removal and isolation system, which relies on an active spray system for pressure suppression (i.e., located just below the dome of the containment building), in combination with a filtered air discharge system.

List of Acronyms

AECL – Atomic Energy of Canada Ltd.
CANDU – CANada Deuterium Uranium
CT – Calandria Tube
EC6 – Enhanced CANDU 6
ECCS – Emergency Core Cooling System
HTS – Heat Transport System
LOCA – Loss of Coolant Accident
MWe – Megawatts electric
MWth – Megawatts thermal
PHWR – Pressurized Heavy Water Reactor
PT – Pressure Tube
RRS – Reactor Regulating System
SDS 1 – Shutdown System 1
SDS 2 – Shutdown System 2

Sources

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3.2 Pressurized Water Reactor (PWR)

Introduction

PWRs use enriched uranium fuel and light water for cooling and moderation. Three PWR designs have received Design Certification from the USNRC: the System 80+ (1300 MWe), and the AP1000 (1117-1154 MWe). All three of these certified designs were developed by Westinghouse, although none have yet been constructed. The US-APWR (1700 MWe), designed by Mitsubishi Heavy Industries, is undergoing design certification review by the USNRC. It is based on the Japanese APWR, two of which are planned for construction in Japan. The 1600 MWe EPR (i.e., European Pressurized Water Reactor in Europe, and Evolutionary Pressurized Water Reactor in the U.S.), designed by Areva NP, is currently undergoing pre-application review by the USNRC (i.e., review prior to the submission of a design certification application). One EPR is currently being built in Finland, with another authorized for construction in France. Korea Hydro and Nuclear Power also markets two PWR designs, the OPR 1000 and the APR 1400.

The following discussion will use the AP1000 as an illustrative example of currently available PWR technology.

Normal Operation

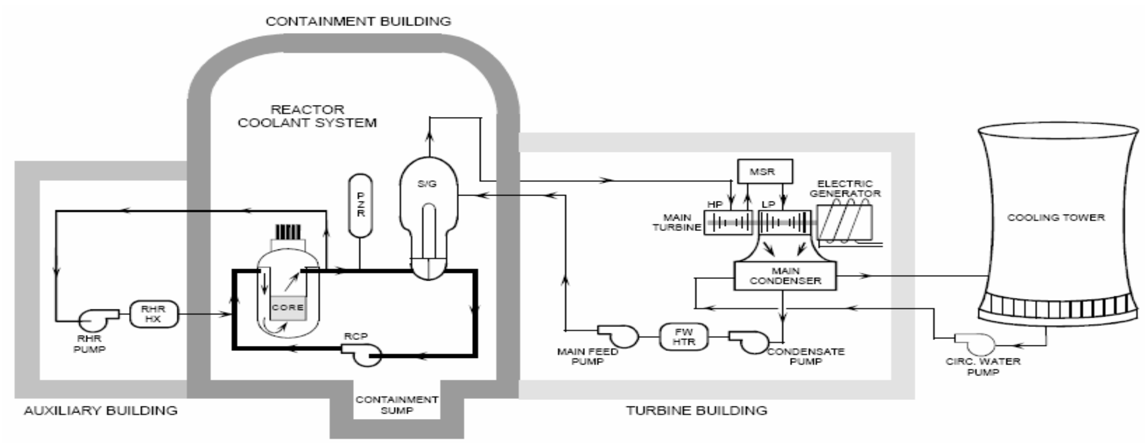

Figure 3.2.1

PWR core cooling and moderation are provided by light water. The coolant is circulated by means of the Reactor Coolant System (RCS) pumps at typical conditions of 15.5 MPa and 315°C. The RCS is shown schematically in Figure 3.2.1. Coolant enters the reactor at about mid-height and flows down the outside of a barrel surrounding the core to the bottom of the reactor. The coolant then reverses and flows upwards past the fuel assemblies in the core, where the coolant removes heat before mixing in an upper plenum. The coolant is circulated through between 1 to 4 cooling loops, depending on the PWR design. Each cooling loop contains a steam generator and pump. A single pressurizer, connected to one of the coolant loops, maintains pressure for the RCS.

The RCS exchanges heat with a secondary cooling system via the steam generators. Within the steam generators, cooler, non-radioactive water fed from the secondary cooling system is forced upwards past inverted U-tubes containing hot, radioactive water from the RCS and is converted to steam at approximately 6.2 MPa and 275°C. The steam then passes outside of the reactor containment building through a main steam line to a turbine, which subsequently turns a generator. The steam from the turbine then condenses in a condenser, which is part of a tertiary water-cooled loop. This water may be supplied by a natural body of water or alternatively, tertiary heat removal may be provided by cooling towers, depending on the environmental characteristics of the site. The condensed water is then pumped across feedwater heaters before it is returned to the steam generators. Preheating the water in feedwater heaters improves thermal efficiency and also prevents thermal shock in the steam generators. The use of a secondary cooling system eliminates the need for radioactive shielding in the building containing the turbine.

In the AP1000 design, there are two steam generators, each connected to the reactor pressure vessel by a single hot leg and two cold legs (refer to Figure 3.2.2). A pressurizer is connected to one of the hot legs and there are four reactor coolant pumps to provide circulation in the RCS. RCS operating pressure is expected to be 15.5 MPa, with a hot leg temperature of 321°C.

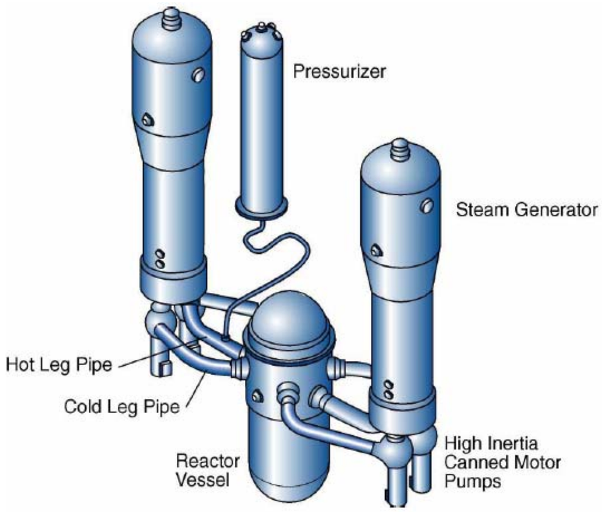

Figure 3.2.2

Reactor Core

A PWR consists of a thick pressure vessel (refer to Figure 3.2.3) containing typically 150 to 250 fuel assemblies as well as dozens of reactivity control/absorber rods, which are inserted from above, directly into the fuel assemblies.

Mechanical reactivity control is provided by two types of control rods, which together comprise the control rod drive system. Both types of control rods consist of neutron-absorbing rods fastened at the top end to a common spider assembly. The control rods assist primarily in controlling core power distribution, but are also used as the primary shutdown mechanism for normal operation, transients and accidents.

Chemical reactivity control is achieved by changing the concentration of soluble boron absorbers in the reactor coolant. Boron concentration is used to compensate for slow reactivity changes during operation, reactivity changes during start up, power changes, and for shutdown and is adjusted to obtain optimum positioning of the control rods. Also, boron concentration is used to provide shutdown margin for refuelling operations, maintenance or emergencies.

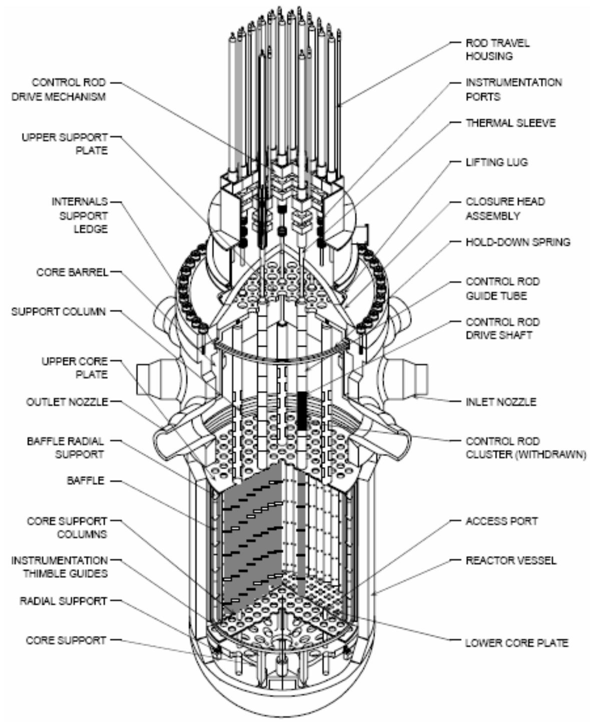

Figure 3.2.3

<u>Fuel Design</u>

A PWR uses enriched uranium (typically ranging between 3.6 and 4.1 wt. % U235 in total U), Zircaloy clad fuel rods arranged in vertical fuel assemblies, which are approximately 4 meters in length.

AP1000 fuel assemblies consist of 264 fuel rods in a 17x17 square array. The fuel rods consist of cylindrical, ceramic pellets of slightly enriched uranium dioxide. Fuel assemblies of three different enrichments (2.35, 3.40 and 4.45 wt.%U235 in total U) are used in the initial core loading. The two lower enrichments are interspersed to form a checkerboard pattern in the central portion of the core, with the highest enrichment fuel contained in the periphery of the core. The pellets are slightly dished to better accommodate thermal expansion and fuel swelling, and to increase the void volume for retention of fission products that are released from the fuel matrix. The pellets are contained in ZIRLO tubing (an advanced zirconium-based alloy), which is plugged and seal-welded at the ends to encapsulate the fuel. The fuel rods are designed with upper and lower plenums to accommodate fission gas release. The fuel rods are also internally pressurized with helium to minimize clad stresses under reactor coolant operating pressures and aid in heat conduction. Reloaded cores are anticipated to operate approximately 18 months between refuelling and studies have shown that the AP1000 reactor can also operate with a full core loading of mixed oxide (MOX) fuel.

Special Safety Systems

The AP1000 has two passive safety systems: the Passive Core Cooling System (PXS), which provides direct cooling to the reactor, and the Passive Containment Cooling System (PCS).

The PXS maintains core cooling by utilizing three sources of water: Core Makeup Tanks (CMTs); accumulators; and an In-containment Refuelling Water Storage Tank (IRWST) (refer to Figure 3.2.4). Two CMTs are designed to accommodate small leaks in the RCS, using gravity as a driving force. The CMTs are also used during large break loss-of-coolant accidents (LOCAs) to rapidly reflood the reactor core. Two accumulators are designed to meet the need for higher initial makeup flows during large LOCAs. Gas pressure forces open check valves that normally isolate the accumulators from the RCS.

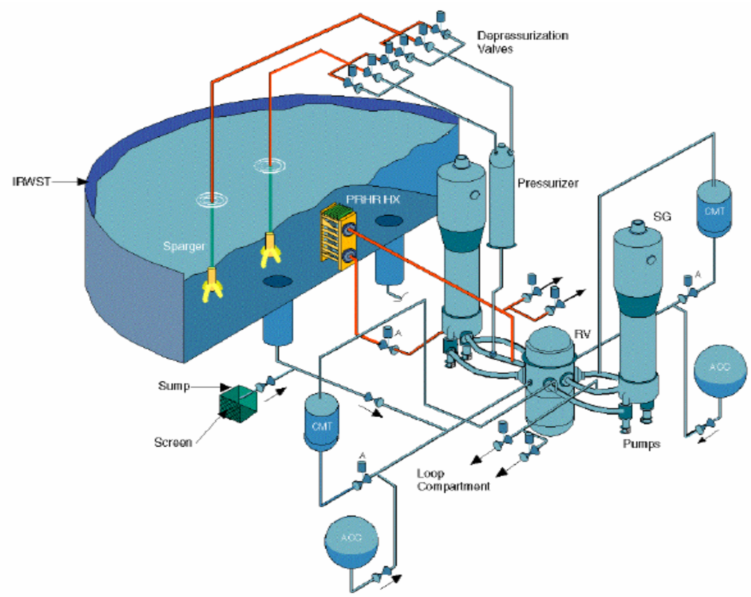

Figure 3.2.4

The IRWST provides long-term injection water at low pressure (i.e., atmospheric) during a LOCA. Under such conditions, evaporating water from the RCS will rise towards the top of the containment vessel and condense on its cool inner surface (i.e., the inner surface is cool due to the operation of the PCS), thus providing a means for heat exchange with the PCS. The condensed water is then collected in the IRWST, which is located near the base of the containment vessel, but still above the PCS. The IRWST in turn feeds the RCS. Long term cooling is facilitated by this closed-loop cycle.

The PXS also contains a Passive Residual Heat Removal system (PRHR), to protect the plant against transient upsets to the steam generator feedwater and steam systems. The PRHR consists of a bank of tubes connecting the IRWST to the RCS in a natural circulation loop. The PRHR is normally isolated from the RCS by closed valves, which will fail open if power is lost. The IRWST water volume is sufficient to absorb decay heat for about 2 hours before the water would start to boil. After that, steam will be generated and enter containment. This steam would then condense on the interior of the containment vessel and drain back into the IRWST in a similar closed loop cycle to the one described with respect to a LOCA.

The containment shield building surrounds the containment vessel and is designed such that outside cooling air will pass upwards along the sides of the containment vessel and rise towards an outlet at the top of the structure (refer to Figure 3.2.5). Under accident conditions, the steel containment vessel provides a heat transfer surface that allows heat transfer from inside containment to the cooling air. This air-cooling is also supplemented by water evaporation on the surface of the containment vessel. This water is drained by gravity from a tank located on top of the containment shield building. This heat exchange system is designated the PCS.

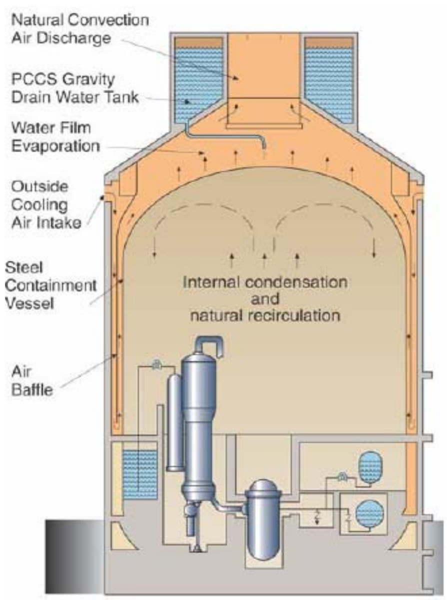

Figure 3.2.5

List of Acronyms

AP – Advanced Passive
CMT – Core Makeup Tank
EPR – European Pressurized Water Reactor in Europe, and Evolutionary Pressurized Water Reactor in the U.S
IRWST – In-containment Refueling Water Storage Tank
LOCA – Loss of Coolant Accident
MWe – Megawatts electric
MOX – Mixed Oxide
PCS – Passive Containment Cooling System
PRHR – Passive Residual Heat Removal System
PWR – Pressurized Water Reactor
PXS – Passive Core Cooling System
RCS – Reactor Coolant System
U – Uranium
U-235 – Uranium 235
USNRC – United States Nuclear Regulatory Commission

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3.3 Boiling Water Reactor (BWR)

Introduction

BWRs use enriched uranium as fuel and light water as the moderator and heat transport fluid. There are two boiling water reactor designs available from General Electric (GE).

The Advanced Boiling Water Reactor (ABWR) is a Generation III BWR, with a typical output of 1356 MWe (3926MWth), up to a maximum output of 1600 MWe. An ABWR has a typical capacity factor of 87% and an average operating cycle of 18 months with refueling outages lasting approximately 43 days. The ABWR has received Design Certification from the United States Nuclear Regulatory Commission (USNRC). Four ABWRs are operating in Japan, two are under construction in Taiwan and two more are being considered for construction in the U.S.

The Economic Simplified Boiling Water Reactor (ESBWR) is a Gen III+ BWR. The ESBWR is designed to provide 1560 MWe (4500 MWth), and has an expected capacity factor of greater than 95% based on an outage length of less than three weeks for a 24 month operating cycle. Two U.S. utilities have applied for Early Site Permits for this design. The following uses the ESBWR as an illustrative example of currently available BWR technology.

Normal Operation

The BWR design eliminates the secondary cooling cycle in that light water is boiled directly in the reactor core and passed to the turbines (refer to Figure 3.3.1). This eliminates the need for steam generators, however, the steam in the turbine is radioactive and therefore the turbines require shielding. The main steam lines exit the Reactor Pressure Vessel (RPV) from one side and pass through containment and into the turbine building. A steel shield surrounds the turbines. Turbine exhaust steam is condensed and passed through a purification system and several feedwater heaters and pumps before being sent back into containment, where it is reheated into steam by the RPV. Pumps allow the operator to vary coolant flow through the core and consequently to adjust reactor power.

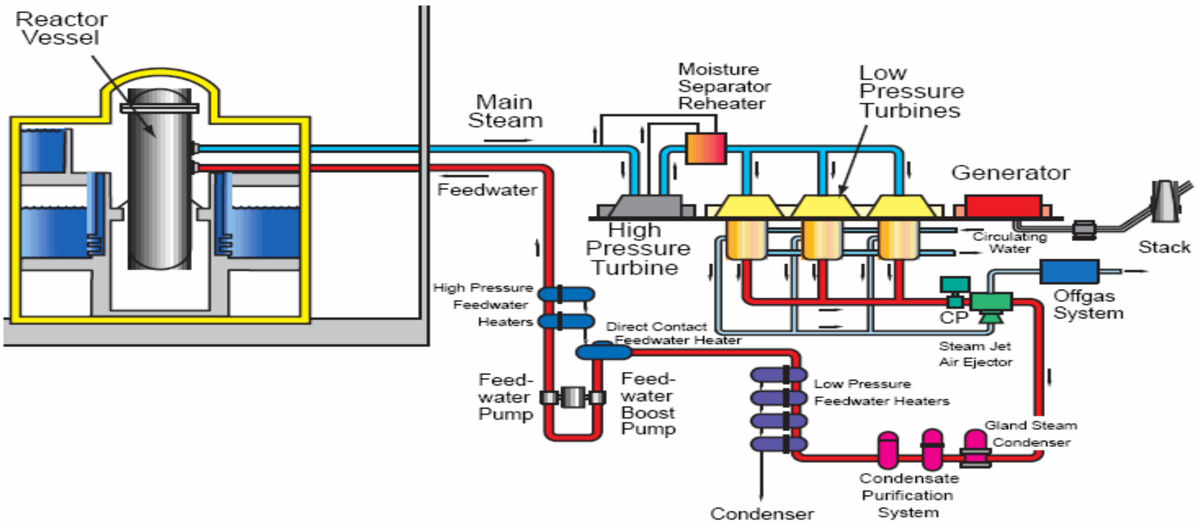

Figure 3.3.1

Decay heat, generated immediately following shutdown, is exhausted by bypassing the turbine and dumping steam directly to the condenser. Once pressure has decreased to approximately 0.446 MPa, the residual heat removal system is used, which pumps water from the recirculation system through a heat exchanger connected to the service water system.

The reactor core isolation cooling system provides cooling to the RPV when the main steam lines are isolated and the main turbine is unavailable. Instead, steam is fed to a reactor core isolation cooling system turbine to power a pump. This pump sends water from a condensate storage tank into the RPV via the feedwater inlet, to cool the core. Exhaust steam from the reactor core isolation cooling system turbine is condensed and collected in the suppression pool, which is also used as an alternate supply of coolant.

Reactor Core

A BWR consists of a RPV containing a fuel core topped by steam separators and steam dryers (refer to Figure 3.3.2 as an example). The core is surrounded by a jacket called a core shroud, resulting in an annular gap between the core and the inner surface of the RPV. Coolant enters the RPV at a level just below the steam separators and cascades down this annular gap. It is then collected by a recirculation system located outside the RPV and forced through jet pumps (located in the annular gap) prior to entering the core. The coolant boils in the core and the resulting vapour passes through the steam separators and dryers to separate moisture from the steam before it is sent to a main steam line and on to the turbine.

Water quality is maintained by the reactor water cleanup system, which removes fission and corrosion products and other insoluble impurities. The reactor water cleanup system takes water from the recirculation system as well as from the bottom of the RPV, and returns it to the feedwater piping.

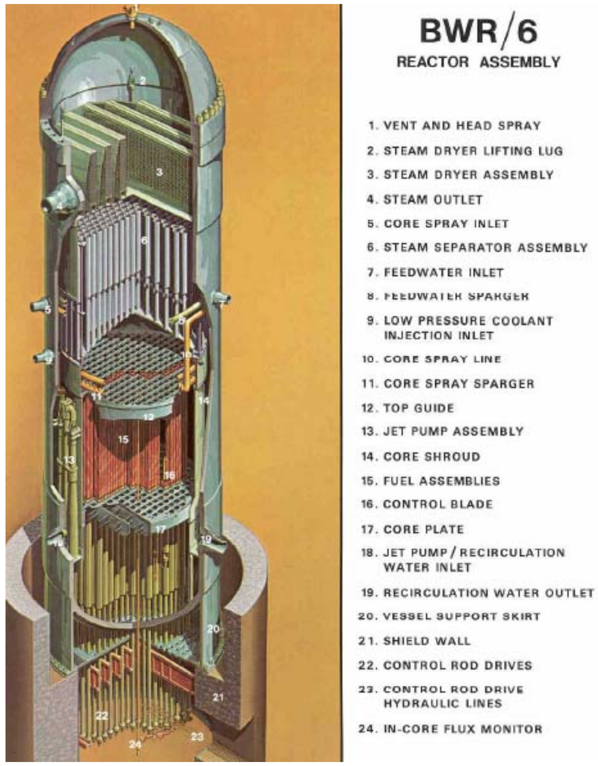

Figure 3.3.2

The ESBWR RPV is very similar to other BWR RPVs, with the exception that there are no reactor internal pumps to drive circulation through the core. Instead, the RPV is designed to establish natural circulation cooling by exploiting the density difference between the feedwater entering from the vessel annulus and the steam/water mixture within and above the “chimney” (refer to Figure 3.3.3). The system operating pressure is 7.17 MPa, with a feedwater temperature of 215.6 °C.

<u>Fuel Design</u>

BWR fuel (refer to Figure 3.3.4) consists of ceramic fuel pellets composed of enriched uranium dioxide (UO_2), contained within zirconium alloy clad fuel rods approximately 3.5 meters long. These rods are arranged in an 8 x 8 matrix contained within a square fuel channel to permit coolant flow. Four fuel channels are arranged into a control cell assembly and a control rod with cruciform cross-section is fitted to slip within the gaps between the fuel channels. This control rod is inserted from below, counter gravity,

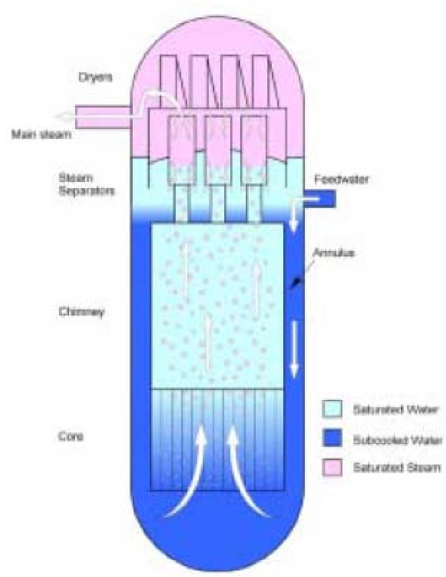

Figure 3.3.3

since the top of the core is occupied with steam production. A BWR reactor core will typically contain approximately 250 control cell assemblies.

The ESBWR core consists of 1132 fuel assemblies, each 379 cm long. Reactivity control and power shaping is provided by 269 control rods. The control rods contain stainless steel tubes packed with boron carbide powder (and sometimes hafnium).

ESBWR fuel consists of 4.2% enriched UO_2 within Zircaloy-2 clad fuel rods. There are 92 fuel rods per assembly, arranged in a 10 x 10 array within a vertical fuel channel. The 8 remaining spaces of the array are taken up by two large water passages ("water rods") to improve moderation. Some fuel rods contain a burnable poison.

Special Safety Systems

BWRs have a standby liquid control system to shut down the reactor independent of the control rods. The system uses boron poison injection and is manually initiated.

BWRs have an Emergency Core Cooling System (ECCS) to provide core cooling during loss of coolant accidents (LOCAs). The ECCS consists of two high-pressure and two low-pressure systems. The high-pressure systems are the High Pressure Coolant Injection (HPCI) system and the Automatic Depressurization System (ADS). The low-pressure systems are the Low Pressure Coolant Injection (LPCI) mode of the residual heat removal system and the Core Spray (CS) system.

The HPCI system uses a turbine and pump to provide cooling to the core in a manner identical to the reactor core isolation cooling system. The ADS consists of safety relief valves to provide RPV depressurization to the suppression pool, for small to intermediate size LOCAs when the HPCI system is assumed unavailable or ineffective.

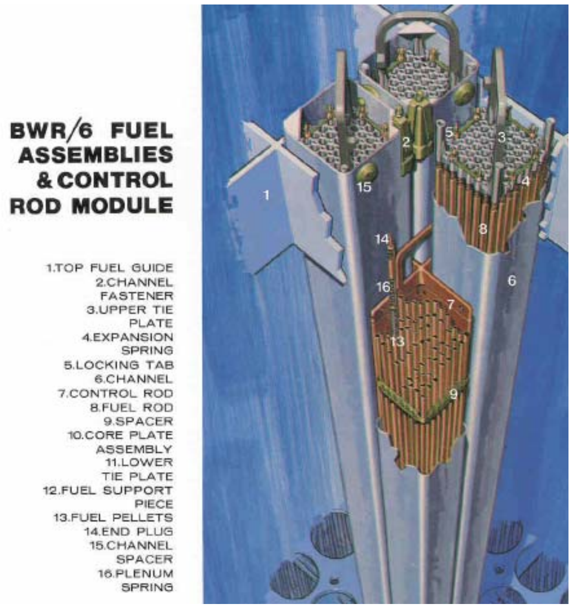

Figure 3.3.4

In the LPCI mode of the residual heat removal system, valves are connected such that pumps withdraw water from the suppression chamber and move the water into the recirculation system via the residual heat removal heat exchanger, in order to provide core cooling. Another residual heat removal mode enables cooling spray to the drywell and suppression chamber. The CS system pumps water from the suppression pool into spargers in the RPV, directly above the fuel assemblies.

The ESBWR uses several passive safety systems for emergency core cooling. The Isolation Condenser System (ICS) is used to limit reactor pressure following isolation of the main steam lines. The ICS connects the RPV to heat exchanger piping contained within a tank located above containment. Condensed water is returned to the RPV.

The Passive Containment Cooling System (PCCS) is used to reduce containment pressure during a LOCA. It uses identical systems to the ICS, except that the inlet piping is located at the top of containment, to collect LOCA steam, and the condenser outlet is located in a special in-containment annular tank used to provide gravity-driven high-pressure coolant to the RPV.

The specific containment configuration of BWRs varies depending on design, but always consists of a cylindrical (or flask or conical) shaped concrete drywell and a torus-shaped suppression chamber (also known as a wetwell). The drywell surrounds the reactor and its function is to withstand and contain steam during a pipe rupture, and to direct steam via piping to the suppression chamber. The suppression chamber contains a large volume of water (called a suppression pool) that is used to rapidly condense steam directed from the drywell. The suppression chamber typically either surrounds the drywell or is located directly beneath it. Both the drywell and the suppression chamber are enclosed within primary containment, which may be a steel lined concrete structure or simply a freestanding steel containment structure (refer to Figure 3.3.5). Primary containment is surrounded by secondary containment (i.e., the reactor building), which houses the spent fuel storage bays, safety systems and auxiliary reactor system. In the case of a freestanding steel containment, a shield building surrounds primary containment. Spent fuel storage bays are located outside the shield building.

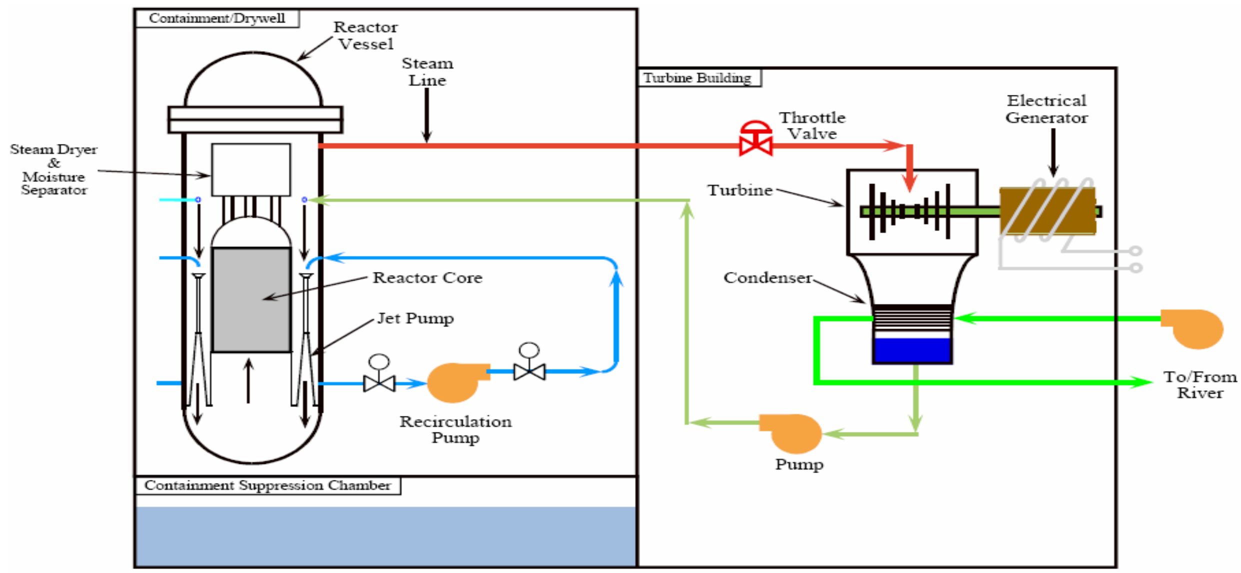

Figure 3.3.5

<u>List of Acronyms</u>

ABWR – Advanced Boiling Water Reactor
ADS – Automatic Depressurization System
BWR – Boiling Water Reactor
CS – Core Spray
ECCS – Emergency Core Cooling System
ESBWR – Economic Simplified Boiling Water Reactor
GE – General Electric
HPCI – High Pressure Coolant Injection
ICS – Isolation Condenser System
LOCA – Loss of Coolant Accident
LPCI – Low Pressure Coolant Injection
MWe – Megawatts electric
MWth – Megawatts thermal
PCCS – Passive Containment Cooling System
RPV – Reactor Pressure Vessel
UO_2 – Uranium Dioxide
USNRC – United States Nuclear Regulatory Commission

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3.4 Pressurized Hybrid light and heavy Water Reactor (PHR)

Introduction

The Advanced CANDU Reactor (ACR) developed by Atomic Energy of Canada Limited (AECL) is a Generation III+ reactor in that it has several passive safety features. The reactor uses light water to cool the fuel and heavy water for the moderator. The ACR is currently the only reactor within the PHR class. The first ACR to be developed was the ACR-700, although it is not a design option actively being offered by AECL. The ACR-700 is designed to generate 753 MWe (gross), 2034 MWth and has a projected capacity factor of 93%.

The ACR-1000 is a scaled-up version of the ACR-700, in the 1200 MWe class. As the ACR-1000 design is still in the development stage, and many of the design features will be similar to the ACR-700, the following discussion will focus on the ACR-700 (refer to Figure 3.4.1).

Heat Transport System

The ACR Heat Transport System (HTS) coolant is light water instead of heavy water. This is possible due to the use of Slightly Enriched Uranium (SEU) fuel. The ACR-700 HTS is a single "figure of eight loop" with two steam generators and four HTS pumps (refer to Figure 3.4.2). Coolant picks up heat from the fuel in the fuel channels (described in next subsection) and then travels via the outlet feeders into an outlet header. Coolant from half the fuel channels in the

Figure 3.4.1

core mixes in the outlet header before passing to one of the two steam generators where heat is exchanged to generate steam to drive the turbines via a secondary cooling system.

The cooled primary side coolant from the steam generator outlet then moves on to two pumps that drive the coolant into an inlet header which supplies the coolant to the inlet feeders connected to the fuel channels that comprise the other half of the reactor core. The figure of eight loop is completed by an identical, reversed circulation sequence on the opposite side of the core.

<u>Reactor Core</u>

The ACR core (refer to Figure 3.4.3) will have the appropriate number of fuel channels in order to provide the design power generation. These fuel channels are filled with fuel bundles, horizontally arranged within a cylindrical vessel called a calandria, which is otherwise filled with heavy water moderator at slightly above atmospheric pressure and at a temperature typically in the range of 70 to 80°C. The moderator is cooled by an independent heat exchanger and circulation system, and also acts as a passive heat sink under accident conditions.

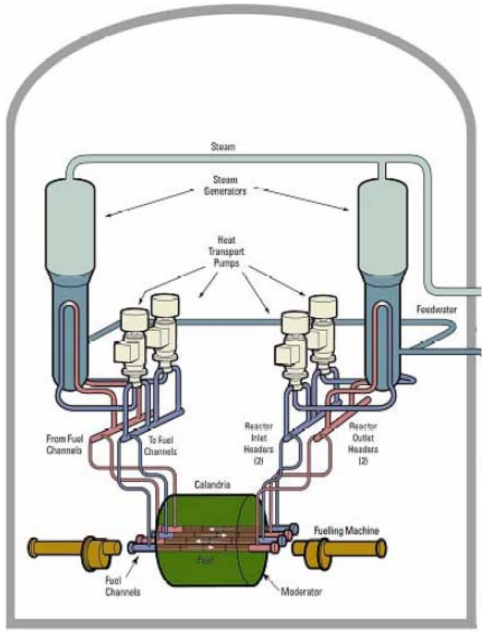

Figure 3.4.2

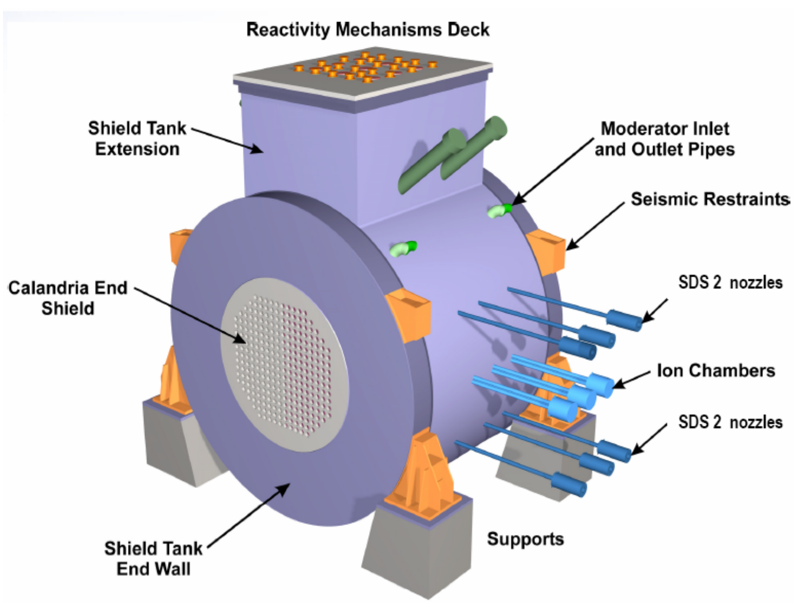

Figure 3.4.3

The reactivity mechanisms used in the ACR-700 include reactivity control devices (i.e., mechanical control absorber units and liquid zone control units) and shutdown systems. Neutron flux measuring devices include self-powered flux detectors, fission chambers and ion chamber units. All reactivity mechanisms operate in the low temperature, low pressure moderator environment and are testable on-line.

The calandria is enclosed by end shields containing light water and shielding balls, and is also radially surrounded by a shield tank filled with light water. The shield tank serves as both a thermal and a biological shield, and also as a heat sink under postulated severe accident conditions.

Each fuel channel in the ACR core is comprised of a thick-walled zirconium alloy Pressure Tube (PT) inside a concentric Calandria Tube (CT), two endfittings, two closure plugs and 12 SEU fuel bundles (refer to Figure 3.4.4). The PT, CT and the annulus between the PT and the CT separate the cool, low-pressure moderator from the hot, pressurized coolant. The annulus between the PT and CT contains a gas, which can be tested for moisture to detect leaks. The end-fittings include closure plugs, which are accessible by robotic fuelling machines, and this allows for on-power fuelling. This feature eliminates the need for outages to replace fuel and helps increase the overall capacity factor of the ACR design.

Thick-walled PTs allow for a peak operating pressure of about 13 MPa and peak temperatures of about 325°C in the HTS design. The use of elevated HTS coolant temperature and pressure allows for enhanced thermal efficiency. The use of SEU fuel means that less moderator is required than for natural enrichment fuel, which results in a compact core design with consequent reduction in heavy water inventory requirements and significantly reduced costs. The more compact core also results in a reduction in the size of the reactor shield tank assembly.

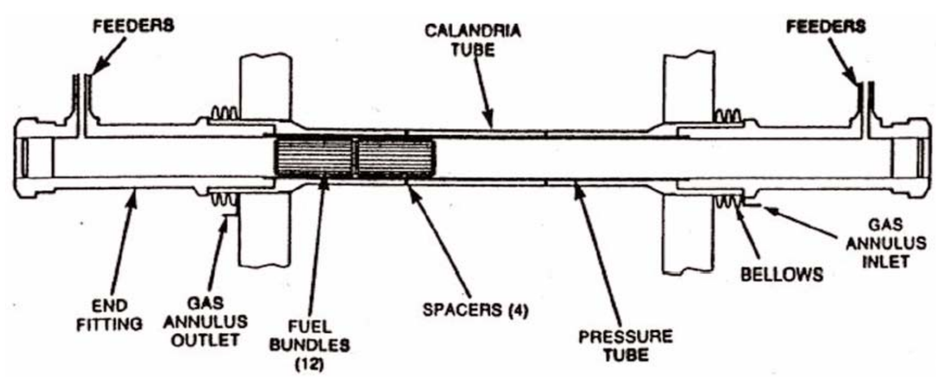

Figure 3.4.4

<u>Fuel Design</u>

The ACR fuel design uses SEU (i.e., typically a few per cent U235 in total U). ACR fuel contains a burnable dysprosium poison in its central element. The use of a 43-element CANFLEX fuel bundle design (refer to Figure 3.4.5) enables the ACR-700 to operate with higher fuel channel and bundle powers and to achieve about three times the fuel burn-up of natural uranium. The higher fuel burnup results in a reduced volume of fuel discharged from the core for the same amount of power produced when compared to the use of naturally enriched uranium fuel.

Figure 3.4.5

Special Safety Systems

The ACR-700 has five special safety systems: Shutdown System 1 (SDS1), Shutdown System 2 (SDS2), the Emergency Core Cooling System (ECCS), the Reserve Water System (RWS) and the Containment System.

The two safety shutdown systems are physically and functionally separate from each other and from the reactor regulating system, which is used to control reactor power during normal operation. Each SDS is independently capable of shutting down the reactor and is passively driven once tripped. Shutdown System 1 (SDS1) consists of 20 mechanical shutoff rods that drop into the core by gravity upon receipt of a reactor trip signal. Shutdown System 2 (SDS2) uses pressurized tanks to inject concentrated gadolinium nitrate solution into the moderator through nozzles spanning the calandria.

Emergency core cooling is carried out by two systems: the Emergency Coolant Injection (ECI) system; and the Long Term Cooling (LTC) system. The ECI system is used for immediate high-pressure coolant injection after a loss of coolant accident (LOCA). The ECI system provides passive injection from pressurized tanks to the reactor inlet headers. There are passive one-way rupture discs that normally separate the two ECI tanks from the reactor inlet headers.

The LTC system is used to provide fuel cooling in the later stage of a LOCA. It does so by recirculating ejected coolant water that is recovered using sumps located at the base of the reactor building. The LTC system is comprised of two redundant divisions, each containing a set of pumps and single heat exchanger, located in separate areas of the reactor auxiliary building outside of containment. The LTC system also provides shutdown cooling following accidents and other transients.

The water for the RWS is contained in an Integrated Dome Reserve Water Tank located in the dome of the reactor building (refer to Figure 3.4.6), at a higher elevation than all other systems, to ensure passive gravity-powered water supply. The RWS can provide emergency feedwater to the steam generators, make-up water to the HTS, and backup supply water to both the moderator and shield tank when they act as a heat sink for severe accidents.

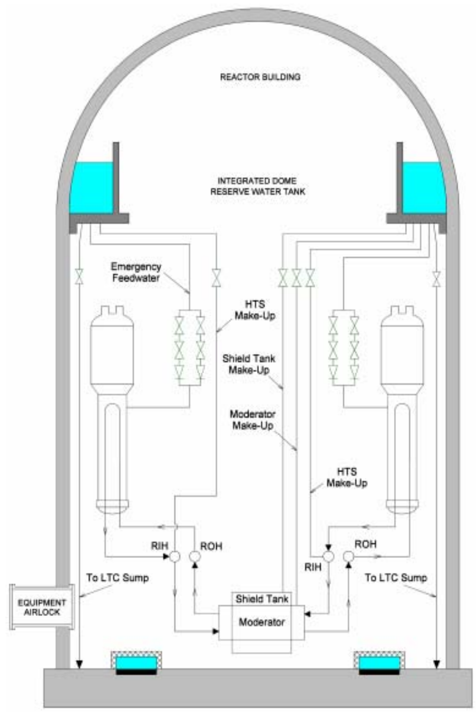

Figure 3.4.6

The ACR-700 reactor building (refer to Figures 3.4.1 and 3.4.6) is a steel-lined, pre-stressed concrete structure that provides biological shielding and an environmental boundary. Design simplifications such as a smaller reactor and fewer steam generators result in a relatively small reactor building for the ACR-700. Heat removal from the containment atmosphere after an accident is provided by the containment cooling system, which is comprised of local air coolers suitably distributed inside the reactor building.

The Containment Isolation System automatically closes penetrations to the reactor-building atmosphere upon signals of high pressure or high radioactivity in the reactor building. Hydrogen control following a LOCA is provided by Passive Autocatalytic Recombiners (PARs).

List of Acronyms

ACR – Advanced CANDU Reactor
AECL – Atomic Energy of Canada Limited
CANDU – Canada Deuterium Uranium
CT – Calandria Tube
ECCS – Emergency Core Cooling System
ECI – Emergency Coolant Injection
HTS – Heat Transport System
LOCA – Loss of Coolant Accident
LTC – Long Term Cooling
MWe – Megawatts electric
MWth – Megawatts thermal
PAR – Passive Autocatalytic Recombiner
PHR – Pressurized Hybrid light and heavy water Reactor

PHWR – Pressurized Heavy Water Reactor
PT – Pressure Tube
RWS – Reserve Water System
SDS 1 – Shutdown System 1
SDS 2 – Shutdown System 2
SEU – Slightly Enriched Uranium
U – Uranium
U235 – Uranium 235

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