Énergie NB Power

SUMMARY OF EVALUATION OF UPDATED SEISMIC HAZARDS

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Upon renewal of the Point Lepreau Generating Station's (PLGS) Power Reactor Operating Licence in 2012 by the Canadian Nuclear Safety Commission (CNSC), the completion of an updated site-specific seismic hazard assessment was made a condition of the Station's licence renewal. NB Power Nuclear (NBPN) was also mandated by the CNSC to share the results of this assessment as part of its public information program. The specific wording in the decision for renewal was:

> *The Commission requires that NBPN perform a site-specific seismic hazard assessment. The Commission notes that NBPN has submitted an assessment plan as a part of its response to the CNSC staff action plan on the CNSC Fukushima Task Force Report recommendations. The Commission further requires that NBPN share the results of this assessment as part of its public information program.*

While the decision does not specifically require completion of the hazard results by a particular date, NB Power committed to the Commission that it would strive to complete the assessment and make the results public by the end of 2014 in accordance with the CNSC Fukushima Action Plan. PLGS staff has worked with expert consultants on the site-specific seismic hazard assessment since 2012. The work required to perform a seismic hazard assessment to modern standards is a highly complex undertaking. Considerable data exists for more frequent and smaller earthquakes. However, the data related to very rare, large earthquakes is scarce resulting in higher uncertainty when predicting how large these very rare earthquakes may be.

While PLGS staff expected the work to have been completed by the end of 2014, the complexity of the work has required more time be dedicated to finalize the assessment to better support its overall conclusions. NB Power is reviewing the assessment results, which includes review by third-party experts. While some reviewers have expressed concern that the assessment is overly conservative in predicting rare and large earthquakes and the seismic hazard may be lower than indicated in the new assessment, NB Power has evaluated safety of the plant assuming the report presents a “worst-case” scenario to confirm the public is well protected and are safe for a seismic hazard more extreme than historically regarded as credible.

The new method reflects the best modern practice and has brought new understanding and insights that are discussed below.

The evaluation answers the following questions:

- How was Point Lepreau built to withstand earthquakes?
- How has our understanding of earthquakes changed since the 1970’s and 1980’s?
- Has the earthquake hazard substantially changed from what we knew in the mid-to-late 1970’s and 1980’s?

- How does plant design meet requirements, considering the potential earthquake hazard from nearby faults?
- How does NB Power evaluate the risk of damage to the plant if one of those very rare, large earthquakes occurs? Does that risk assessment align with international guidelines?
- Does the current earthquake hazard increase risk to public health in any substantial way?
- Is the public protected?
- Is there any future work that NB Power should do to match industry expectations?
- What can reasonably be done to further enhance the seismic plant design?

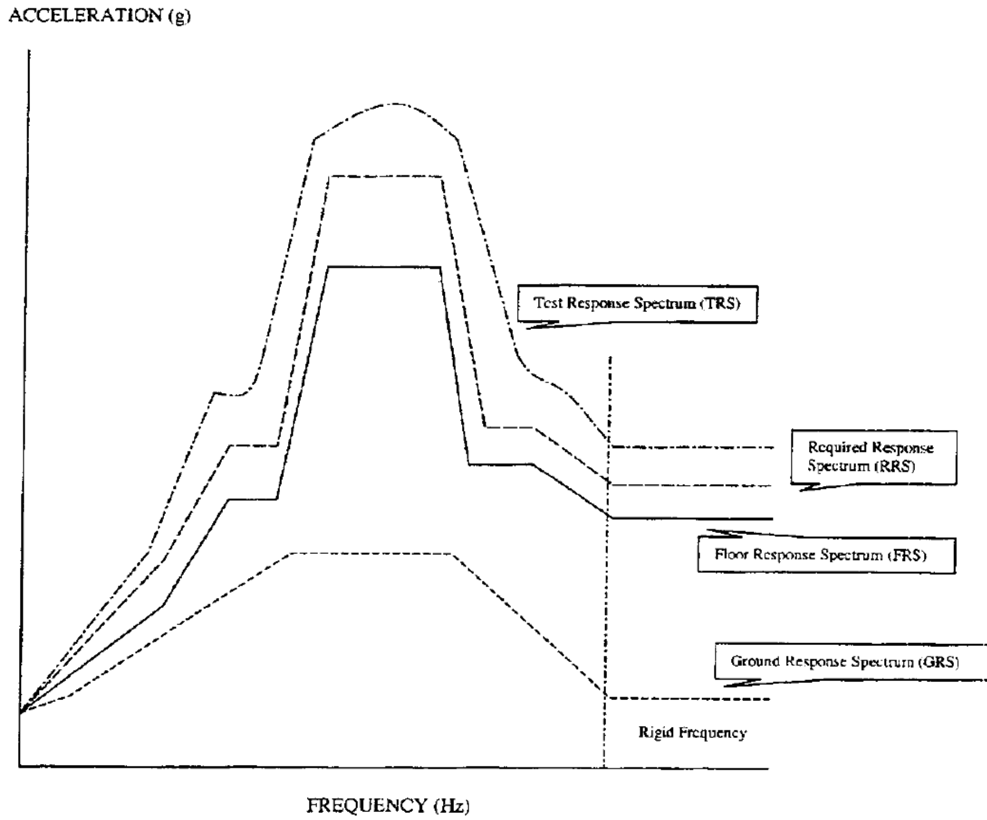
How was Point Lepreau built to withstand earthquakes?

The nuclear energy industry has a simple, yet effective, approach: expect the unexpected and prepare for it. Nuclear plants are designed and built with layer upon layer of protection against earthquakes. In recent years as North America and regions abroad have experienced significant earthquakes, experience has confirmed the seismic robustness of nuclear plants.

Nuclear plants have several aspects of seismic protection, including safety factors applied to the reactor designs, conservative requirements in engineering codes and standards, and specific requirements for the strength of steel and concrete used to build the plants. These design and construction practices are above and beyond the protection needed to safely withstand significant ground motion. Key systems, structures and components at Point Lepreau that ensure worker and public safety were also designed to withstand significant earthquakes based on knowledge of the earthquake hazard for the region in the mid-to-late 1970's. The plant can be safely shut down and maintained in the shutdown state for earthquakes of even larger size.

When seismologists report the size of an earthquake they express its size relative to the Richter scale. The Richter scale is used as a means of communicating to the public only, and it does not have direct technical meaning. Therefore, nuclear power plants are not designed using the Richter scale, but rather based on the size of the earthquake expressed as either a velocity or acceleration as a unit of gravity, or g. This basis is referred to as the Design Basis Earthquake (DBE) which represents the minimum that the buildings and equipment at Point Lepreau were designed to withstand at ground level with predicted rare occurrence of approximately once every thousand years or so. This is represented as a Ground Response Spectrum (GRS) graph shown by the bottom line of Figure A below. The vertical axis in the figure represents acceleration response that a structure, system or component might experience during an earthquake and the horizontal axis represents the frequency of the structure, system, or component. As building heights rise above ground level, equipment will experience a higher level of shaking for the same earthquake defined by a Floor Response Spectrum (FRS). The buildings and equipment are then built, analyzed and tested to make sure they can withstand far higher earthquake sizes (or magnitudes) than the design basis.

Figure A



The shape of the GRS is referred to as a standard spectral shape. This is the response characteristic that has been used in the design of most nuclear power plants built in North America. A great deal of progress has been achieved over the years since nuclear power programs began to understand earthquakes and the effects they might have on nuclear power plants. Experts and experience have indicated that earthquake frequencies above 10 Hz (number of vibrational cycles per second) do not typically cause substantial damage to structures and equipment of nuclear power plants because their natural frequencies tend to be more in the range of, respectively, 2-8 Hz and 1-10 Hz. This is important to remember when evaluating plant design against potential earthquake hazards.

How has our understanding of earthquakes changed since the 1970's and 1980's?

Given the new methodology, our understanding of the high vibrational frequency components of an earthquake and how large that can be has changed. Also, our understanding of very rare and very large earthquakes has changed and we now calculated hazards in more detail that can be used in approximate risk estimates. The hazard assessment shows that the earthquake magnitudes for more frequent earthquakes that might occur over the lifetime of the plant is lower than previously predicted. The assessment also shows that the magnitudes of very rare earthquakes that are unlikely to occur over the lifetime of the plant are larger than historically regarded as credible.

What has led to this new finding of potentially very rare, large earthquakes occurring more often?

In general terms, past assessments of earthquake hazards were based on the historical record of earthquakes, such as written accounts, to estimate the magnitude of the earthquake based on what people reported feeling or photos of the damage or, more recently, seismograph readings from faults that may be active. Those assessments represent, at best, a first approximation. Therefore, one part of the new methodology for PLGS' updated hazard assessment included a "paleoseismology" study. This involved field work by experts that NB Power hired to identify evidence of large earthquakes that may have occurred since the ice age and how long ago that may have occurred. We used this information to modify the seismic hazard and increase the hazard estimates for very rare, large earthquakes. Not surprisingly, in this type of work there is a large amount of uncertainty as to the source, the magnitudes and hazard estimates because real, tangible data is so scarce and does not provide a direct indication of the earthquake size.

Has the earthquake hazard substantially changed from what we knew in the mid-to-late 1970's and 1980's?

In the early 1980's Atomic Energy of Canada Ltd, the designer of Point Lepreau, and Maritime Nuclear, a consulting firm, performed a hazard assessment for site. The hazards for the site used median-centered data from the National Building Code of Canada and represented the hazard as median peak ground acceleration curves derived from three models. Therefore, it is appropriate to compare the updated median peak ground accelerations from the new study against that earlier work:

Estimated Earthquake Recurrence [i.e. once every X years]	**Peak Ground Acceleration (g)**	
	New Study [median]	**AECL and Maritime Nuclear (1984) [median]**
475 years	0.054	0.09 – 0.12
1,000 years	0.094	0.11 – 0.14
2,475 years	0.171	0.17 – 0.25
10,000 years	0.374	0.25 – 0.43

This table helps to illustrate our understanding of earthquake hazards today compared to what we thought we knew in the early 1980's. Specifically, those very rare and large earthquake magnitudes, at least up to a return period of once every 10,000 years, are certainly within the range of that earlier modeling. However, interestingly, the magnitude of smaller and more frequent earthquakes that are more likely to be experienced over the plant operating period of Point Lepreau are smaller than previously predicted.

How does plant design meet requirement, considering the potential earthquake hazard from nearby faults?

Experience from past studies in other regions has shown that, generally, the uniform hazard response spectra are less than the design basis standard spectral shape response spectra in the range of 1-10 Hz that is important to plant equipment. As discussed earlier, frequencies greater than 10 Hz is not expected to cause damage to most structures and equipment in a nuclear power plant. This is also the case for Point Lepreau, as shown below. The following figure shows an overlay of the new uniform hazard response spectra (UHRS) predicted for a once in a thousand year recurrence over the Point Lepreau Design Basis Earthquake (DBE) response spectrum which is also for a once in a thousand year recurrence interval.

As the above figure shows, the UHRS is below the design basis earthquake response spectrum for frequencies below 10 Hz and exceeds the design basis at higher earthquake vibration frequencies. NB Power is aware that this is consistent with past experience in other regions who have done similar studies.

An exceedance above 10 Hz is not an issue for Point Lepreau in terms of existing plant design. As noted earlier, the important point of the above comparison is that in the vibrational frequency range that might cause damage to most structures and equipment (i.e. < 10 Hz or so), the above new updated hazard assessment shows that the hazard is lower. This is positive from a safety perspective. Based on industry knowledge, high frequency aspects of an earthquake do not damage plant structures and equipment because their natural frequencies are lower. NB Power has also consulted with the Electric Power Research Institute to understand what effect those higher frequencies might have on more sensitive instrumentation, which we believe is unlikely to have an adverse effect on our ability to control and cool key plant systems.

How does NB Power evaluate the risk of damage to the plant if one of those very rare, large earthquakes occurs? Does that risk assessment align with international guidelines?

Central to NB Power's evaluation effort was the hiring of external experts to examine what the very rare, large earthquakes may mean to us in terms of safety and plant design. Even though Point Lepreau is not a new plant, we followed industry practice and the Canadian earthquake standard for new plants to examine what might happen for very rare earthquakes with a predicted return period of up to once every 10,000 years. There are two methods that are used in the Canadian industry to evaluate seismic safety for these very rare, large events. One method is called a PSA-based Seismic Margin Assessment (PSMA), which provides an indicator of what size of earthquake the plant is able to withstand before the reactor might be damaged or a large release might occur with a 5% probability or less. The other method, which builds further on a PSA-based Seismic Margin Assessment, is a Seismic Probabilistic Safety Assessment (PSA) that provides an indication of the likelihood that the reactor will be damaged or that a radiological release will occur following a large earthquake. During plant refurbishment, to avoid the large uncertainties in hazard estimates, NB Power chose to perform a PSA-based Seismic Margin Assessment (PSMA) to confirm that the plant could withstand a very rare, large earthquake. At the time, the PSMA showed that our objectives were met. It is important to note that PSA-type analyses are best estimate, cannot model all aspects of the plant and, therefore, risk estimates calculated by a PSA are an indicator of plant safety but are not the only measure of safety for a nuclear power plant. These analyses provide us with additional information that supports operation of the plant and helps us to identify vulnerabilities where our efforts can be focused in terms of continuous safety improvement. There are also many other programs and activities carried out in a nuclear power plant that ensure public safety that cannot be reasonably modelled in a PSA. The programs and activities are regularly monitored by the Canadian Nuclear Safety Commission.

With higher hazards estimated from the new study for those very rare and large earthquakes, NB Power has been reevaluating the seismic capacity estimated for various structures and equipment. Through this process, we have determined that many such structures and equipment are stronger than first considered in the PSMA.

NB Power is planning to perform a full seismic PSA to calculate seismic risks following best practice. In the interim, to estimate the risk of damaging the reactor core or experiencing a large radiological release NB Power has engaged independent experts to perform a seismic risk estimate following an approach applied at another Canadian nuclear power plant. The objective is to provide a high level view of whether or not there are areas where we should focus any future work and effort to enhance the seismic robustness of the plant.

The Canadian Nuclear Safety Commission has recently requested the Canadian industry to aggregate risks estimates from various hazards (internal and external) for comparison against safety goals and to take credit for safety improvements made to the plant in response the CNSC's Fukushima Action Plan (new Emergency Mitigating Equipment). While work is ongoing to determine what the appropriate method for aggregating risks is, a simple and conservative summation is provided below for events occurring with the reactor at power.

Results are pro-rated based on planned biennial maintenance outages of approximately 35 days in length:

Postulated Event Type	Mean Severe Core Damage Frequency (occurrences /reactor-year)	Mean Large Release Frequency (occurrences /reactor-year)
Internal Events	8.17E-06	6.21E-08
Internal Floods	3.21E-06	1.84E-07
Internal Fires	2.47E-05	4.80E-07[1]
Seismic Events	2.88E-05[1]	3.46E-06[1]
TOTAL	**6.49E-05**	**4.19E-06**
International Target	1E-04	1E-05
Target Met?	**YES**	**YES**

Note that only the seismic events risk estimates in the above table take credit for our new Emergency Mitigating Equipment procured in response to the CNSC Fukushima Action Plan. That equipment lowers the risk estimates because they provide additional defense in protecting the plant against extreme events and, hence, lowers the likelihood of an event progressing to core damage or a large release. If we were to also credit that equipment in the event types for postulated internal events, internal floods and internal fires, those risk estimates would also be lower.

As shown in the above table, the risk of incurring severe reactor core damage or experiencing a large radiological release from the plant is acceptably small and meets international guidelines, even when aggregating using conservative, simple summation. As the industry determines what the appropriate technical method is for performing such aggregation, we are confident that the calculated risk estimates would be even lower.

It should be noted that the risk estimates noted above for seismic events is based on an interim approach. Going forward we plan to update our methods for calculating the risks and performing a full seismic PSA. By doing this we expect to gain additional insights into how the plant responds to earthquakes and identifying reasonable, cost beneficial opportunities to continuously improve plant safety. In the meantime, the seismic risk estimates provided above give us a measure of confidence that the risks associated with seismic events is acceptably small.

As part of our overall scope of work, we will also continue to improve our estimates of individual structure and equipment seismic capacities that will further reduce the seismic event risk estimates.

Does the current earthquake hazard increase risk to public health in any substantial way?

No. During plant refurbishment, NB Power exceeded the requirements of the Canadian Nuclear Safety Commission for Probabilistic Safety Assessment by going a step further and assessing the potential off-site consequences of a highly improbable severe accident. This assessment used very conservative assumptions to evaluate risk to the public in the highly unlikely event of an accident that progressed to the point of a large radiological release following a severe accident. The assessment showed that the risk to public health was quite small.

In lieu of a full seismic PSA being completed at this time, NB Power hired experts to provide their opinion or judgment as to what impact aggregating seismic risks may have on public health risk. Our experts have indicated that no significant impact is anticipated.

Is the public protected?

Yes. The industry's highest priority is the safety of our workers, their families and others who live near our nuclear power plants. Since the future of nuclear energy depends on continued safe operation, nothing is more important. Our current understanding of the seismic hazard for the Point Lepreau region does not reveal any tangible challenge to the plant to safely shut down and protect our workers and the public.

Is there any future work that NB Power should do to match industry expectations?

NB Power recognizes that the method utilized above for calculating seismic risk estimates is an interim measure only. In the spirit of continuous improvement, additional work going forward includes:

1. Completing the third party review of the draft site-specific seismic hazard assessment and issue the report
2. Updating the PSA-based Seismic Margin Assessment methodology to reflect the new seismic hazard information
3. Continuing to refine seismic capacity estimates for structures and equipment
4. Following the Electric Power Research Institute's High Frequency Program
5. Developing full seismic PSA methodology reflecting industry practice
6. Performing a full seismic PSA
7. Updating the off-site consequence assessment to aggregate seismic risks to confirm no adverse impact on public health risk

What can reasonably be done to further enhance the seismic plant design?

In evaluating plant seismic capability to withstand earthquakes as predicted by the new seismic hazard assessment, NB Power has identified some opportunities that could further improve plant seismic design and safety. We are following up to determine the full benefit and cost of those opportunities and scope of work as part of our decision-making and business planning processes. Also, in the course of performing the additional planned work to refine seismic and public health risk estimates and, in the context of our safety-first philosophy, NB Power is committed to disposition any additional improvement opportunities that may arise.

Conclusion

Our evaluation of the site-specific seismic hazard assessment demonstrates the capability of the plant to withstand very rare, large earthquakes. The consequential risk, expressed as the potential for damaging the reactor core and causing an unlikely large radiological release; which could adversely affect public health from operation of Point Lepreau, was found to be acceptably low.

Our conclusion is that the safety case for PLGS continues to be strong and that the plant is operating safely under our current understanding of possible earthquake hazards. In a very unlikely case of some seismic damage occurring to the plant, the reactor will be safely shut down and maintained in a shutdown state until we can confirm, in conjunction with the Canadian Nuclear Safety Commission, that it is safe to restart the plant. There would be no consequence to the public and the environment.