# Adaptation of the ITER Facility Design to a Canadian Site

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**Abstract.** This paper presents the status of Canadian efforts to adapt the newly revised Iter facility design to suit the specific characteristics of the proposed Canadian site located in Clarington, west of Toronto, Ontario. Iter Canada formed a site-specific design team in 1999, comprising participants from three Canadian consulting companies to undertake this work. The technical aspects of this design activity includes: construction planning, geotechnical investigations, plant layout, heat sink design, electrical system interface, site-specific modifications and tie-ins, seismic design, and radwaste management. These areas are each addressed in this paper.

## 1. Introduction

During the Engineering Design Activity (EDA) phase, Iter designers developed a generic site arrangement, which was used to provide a framework for system design and cost estimating. The generic design was assumed to be a “greenfield” location without any constraints related to topology, geology, or existing site services. In 1999, this arrangement was revised to reflect the smaller footprint required by the ITER-FEAT design (hereafter referred to as Iter) but retains many of the same relationships between the major buildings, services and systems.

In May 2000, Iter Canada made the significant step of choosing between its two candidate sites, following a comprehensive review process where both sites were rated on the basis of an extensive criteria set which included the Iter site requirements, site adaptation and operating costs, licensing and environmental assessment issues, risk management issues (relating to timely approvals, public acceptance, impact on existing site operations, etc.), Iter staff feedback, and input from both siting communities. The site in Clarington, Ontario was chosen as Canada’s proposed site for the Iter project. The Clarington site can meet or exceed all the Iter compulsory site requirements and site design assumptions [1]. In nearly all cases, the Clarington site conditions are more favourable to construction and operation of Iter than the Iter Site Design Assumptions.

Iter Canada's site-specific design team has begun to adapt the generic design of the Iter facility to suit the specific characteristics of the proposed Clarington site, as outlined in the following sections of this paper. Iter Canada has been supporting the overall development of fusion technology and the Iter Joint Central Team activities since its inception in 1988, and has been engaged in site specific work for many years[2-5].

## 2. Physical Aspects of the Proposed Clarington Site

The Clarington site is located on the shore of Lake Ontario, approximately 60 km east of Toronto, Ontario (Figures 1& 2). The site is bounded by Lake Ontario to the south, the Darlington Nuclear Generating Station on the west, the MacDonald-Cartier Freeway (Highway 401) on the north, and the Blue Circle Cement Plant to the east. The area of the site is approximately 184 ha and is divided by an easement for the Canadian National Railway.

The land is currently owned by Ontario Power Generation (OPG, formerly Ontario Hydro), but ownership will be transferred to the Iter legal entity when it is appropriate to do so.

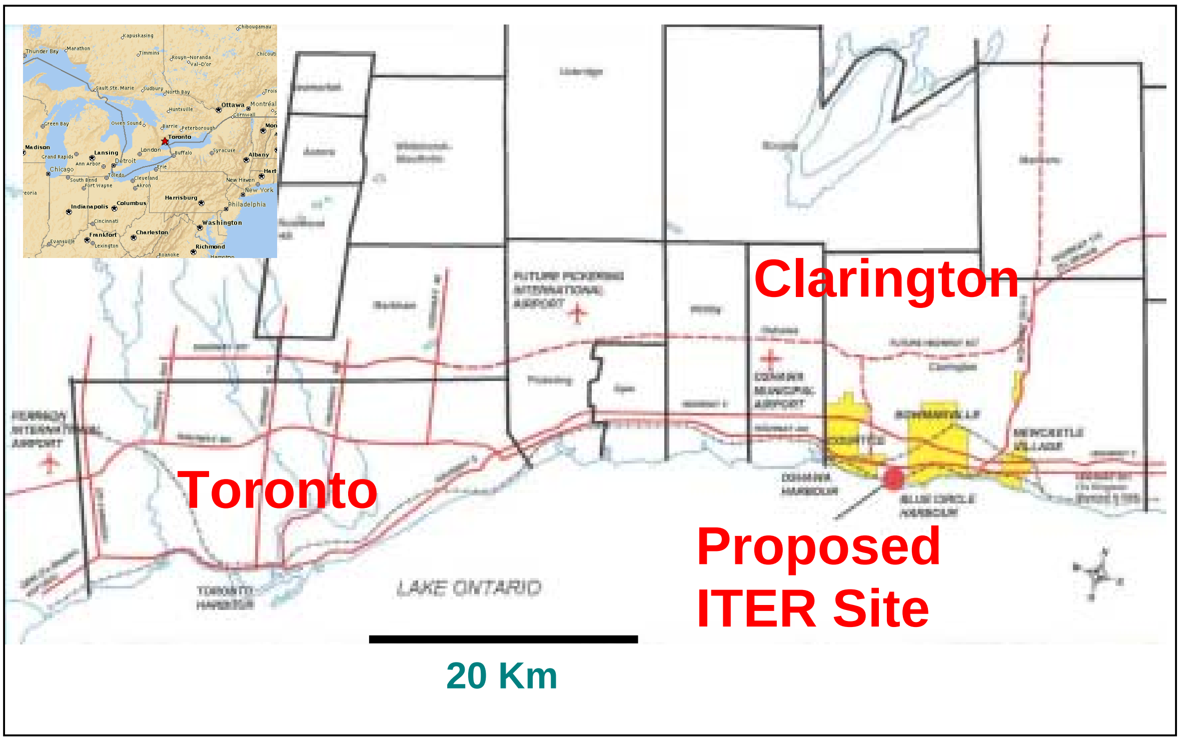


*FIG. 1. Location of the Clarington Site Proposed for Iter.*


*FIG. 2. Aerial Photo of the Proposed Iter Site Between the Blue Circle Cement Plant and the Darlington Generating Station.*

## 2.1 Facility Layout and Site Integration

To provide the greatest operational flexibility for Iter and to minimize the impact of Iter operations on electricity production at the neighbouring OPG site, the area designated for the Iter site facilitates an almost total separation between Iter and OPG operations. This also minimizes tie-ins to the existing OPG infrastructure where possible. Adaptation of the generic Iter site layout to suit the specific aspects of the Clarington site is shown in Figures 3 & 4. Figure 3 shows the planned locations for the construction camp facilities and laydown of materials and equipment while Figure 4 is a 3D visualization of the site layout.

The site area usage is detailed in Table I, below. In addition to these areas, an area for heavy equipment laydown (2.7 ha) will be "borrowed" from the neighbouring Darlington plant during construction. Barge dock and access to it will also be shared.

TAB. I: CLARINGTON SITE LAND USE

| Use | Area (ha) |
|---|---|
| High Security Area (inside Double Fence) | 15.1 |
| Switchyards | 7.1 |
| Cooling towers and basins | 2.5 |
| Rail Siding | 7.2 |
| Concrete Batch Plant | 2.4 |
| Permanent Parking and Lab Office Building | 2.0 |
| Construction Parking | 6.0 |
| Contractor 1 Laydown | 4.7 |
| Contractor 2 Laydown | 5.9 |
| Contractor 3 Laydown | 2.8 |
| Temporary Buildings & Pipe Warehouse | 5.7 |
| Spoils Areas | 9.5 |
| Roads and Unassigned | 113.1 |
| **Total** | **184** |

The Clarington site is accessible by road transport, railroad and barge. The highway access is via a multi-lane freeway (Ontario Route 401), which connects to all major highways in the greater Toronto area. Objects greater than 4 m in height or width will require oversize permits, and special precautions will be required for objects taller than 5 m. A railroad passes through the Darlington site, and a dedicated siding area already exists. Objects transported by rail can arrive at the site within about 800 m of the tokamak building. Very large objects can be shipped directly to the site. A barge slip exists in the forebay area of the Darlington Generating Station. Alternate dockage facilities are also available from the neighbouring Blue Circle Cement Plant. These facilities were used extensively during construction of the Darlington station for off-loading of large components. Objects shipped to the site by deep-water ocean will arrive via the St. Lawrence Seaway. The Seaway limits the draft and width of ships to 7.5 m and 24 m respectively. Objects such as the largest PF coils could still pass through the Seaway, but would have to be carried in an inclined position to meet the width restriction. The lakefront location of the Clarington site creates the possibility that the envelope for objects shipped to the site could be increased. It is even conceivable that assembled TF/VV sectors might be completed elsewhere and shipped to the site.

Modifications to the existing Clarington site will be required to accommodate Iter. These have been studied by Iter Canada and include:

- addition of dedicated access road
- addition of new bridge over railway
- modifications to existing roads
- addition of heavy haul roads
- temporary buildings for ITER construction
- addition of permanent roads and parking facilities
- piped utilities
- refurbishment of barge dock and rail siding
- electrical system tie-ins.

## 2.2 Connection to the Electrical Grid

The Clarington site is adjacent to a major node on the Ontario electric grid, which is one of the largest electric power systems in North America, with an installed generating capacity of over 30,000 MW. The primary grid voltage at Clarington is 500 kV. Two parallel, single-circuit 500 kV lines are proposed to meet the Iter pulsed power needs (magnet power and plasma heating systems) and steady state electrical requirements. This choice is based on system study results, as given below, where the frequency and voltage variations due to Iter load swings are within limits imposed by The Independent Market Operator (IMO) that regulates the Ontario Power System. The existing 500kV switching station at the site will require expansion. The north and south busbars of the gas insulated switchgear (GIS) of this station could be extended to tie-in with a new GIS with three circuit breakers in a breaker-and-a half configuration. This new GIS would be located in a new building, approximately 30 m east of the existing GIS building. The length of the new overhead transmission lines will be about 660 m. These connections will be made so that either line can be removed for service during maintenance.

A preliminary power system simulation study has been conducted to model the response of the Ontario Power System to the Iter electrical loads for the power requirement parameters as defined for the current Iter design [6].. The pulse power loads were modelled under various conditions:

- a step active power loading 0 to 500 MW with reactive step power loadings of 0 to 240 MVAr and 0 to 800 MVAr;
- a less severe power loading of 0 to 500 MW in 3s (in steps of 60 MW and 100 MW) and a reactive power loading of 800 MVAr in 3s (in steps of 80 Mvar and 200 MVAr).

The study results are given in Table II for different grid loading situations. Acceptable frequency and voltage deviations are specified by the IMO as $\pm$30 mHz and 4% respectively. These preliminary results show that these conditions are met for cases that represent realistic Iter loads with the exception of the light system loading condition, where locally installed reactive power compensators may be required to limit the voltage deviation to 4%.

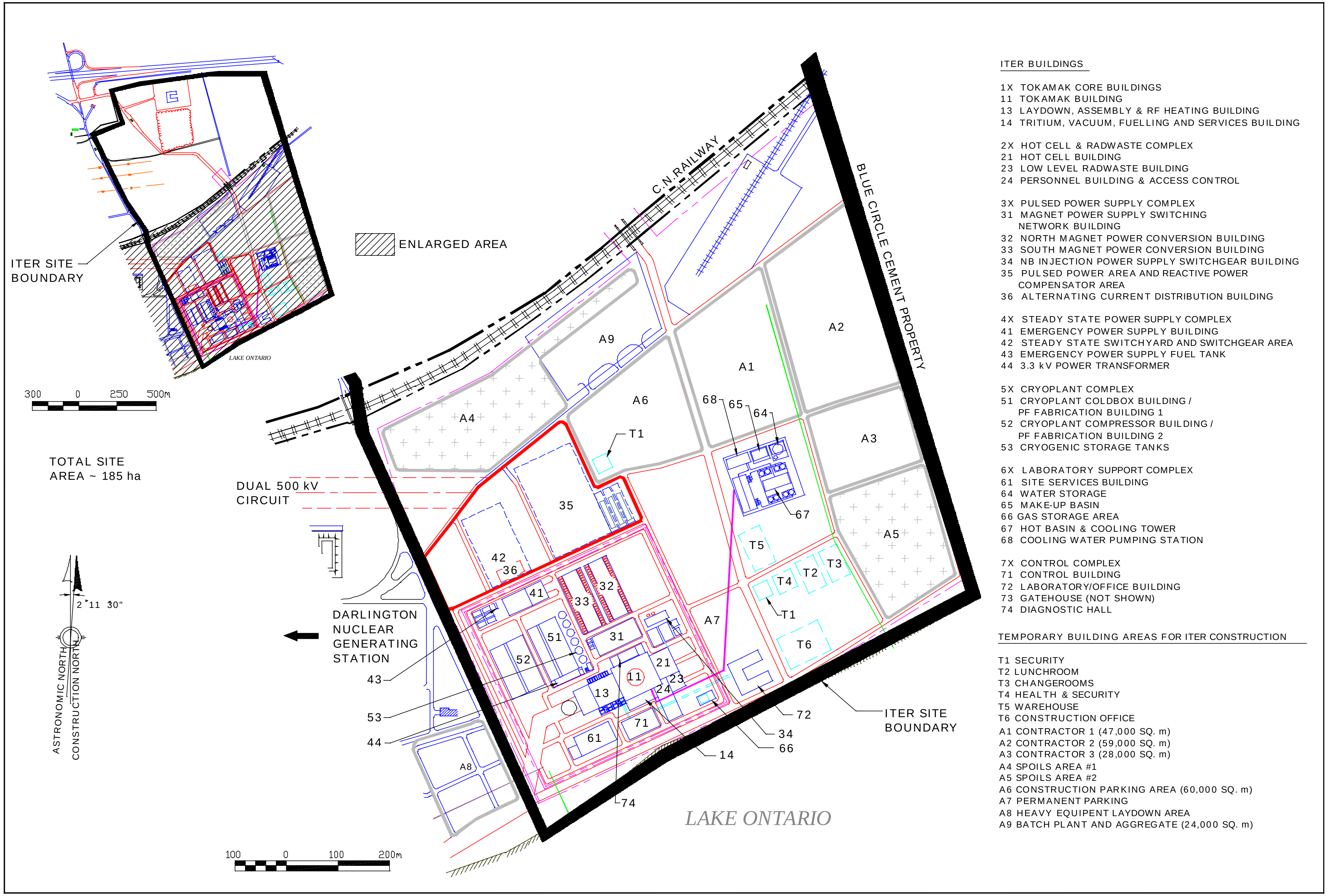


*FIG. 3. Iter Facility Layout Adapted for the Clarington Site.*

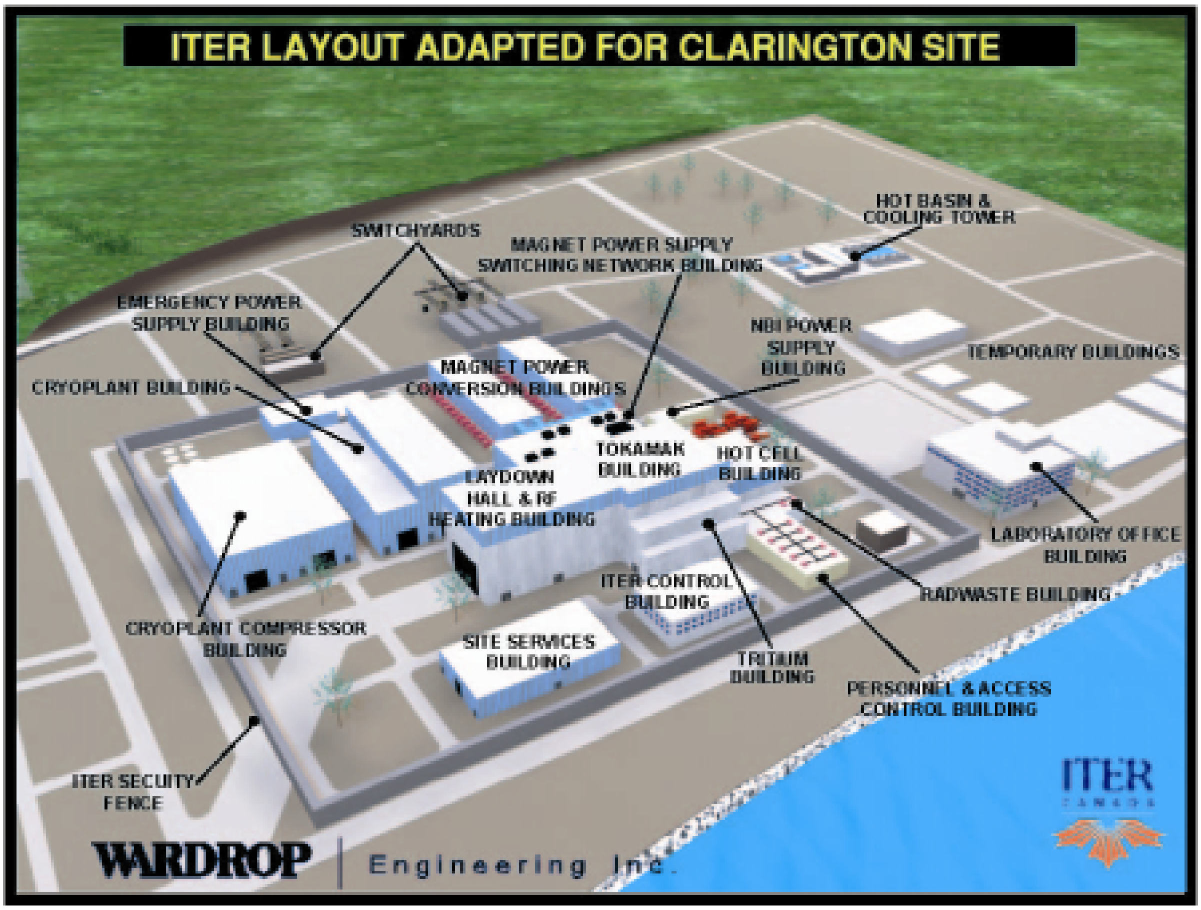


*FIG. 4. Visualization of the Iter Site Layout*

TAB. II: RESULTS OF PRELIMINARY POWER SYSTEM SIMULATION STUDY.

| **Loading Condition** | **Units in Service** | **Frequency Deviation $\Delta f$ (mHz)** | **Voltage Deviation $\Delta v$ (%)** | |
|---|---|---|---|---|
| | | Closest Consumers at Richview 230kV | 800MVAr | 240MVAr |
| *Heavy* (single step, 0-500MW) | 4 of 4 | 14 | 3.7 | 1.6 |
| | 2 of 4 | 14 | 3.8 | 1.8 |
| | None | 11 | 4.2 | 2.2 |
| *Light* (single step, 0-500 MW) | 1 of 4 | 16.5 | 6.4 | 4.4 |
| *Heavy* (0 to 500MW in 3s in steps of 60MW and 100MW) | 4 units in service | < 5 | 2.5 | 1.6 |

### 2.3 Heat Sink Design

Preliminary designs have been developed for two heat sink options at the Clarington site – the cooling tower design proposed in the Iter design, and a once-through cooling option using some aspects of the existing infrastructure at the site (Figures 5 & 6). The design basis for both options assumes a maximum cooling requirement of 1200 MW for periods of 3600s however it is recognized that phased construction of the heat sink may be desirable, since this requirement will not occur until sometime after the DT operating phase.

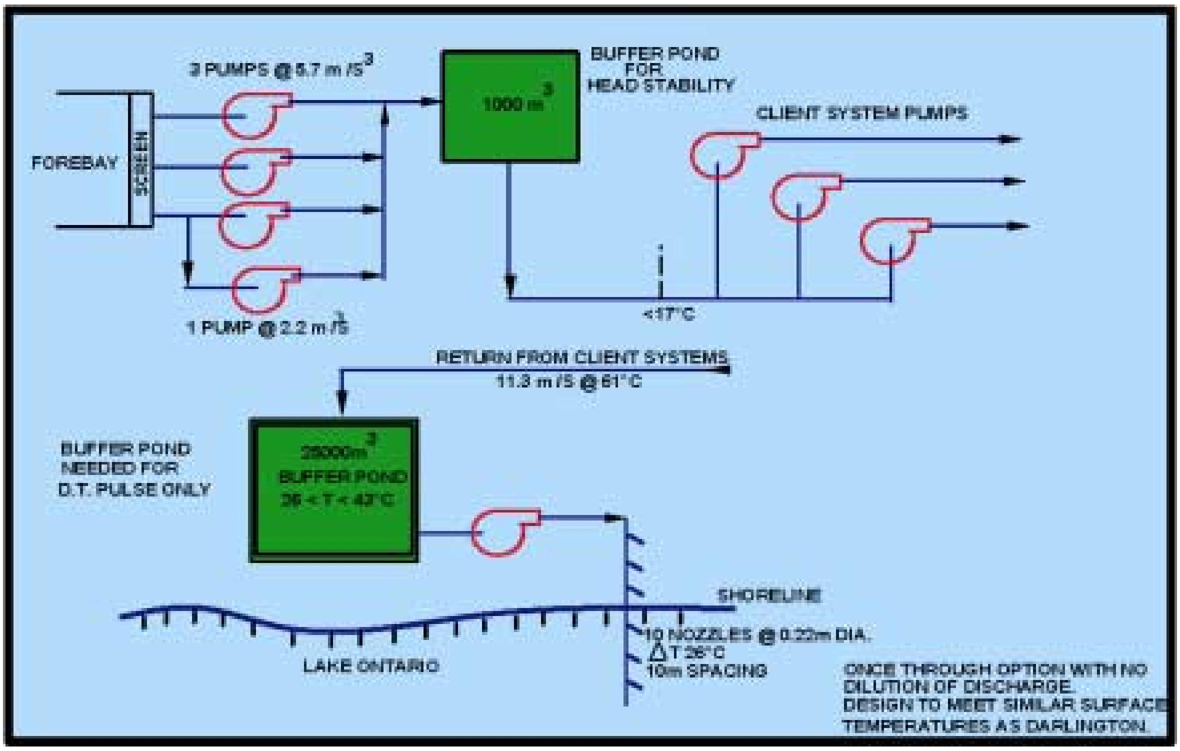


*FIG. 5. Cooling Tower Option*

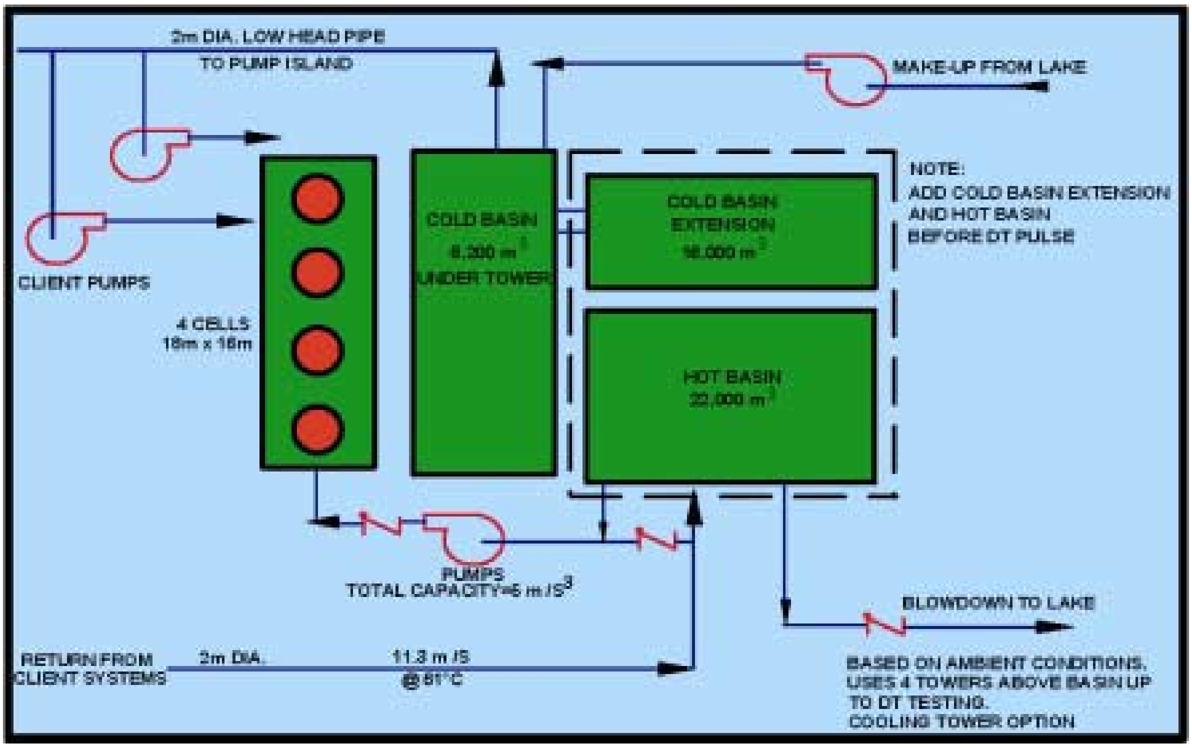


*FIG. 6 Once Through Cooling Option*

*Cooling Towers*

Preliminary sizing indicates that four mechanical draft cooling towers are adequate to meet Iter's requirements, with a total capacity of 500 MW. The total area required by the towers is estimated to be 18 m x 66 m, including a 5 m deep concrete basin located beneath the towers, with a capacity of 6200 $m^3$. Cooling water would be gravity feed from the cold basin, through a 2 m diameter pipe to the Iter heat exchangers (flowrate of 11.3 $m^3/s$ at 34ºC, returning at 61ºC). The design of the system is based on a wet bulb temperature of 25.5ºC during summer conditions.

Following the DT operating phase, additional basin capacity will be required. Earth basins for cold and hot coolant streams, sized at 16,000 $m^3$ and 22,000 $m^3$ respectively, can be added to meet the full heat sink demand, resulting in a total cycle time of 5 hours.

*Once Through Cooling Option*

By making optimum use of the existing site infrastructure, the once through cooling option has the advantage of providing lower temperature cooling water (17ºC lower than the cooling tower option) which could reduce the size and cost of the Iter heat exchangers. The disadvantage of this option is that it requires tie-in to the existing nuclear plant systems, may be more difficult to obtain environmental permits, and could prove to be more costly.

To meet the required 11.3 $m^3/s$ coolant flow, three 5.7 $m^3/s$ pumps (one standby) would be required, plus a smaller 2.2 $m^3/s$ pump to meet the dwell period demands. Pending OPG review and approval, coolant water could be drawn from the existing water intake (perhaps the forebay of the nuclear plant). A 2 m diameter discharge line into the lake would have to be separately constructed and would likely extend 0.5 km into the lake, utilizing a spaced nozzle diffuser system at a depth of 8 m. Local mixing at these nozzles reduces the initial intake to discharge temperature rise to 12.3ºC, which meets the environmental permitting requirements that limit the increase of the lake surface temperature to a 2ºC rise.

Following the DT operating phase, an earth berm lagoon with an approximate capacity of 25000 $m^3$ will be required to buffer the discharge to the lake and achieve a steady state discharge temperature to accommodate the more demanding cooling.

## 2.4 Geotechnical/Seismic Considerations

The Clarington site is well characterized and documented, comprising data from over 80 boreholes [7-13]. The foundation conditions in the area proposed for Iter consist of a thick layer of dense glacial till overlying bedrock. The bedrock is fairly level, and is found at a depth of about 25 m below grade. The load bearing capacity of the bedrock is very high, probably exceeding 100 $tons/m^2$. The load bearing capacity of the glacial till is fairly consistent over its vertical range, and is about 40 $tons/m^2$. In some areas of the site, a layer of sand, silt, and clay interrupts the till; however, it is also quite strong.

Using the existing site data, preliminary excavation estimates can be made for the Iter buildings, assuming the current proposed tokamak building embedment level of approximately 16 m (Figure 7). Table III shows these estimates developed for both open and supported excavation. The Clarington site was originally part of an area prepared for the potential, future construction of a second nuclear generating station at Darlington and is overall, quite flat. Excavated material, which must be removed for the Iter structures, can readily be disposed of on the site, in two areas already identified for spoils, south of the CNR tracks.

TAB. III: PRELIMINARY DESIGN OF ITER EXCAVATION OPTIONS.

| **Items** | | **Unit** | **Option 1: Open Excavation** | **Option 2: Supported Excavation** |
|---|---|---|---|---|
| Excavation | Soil Excavation | $m^3$ | 756000 | 347688 |
| | Rock Excavation | $m^3$ | 29000 | 29000 |
| Dewatering Wells | Pumped Wells | m | 710 (total length of 37 wells) | 650 (total length of 35 wells) |
| | Eductor Wells | m | 2200 (total length of 88 wells) | 1600 (total length of 71 wells) |
| Granular Backfill | | $m^3$ | 279000 | 61000 |
| Slope Protection | | $m^3$ | 5000 | 2000 |
| Wall Support Depth | | m | - | 18 |
| Wall Support Perimeter | | m | - | 540 |

Because of the proximity of bedrock to grade at the Clarington site, it may be advantageous to increase the embedment of the tokamak building, so that the upper horizontal port elevation is aligned with grade. Although this would increase the excavation quantities estimated in Table III, the basemat thickness could be reduced by 30% or more, since it can be founded directly on the bedrock layer. This basemat thickness can be further reduced by rock socketing the main support columns into the bedrock and using pad and strip footings to meet the allowable bearing pressure requirements.

The Clarington site has no history of seismic activity but extensive study was required for the safety analysis of the neigbouring Darlington nuclear plant [14,15]. The local building code for the site is the Ontario Building Code, which refers to the National Building Code of Canada (NBCC) for the definition of seismic zones. The ground motion parameters are statistically derived, based on a probability of exceedance of 10% in 50 years. For Clarington the peak ground deceleration is 0.05 g, which corresponds to the Iter SL-0 level of seimic classification[16].

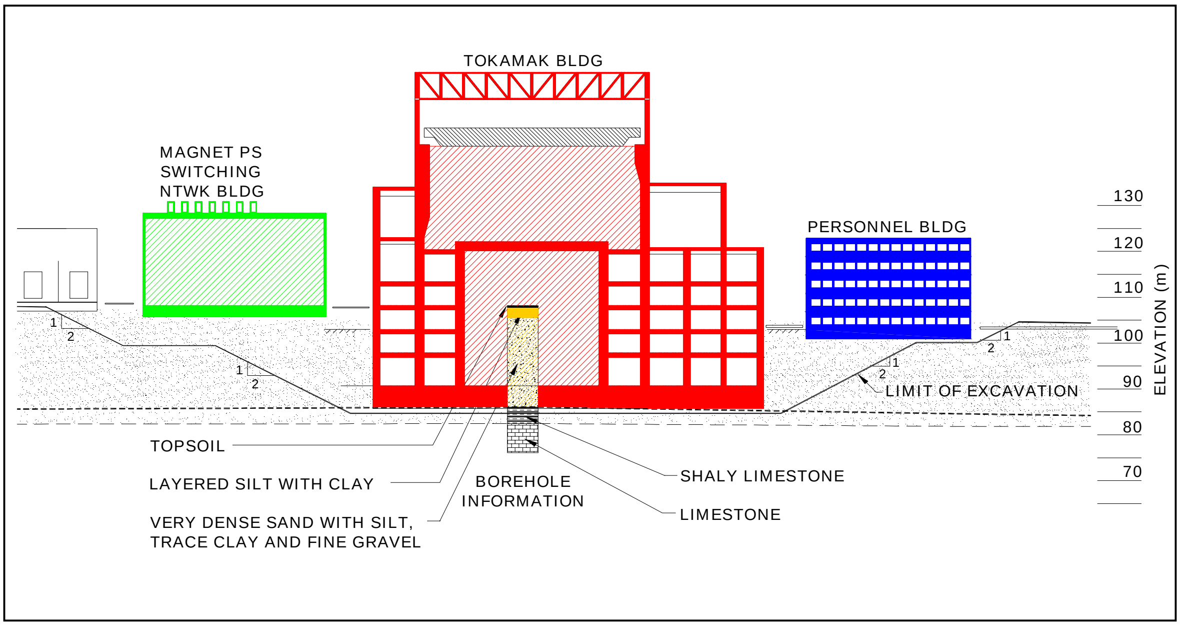


*FIG. 7. Typical Subsurface Profile Showing Option for Open Excavation*

## 2.5 Site Meteorology

The meteorology of the Clarington site is also well characterized, as are the environmental conditions required to perform detailed safety analyses [17]. Table IV contrasts the Iter design assumptions with the conditions at Clarington.

TAB IV: SITE METEOROLOGICAL CONDITIONS

| Meteorological Parameter | ITER | Clarington |
|---|---|---|
| Maximum Wind Speed, km/hr | 140 | 140 |
| Maximum Air Temperature, 24 hr average, degrees C | 30 | 30 |
| Minimum Air Temperature, 24 hr average, degrees C | -15 | -22 |
| Maximum Relative Humidity, 24 hr average, percent | 95 | 95 |
| Maximum Relative Humidity, 30 day average, percent | 90 | 90 |
| Elevation above sea level, m | <500 | 75 |
| Maximum Snow Load, kg/m$^2$ | 150 | 214 |
| Maximum Icing, mm | 10 | 15 |
| Maximum Rainfall, 24 hrs, cm | 20 | 7.6 |
| Maximum Rainfall, 1 hr, cm | 5 | 5 |
| Worst Case Air Pollution (IEC 71-2), Level | 3 | 3 |

## 3. Radioactive Waste Management

Management of the operational wastes generated by Iter will likely require a dedicated facility for radioactive waste management, using existing Canadian standards which are followed by OPG. Waste volumes and activity levels were estimated on the basis of reduction factors applied to the characteristics which were determined for the 1998 Iter design [18]. Using this basis, the volume of operational waste is estimated to be about 4,600 tonnes, of which 3,000 tonnes are comprised of in-vessel components (blanket modules and high heat flux divertor components). These components would be characterized as mainly intermediate level waste, using existing Canadian/OPG criteria. The remaining operational waste consists of service wastes and other components, and would likely be characterized as low level waste.

The types of facilities and containers required for Iter were studied in the context of current OPG practices and standard equipment [19, 20]. Typical wastes produced at the OPG nuclear stations, and typical storage methods for low level and intermediate level radioactive waste have also been contrasted with predicted Iter storage, handling, and capacity requirements.

It is envisioned that the basic facilities required would be:

- low level storage building(s), for storage of low level wastes (mainly service waste)
- a volume reduction/transfer facility, for compaction and sorting of wastes
- a laydown area, for temporary storage of reusable contaminated equipment
- in-ground containers for storage of intermediate level wastes (mainly reactor first wall components)
- transfer vehicles and storage/maintenance facilities for these vehicles
- transfer and storage containers

As much as possible, waste storage containers currently used by OPG would be used to meet Iter requirements. These include standard containers for operational wastes, 1 $m^3$ containers, compactor boxes, 200 litre drums, and oil pallet tanks. OPG's standard in-ground containers (know as IC-18's), with a capacity of 17.5 $m^3$, would be used to store the majority of the in-vessel components. If cutting of blanket modules is maximized to optimize IC-18 capacity, then approximately 50 of these containers will be required, however this is largely dependent on the assumed high level of replacements for these components, which requires further study.

Preliminary sizing showed that the above facilities would be easily accommodated in an area of less than 200 m by 250 m, which is comparable in size to one of the contractor areas shown in the site layout.

## 4. Construction Planning and Scheduling

In June 2000, a six member Canadian engineering & construction consortium was formed as the entity responsible for the detailed design and construction of the buildings and services infrastructure, comprising the "non-transportable" scope that will be undertaken by the host party. This team comprises the lead Canadian private-sector companies with capabilities in nuclear design and in the design and construction of large infrastructure projects. By utilizing the expertise of this team, a detailed plan is being developed for Iter construction, together with proposed plans for a construction organization that will deal effectively with the complex integration of contributions from the Iter parties. Existing labour estimates for construction of Iter buildings and integration of Iter components are also being reviewed and benchmarked against Canadian experience.

An example of this activity is the examination of the construction sequence. The construction of the tokamak will provide the opportunity to reduce construction costs by employing deep lift and high volume concrete pours. Preliminary study has been made of the number of concrete pours and quantity requirements for the 5 m thick basement (if required at a Canadian site), in addition to walls and slabs [21]. Reinforcing arrangements for base mats, wall pours, and formwork have also been addressed in this work.

Members of this Canadian team continue to work together with the Iter Joint Central Team (JCT) to review the assembly plan for the Iter tokamak, to detail the proposed construction schedule, and to develop Canadian cost estimates for the those aspects of the project envisioned to be the host party scope.

## 5. Conclusions and Recommendations

The Clarington site meets or exceeds Iter requirements, is well characterized, and provides many opportunities for cost reduction, provided the Iter design can be further adapted and optimized to take advantage of these opportunities. This paper has summarized the results of preliminary design activities undertaken by Canadian engineering companies to demonstrate the suitability of the Clarington site as the optimum site for the Iter project.

Iter Canada recognizes the need to choose a site quickly and to move forward with design activities that allow the Iter project to be adapted to suit a specific site. For this reason, it is not recommended to continue to develop a generic design that does not recognize relevant codes and standards and/or specific site conditions. Now is the time to choose a site, and get on with building Iter.

## 6. Acknowledgements

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## 7. References


[1] Iter Site Requirements and Iter Site Design Assumptions, File No. N CL RI 3 99-009-24 W 0.1, September, 1999

[2] “Technical Feasibility Study for Iter Siting”, Prepared by S. Smith, Wardrop Engineering Inc. for the Canadian Fusion Fuels Technology Project (Report No. I-9334), January 1993.

[3] “Siting the International Thermonuclear Experimental Reactor at Bruce or Darlington”, Report by the OHN Iter Team, May 16, 1995

[4] “Technical Appendix – Additional Information for EFDA Review of Canadian Site-Specific Design Activities”, Prepared by Iter Canada, February 2000.

[5] "Expression of Interest toHost Iter", Prepared by ITER Canada, January 2000.

[6] VADIVEL, K., et al., Iter Canada Site Specific Design Study, Study Report on Task No. 4 - Electrical System Interface, Revision 1, (2000).

[7] "OPG Report #72014 (177-47), ""Bowmanville Site Geotechnical Investigation Studies and Evaluation - Site Development Phase,"" April 1972.

[8] "OPG Report #74010, ""Bowmanville Site Interim Report - Preliminary Engineering Phase - Site Grading and Reclamation - Results of 1973 Investigation & Geotechnical Evaluation,"" April 1974.

[9] "OPG Report #77029, ""Darlington G.S. Results of the 1976 Field Investigation and Geotechnical Evaluation,"" April 1977.

[10] "OPG Report #79003, ""Darlington G.S. Cooling Water Intake Tunnel Geotechnical Investigations and Evaluation,"" February 1979.

[11] "OPG Report #77124, ""Darlington G.S. Results of 1977 Geological Investigation & Geotechnical Evaluation - Powerhouse & Forebay Areas,"" June 1978.

[12] "OPG Report #81406, ""Darlington G.S. Structural Geology,"" November 1981.

[13] "OPG Report #85174, ""Darlington GS A Borehole UN-2 Geological Investigation,"" July 1985.

[14] Darlington G.S. Site Seismic Risk Analysis. Report No. 75360. Earth Physics Branch, Department of Energy Mines and Resources. n.d.

[15] Design Basis Seismic Ground Motion for Darlington Nuclear Generating Station by P.W. Basham. Seismological Service of Canada. Internal Report 75-65. Division of Seismology and Geothermal Studies, Earth Physics Branch, Department of Energy Mines and Resources, December 1975.

[16] GLASS, A., Iter Canada Site Specific Design Study, Study Report on Task No. 5 – Seismic Design Requirements, Revision 0, January 20, 2000.

[17] "Darlington NGS Safety Report", Volume 1, Chapters 1&2, A Report to the Atomic Energy Control Board, March 1999.

[18] KASHIRSKI, A. "Iter Waste Streams and Characteristics Data Book (WSCDB) Version 2.1," Report number S 83 RI 4 97-12-13 R 0.2. ITER EDA, December 19, 1997.

[19] "Waste Acceptance Criteria (WAC-01) BNPD Radioactive Waste Operations Site 2," Ontario Power Generation, March 1997.

[20] "Waste Acceptance Criteria (WAC-02) Packaging of Low & Intermediate Level Radioactive Waste – Catalogue of WMSD Supplied Packages," Ontario Power Generation, February 1997.

[21] Study Report On Tokamak Building Optimization Of Construction Sequence"(Rev 0), Acres International Limited, August 2000.